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A Microleakage Study of Cements with Stainless Steel Crowns

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A Microleakage Study of Cements with Stainless Steel Crowns

by

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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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ABSTRACT OF THE DISSERTATION

A Microleakage Study of Cements with Stainless Steel Crowns

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Loma Linda University, June 2007
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PURPOSE: To compare the ability of newer adhesive resin cements and traditional glass ionomer cements to prevent microleakage under stainless steel crowns on extracted permanent third molars.

METHODS: All teeth were hand prepared and stainless steel crowns were cemented according to manufacturers' instructions. The specimens were thermocycled for 500 cycles and immersed in 2% methylene blue dye solution for 8 hours. Each tooth was imbedded in resin and cut into 1mm thick sections by a slow speed diamond saw. The amount of microleakage was measured in microns under a traveling microscope. The measurements of each section of a tooth were averaged and only one number was recorded per specimen. The open margin distance for each specimen was measured. Statistical methods employed were the Kruskal-Wallis rank test and the Mann-Whitney U test.

RESULTS: Nexus 2 had statistically significant less microleakage than other three cements tested (p=0.0089). There was no statistically significant difference in microleakage between Ketac Cem and RelyX Unicem (p=0.0529) or between Ketac Cem and Maxcem (p=0.0535). There was also no statistically significant difference in microleakage was established between RelyX Unicem and Maxcem (p=0.0947).

CONCLUSIONS: Nexus 2 had statistically significant decreases in microleakage when compared with Ketac Cem, RelyX Unicem, and Maxcem cements. There were no statistically significant differences in microleakage between the remaining three cement systems.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

When large carious lesions are removed from a primary tooth, the remaining healthy tooth structure often has insufficient resistance and retention form for clinically acceptable resin or amalgam restorations. Stainless steel crowns are often the preferred restoration in these situations.[11, 40] Despite excellent success rates for stainless steel crowns, clinical failures do occur. Well-documented causes of clinical failure include: crown loss, defective margins and pulpal pathology.[6, 28, 39, 40] Due to the reasons for stainless steel crown failure, it is simple to justify the importance of quality tooth preparations, suitable crown selection and adjustment, and the utilization of an optimal luting cement.[2, 27, 34, 40]

Many types of cements have been studied as possible luting agents for stainless steel crowns. These cements include: zinc phosphate, polycarboxylate, glass ionomer, resin reinforced glass-ionomer and resin cements.[2, 16, 40] Zinc phosphate cements were replaced as the standard luting agent for stainless steel crowns due to its inferior properties in comparison with glass ionomer and newer adhering resin cements.[43] Pediatric dental literature primarily endorses the use of glass ionomer cements for stainless steel crowns.[16, 26, 40] Glass ionomer cements are considered non-adhesive because no adhesive agent is used. Glass ionomer cements bond chemically to tooth structure.[8, 40] One main benefit of using glass ionomer or resin-reinforced glass ionomer cements is their ability to release fluoride.[8, 40] It is important to note, however, that the required amount of fluoride release to result in a clinically cariostatic benefit is not yet known.[8]

Despite its popularity, literature does exist that discusses the inferiority of glass ionomer cements. A few of the disadvantages listed included: setting shrinkage,[22] water solubility, relative lack of strength and poor marginal adaptation.[8, 18, 43]

Less research has been conducted on resin cements in comparison to nonadhesive cements (i.e. zinc phosphate, polycarboxylate or glass ionomer cements). Modern resin cements have improved physical characteristics, possess the ability adhere to tooth structure via bonding agents and are fluoride releasing.[4, 21, 35, 36] Older generation resin cements were technique sensitive and required multiple steps for the cementation process. However, the latest self-etching, dual-cure resin cements have the advantages of one-step efficiency and ease of application. These features are clearly beneficial in the pediatric dental population.[37] Thus, if these materials perform similarly to traditional resin cements under clinical situations, superior clinical success may be possible with the application of modern adhesive luting agents underneath stainless steel crown restorations.[21, 40] Due to its recent development, little research has been completed with the latest self-etching, dual-cure resin cements and more studies are needed with these products due to their immense popularity in the dental field.

