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School of Dentistry
Virginia Commonwealth University

This is to certify that the thesis prepared by Charles Austin Davis Jr., D.D.S., entitled
RETENTIVE CEMENT STRENGTHS WITH PASSIVE FIT PRIMARY ANTERIOR
ESTHETIC CROWNS

has been approved by his or her committee as satisfactory completion of the thesis requirement
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May 1, 2012
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RETENTIVE CEMENT STRENGTHS WITH PASSIVE FIT PRIMARY ANTERIOR
ESTHETIC CROWNS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science
in Dentistry at Virginia Commonwealth University.

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Abstract

RETENTIVE CEMENT STRENGTHS WITH PASSIVE FIT PRIMARY ANTERIOR ESTHETIC CROWNS

By Charles Austin Davis Jr., D.D