Microleakage, by definition, is the passage of bacteria, fluids, molecules or ions between a cavity wall and the restorative material applied to it.[23] An inadequate marginal seal can permit the microleakage of both bacteria and their toxic metabolic waste products into tooth structure.[3, 7, 40] Microleakage has been shown to cause recurrent caries, inflammation of pulp tissue, post-operative hypersensitivity and reinfection of teeth with root canal treatment.[1, 21, 25, 35, 40] For teeth with a history of root canal treatment, coronal microleakage has been identified as the major cause of treatment failure.[40, 42] Despite the plethora of cements available in today's dental market, unfortunately all luting agents allow some degree of microleakage.[21, 36]

There are many causes for the microleakage found with cementation agents. When insufficient bonding occurs between the luting agent and tooth structure, leakage will occur. Another source of leakage is the discrepancy between the coefficients of thermal expansion of cement and tooth structure. Thermal expansion regularly occurs within a patient's mouth, This is simulated in the laboratory using thermocycling techniques. Further reasons for microleakage involve polymerization shrinkage and cement solubility for both resin cements and conventional glass ionomer cements.[22]

Many studies involving the microleakage of luting agents beneath full coverage gold, porcelain or porcelain-fused-to-metal crowns have been published.[1, 2, 4, 9, 18, 25, 26, 36, 40, 41, 43, 44] However, there are much fewer microleakage studies in which stainless steel crowns were utilized as the coronal restoration. Full coverage gold, ceramic, or porcelain-fused-to-metal crowns are custom made to each prepped tooth and should allow for flush crown-tooth margins. Cement studies completed on such restorations should potentially reveal minimal microleakage due to the superior fit of the crowns. Stainless steel crowns, however, are prefabricated crowns that require trimming and crimping prior to cementing of the restoration. With stainless steel crowns there is an increased likelihood of open margins despite the best clinical efforts in contouring the margins of the crown. Thus, cement system performance with complete coverage crowns may not correlate with its performance with stainless steel crowns and thus a need exists for further research of luting agent microleakage beneath stainless steel crowns.[2, 40]

The purpose of this investigation was to compare the ability of newer resin cements and traditional glass ionomer cements to prevent microleakage under stainless steel crowns using extracted permanent third molars.

Hypotheses

The null hypothesis of the study was that all four cement systems would have the same amount of microleakage after thermal cycling. The alternative hypothesis was that there would be a difference in microleakage between the four cement systems.

CHAPTER TWO

MATERIALS AND METHODS

Materials

Permanent mandibular first molar Ion Ni-Chro Stainless Steel Crowns (3M ESPE, St. Paul, MN) were used on all teeth in this study. The four cement systems tested were Ketac Cem (3M ESPE), Nexus 2 Dual Syringe (Kerr Dental, Orange, CA), RelyX Unicem (3M ESPE) and Maxcem (Kerr Dental). See Table 2.1 below for cement system information.

Table 2.1

Cement Systems

Cement Type	Lot Number	Expiration Date	Adhesive Required	Working Time	Curing Time*	Set Time	Removal of Excess Time
Ketac Cem Aplicap	242050	2009	No	3 min	None	7 min	7 min
Nexus 2 Dual Syringe	445721	2007-11	Yes	3.5 min	40 sec	5.5 min	After seating
RelyX Unicem Aplicap	242618	2007-09	No	2 min	20 sec	5 min	2 sec tack cure
Maxcem	445680	2007-08	No	2 min	20 sec	3 min	2 sec tack cure

*Curing times were applied to buccal, lingual, mesial and distal crown margins

Methods

This study evaluated the microleakage of the four selected cements within the following experiment environment:

Type of Curing

The XL 3000 curing light (3M Dental Product, St. Paul, MN) was used for those resin cement systems that required light curing. An intensity of 580 mw/cm^2 was used. The intensity was measured with a Model 100 Curing Radiometer (Demetron Research Corp, Danbury, CT).

Temperature

The study was conducted at room temperature. The temperatures used for the thermocycling water baths were 5° C and 55° C.

Curing Time

Cements were cured according to the manufacturer's instructions. Nexus 2, RelyX Unicem and Maxcem required the used of the curing light.

One variable in the research study was the selected cement systems chosen for comparison. Ketac Cem is a glass ionomer cement, Nexus 2 is a standard resin cement and both RelyX Unicem and Maxcem are self-etch/self-adhesive resin cements. Stainless steel crown preparations were not standardized in this study due to increased clinical relevance of study results if all teeth were custom prepared. All laboratory procedures were completed at the Loma Linda University School of Dentistry's Biomaterials Research Laboratory.

Forty extracted caries-free permanent third molars were selected and stored in 10% buffered formalin solution. There was a sample size of ten molars per cement treatment group. All debris was removed from the selected teeth with hand instruments. The apical portion of each molar was mounted in acrylic resin blocks. Tooth preparations were accomplished utilizing various selected diamond high speed burs. After the stainless steel crown preps were completed, the cervical margin of prefabricated Ion Ni-Chro crowns stainless steel crowns (3M ESPE) were adjusted to fit each specimen with minimally visible marginal opening. In this study, the margins of the stainless steel crowns were not cut during the fitting procedure. This was done to eliminate the variable of operator cutting error. Thus, only crimping and contouring pliers were used as necessary to ensure an optimal fit, and all stainless steel crowns were only mildly altered from their original manufactured state. Prefabricated permanent first molar stainless steel crowns were able to be used on our extracted third molars because all molars selected for this study had similar occlusal patterns and crown dimensions of permanent mandibular first molars.

Figure 2.1. Twenty completed stainless steel crowns.

Stainless steel crowns of each treatment group were cemented with the assigned luting agent. All cements were applied according to specific manufacturer's instructions. (Figure 2.1) The only cement requiring the use of a bonding agent was Nexus 2. OptiBond Solo plus was recommended by Kerr Dental as the bonding agent of choice for Nexus 2 and it was used according to manufacturer's instructions. Crown seating was accomplished with finger pressure.[25, 36, 40] The occlusal tables of the stainless steel crowns were then loaded axially with 5 kg through by using of a holding jig for 10 minutes. The use of a holding jig allowed for consistent seating force until completion of initial set of the cement.[36, 40] Any excess cement was removed with hand instruments prior to thermocycling. All cemented specimens were placed in distilled water and transferred into a 37 °C incubator for 24 hours to allow for setting completion prior to thermocycling.

The teeth were then thermocycled 500 times. The number of cycles was selected based on an average of cycles used in other studies and the results of previous pilot studies completed for this study. It should be mentioned that literature has shown no significant differences of dye penetration between specimens that underwent 100 cycles versus 1500 cycles.[10]

The teeth in this study were thermocycled in a water bath between 5 and 55 °C with a travel time of 3 seconds. The specimens had dwell times of 30 seconds in each water bath per cycle.[13, 40]

Jet-Set Shine nail enamel (L'oreal USA INC, New York, NY) was applied to all areas of exposed root surface and mounting acrylic prior to dye immersion. There was one millimeter below the crown margins that was left unsealed. (Figure 2.2) All teeth were then submerged into a 2% methylene blue dye solution[10] at room temperature for 8 hours. After removal from the dye, the teeth were rinsed and dried. (Figure 2.3) The length of dye submersion was determined by the results of earlier pilot studies. It should be noted that specimens were dyed in groups of four in order to decrease the total time of potential microleakage occurring while specimens waited to be sectioned. All dye penetration times were kept consistent. All four cement systems were represented in every group of four teeth.

Figure 2.2. Specimens, with nail varnish, prior to dye immersion.

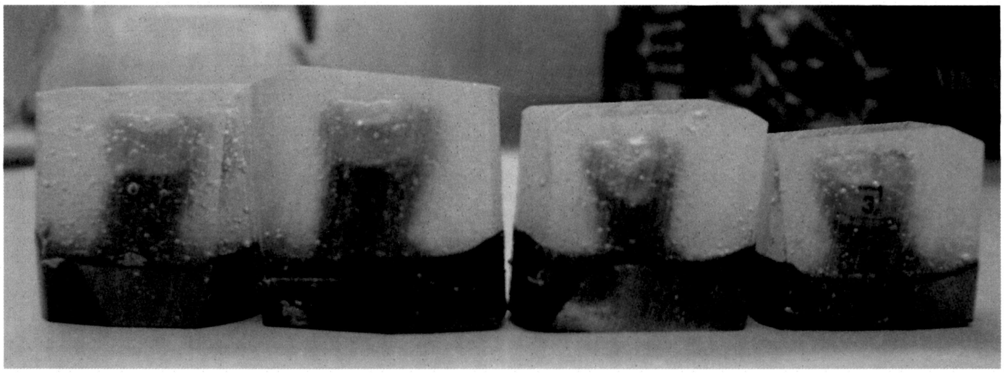

Figure 2.3. Embedded specimens prior to sectioning.

Figure 2.4. One specimen after sectioning.

Sectioning of the sample teeth was completed using a slow speed diamond saw (Beuhler, Lake Bluff, IL). All cuts resulted in buccal-lingual sections with a width of each section approximately 1 millimeter. (Figure 2.4) There were four cuts made per tooth. These four cuts provided five sections with a total of eight surfaces per molar for analysis. The number of surfaces and measuring sites was determined as follows: Two end sections were made with the first and last cuts of the tooth and each end section contained two possible sites of microleakage. These two sites were along the buccal and lingual margins of the stainless steel crown. The remaining two cuts of each molar resulted in three sections with four possible sites of microleakage per section: the buccal and lingual margins of one side of the section, and the buccal and lingual margins of the opposite side of the section. This was the method for collecting sixteen measurements per tooth. This high number of sections was performed in adherence with literature demonstrating that an increased ability to accurately quantify the amount of microleakage is achieved by increasing the number of sections made.[15, 30] Microleakage was measured in millimeters under a traveling microscope (Leco, St. Joseph, MI) using 10X magnification with an accuracy of 5 microns. All measurements made from each section within an individual tooth were averaged. The averaged number, in millimeters, was recorded as the amount of microleakage for that particular molar. This procedure was used for all specimens in each cement treatment group, giving a method in which to compare the amount of cement microleakage for each cement in relation to one another. The amount of crown margin opening at each measurement site was recorded in order to rule out exceptionally open margins as a cause for cement failure. The distance, in millimeters, between the stainless steel crown margin and the tooth was measured at each possible microleakage site with the use of the traveling microscope. These measurements were made in order to rule out open crown margins as a possible cause of microleakage. All measuring was done immediately after crown sectioning to decrease inaccuracy due to specimen dehydration.

Due to the amount of time required to complete the lab procedures, the experiment was finished in two parts. All the above procedures were completed on the first twenty specimens during the first week of testing and included five specimens from each cement system. The procedures for the second week of testing were identical to the first week. Thus, equal representation per cement system was maintained throughout the entire study.

Statistical Analysis

The non-parametric statistical Kruskal-Wallis rank test, was used to detect if there were any significant differences in microleakage among the four cement systems. Once the null hypothesis was rejected, the Mann-Whitney U test was employed to detect if there were any significant differences in microleakage between pairs of cement systems.

CHAPTER THREE

RESULTS

A total of forty extracted mandibular molars were selected for use in this study. One molar was excluded due to insufficient nail varnish which allowed for microleakage from within the pulp chamber and root surfaces. (Figure 3.1) Thus, a total of thirty nine teeth were available for data collection. There were ten molars in the Ketac Cem, Nexus 2 and RelyX Unicem sample groups, and nine molars in the Maxcem group. All tooth preparations remained within the enamel layer of the tooth specimens.

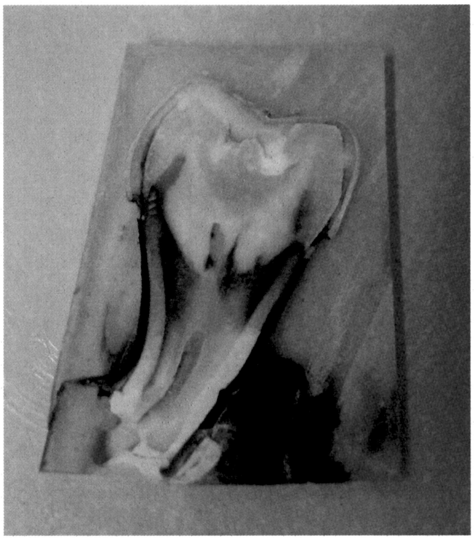

Figure 3.1. One section of the failed specimen.

Table 3.1

Descriptive Statistics

Cement Type	Average Microleakage	Standard Deviation	First Quartile	Median	Third Quartile
Ketac Cem	1.2300	0.5798	0.7471	1.2822	1.4985
Nexus 2	0.5997	0.4222	0.3339	0.5391	0.6171
RelyX Unicem	1.4727	1.2449	0.6173	1.1557	1.1557
Maxcem	1.8533	0.7337	0.8141	1.8339	2.23321

The data is listed above in Table 3.1. The average amounts of microleakage were as follows: Ketac Cem=1.2300mm (SD=0.5798), Nexus 2=0.5997mm (SD=0.4222), RelyX Unicem=1.3727mm (SD=1.2449) and Maxcem=1.8533mm (SD=0.7337). The Kruskal-Wallis rank test showed that cement type had a statistically significant influence on microleakage. Nexus 2 had statistically significant less microleakage than the other three cements. Ketac Cem had statistically significantly more microleakage than Nexus 2 with a p-value of 0.0089. RelyX Unicem and Maxcem also had statistically significantly more microleakage than Nexus 2 with p-values of 0.0355 and 0.0003, respectively. There was no statistically significant difference in microleakage between Ketac Cem and RelyX Unicem (p=0.0529). Nor was there a statistically significant difference in microleakage between Ketac Cem and Maxcem (p=0.0535). Lastly, no statistically significant difference in microleakage was found between RelyX Unicem and Maxcem (p=0.0947). The measurements of open crown margin distance were averaged per cement type and recorded as follows: Ketac Cem=0.11mm, Nexus 2=0.16mm, RelyX Unicem=0.13mm, and Maxcem=0.09mm.

CHAPTER FOUR

DISCUSSION

This study compared conventional glass ionomer cement with two different classes of resin cement systems; Standard Resin Cement system and Self-Etch/Self-Adhesive Cement system. As mentioned previously, there were two different brands of the self-etch/self-adhesive cement system studied. This resulted in a total of four cement systems being tested. The study used extracted permanent teeth, rather than resin dies, to more closely replicate clinical practice. A 2% methylene blue dye solution was used to quantify microleakage underneath the stainless steel crowns. Dye dispersion time was set at eight hours per specimen. There was concern that dye would continue to creep underneath the stainless steel crown until the specimen was sectioned and dried, thus only four teeth, one from each cement group, were dyed at a time and total dye times were documented strictly so that all specimens were dyed for similar amounts of time. Due to the subjective nature of nonparametric scoring methods, microleakage was determined from direct measurements in millimeters with the aid of a traveling microscope. It is important to note that open stainless steel margins never exceeded 0.45mm in width, with an average of 0.15mm opening per measurement site.

The sample size of each test group was chosen so as to compare with similar microleakage studies, yet assure statistical integrity. Because all testing was completed within a standardized and controlled environment on only a small number of specimens, care must be taken not to inappropriately apply the results of this study to all clinical situations. If larger samples were used, it may be possible to detect a statistically significant difference in microleakage among the other three cements. Thus, due to the limited comparative data of cement microleakage under stainless steel crowns, further studies should be conducted to better reveal the most optimum stainless steel crown cement.

It was mentioned earlier that all tooth preparations were within the enamel layer of the tooth specimens. The bond between resins and tooth substrates has been shown to be superior if the bond involves the enamel layer of the tooth versus the dentin. However, it is not uncommon to expose the dentin layer of primary teeth during stainless steel crown preparations due to decreased enamel thickness in the primary dentition. Thus, when applying the results of this study to the pediatric population, cement performance may differ due to the increased likelihood of dentin bonding of the luting agents. Further studies are needed to compare microleakage of cements under stainless steel crowns with tooth preparations that involve the dentin.

The study results showed that the Nexus 2 cement system had lower levels of microleakage at a statistically significant level in comparison to the conventional glass ionomer cement system and both self-etch/self-adhesive cement systems. The ability of a cement to decrease microleakage is highly important. Microleakage has been shown to cause recurrent caries, inflammation of pulp tissue, post-operative hypersensitivity and reinfection of teeth with root canal treatment.[1, 21, 25, 35, 40] Primary teeth are commonly treated with pulpotomies and pulpectomies, and stainless steel crowns are the most durable and reliable method of restoring pulpally treated teeth.[28,39] It is evident that decreased microleakage of a cement system can be a clinical advantage in the pediatric population. However, it should be mentioned that, according to the 3M ESPE Ketac Cem technical profile, glass ionomer cements produce a chemical bond by a reaction with the calcium ions of the tooth substrate. There is the potential that acid etching prior to application of Ketac Cem could result in an increased amount of calcium ions available for bonding. The acid etching process has also been shown to roughen the tooth surface, creating an increased bonding area for micromechanical bonding. Thus, with an increased number of bonds between the cement and tooth substrate and an increased surface area for micromechanical bonding, it is possible to achieve lower amounts of cement microleakage with acid etching prior to glass ionomer cement application.

The results of this study were unique in that no study was found comparing these resin cement systems under stainless steel crowns. While the Nexus 2 cement system showed a statistically significant reduction in microleakage, it must be noted that Nexus 2 is very technique sensitive and requires multiple steps for cementation. These steps were involved with both the prepped tooth and the stainless steel crown restoration. The ease of material use is an important consideration with the pediatric population because the ability for children to sit quietly and cooperatively for procedures is occasionally in question. Thus, when Nexus 2 cement is used according to manufacturer's instructions, there is some reservation as to whether this cement system is appropriate for use in children's dentistry. Ketac Cem had the simplest application process, requiring only a dried tooth preparation and cement capsule trituration as the only pre-cementation conditions. The manufacturer's instructions for Nexus 2 and RelyX Unicem were more involved than for Maxcem, but all three resin cement systems recommended post-cementation light-curing of all crown margins. The curing light was applied for the manufacturer recommended time on each specimen at four locations: mesial crown margin, buccal crown margin, distal crown margin and lingual crown margin. Again, the requirements for each cement type tested were reviewed because of the importance of ease and efficiency of dental materials when working with pediatric dental patients.

An important item for discussion is whether the results of this study are clinically relevant. Nexus 2 Dual Syringe was found to have statistically significantly less microleakage than three other cement systems, but how should dentists relate the findings of this study to clinical dentistry?

It is interesting that there does not appear to be a universally accepted technique for determining the degree of microleakage for dental materials.[1] A review of the literature revealed multiple methods for measuring microleakage. The different materials used to detect microleakage included: dyes, lipopolysaccharides, isotopes and silver nitrate solutions.[1, 2, 4, 9, 18, 25, 26, 36, 40, 41, 43, 44] Several methods of quantifying microleakage were also found and included: scoring systems with microscopes, direct measurement from digital photos of tooth sections, and direct measurement under microscope.[1, 2, 4, 9, 18, 25, 26, 36, 40, 41, 43, 44] It is evident that much diversity exists with current microleakage testing methods. These various microleakage methods have been shown to produce varying results. Thus, it may be possible that the results from one study may differ from another study because of measuring technique. The varying results between studies may not be due to significant differences of the dental materials themselves.[10] This results in the possible dilemma of having no universally accepted standard as to the amount of microleakage that is considered as clinical failure or success. Therefore, when attempting to apply clinical relevance to the findings in this study, the reader must take care not to make inferences beyond the study results. The only clinically relevant deduction one can make based on this study is that Nexus 2 Dual Syringe showed statistically significantly less microleakage in the laboratory setting than Ketac Cem, RelyX Unicem and Maxcem. Thus, one could postulate that there is a potential for similar results in a clinical setting.

One advantage of glass ionomer cements is their successful track-record of over thirty years. Not only is the use of glass ionomer cements supported in the literature, but they have also been endorsed in multiple studies for use with stainless steel crowns.[15,16,40] Nexus 2 resin cement has been on the market for only the past six years, and RelyX Unicem and Maxcem were introduced in 2003 and 2004, respectively. Little research has been done on the comparison of cement performance with stainless steel crowns. In fact most studies found compared cement systems that are not in use today.[11,29] Further testing and research is needed, both in laboratory and clinical situations before it can be determined which is the best luting system for stainless steel crown restorations.

CHAPTER FIVE

CONCLUSIONS

The results of this study were as follows:

1. Nexus 2 showed statistically significantly less in microleakage when compared with Ketac Cem, RelyX Unicem, and Maxcem cements.

2. There were no statistically significant differences in microleakage between the remaining three cement systems.

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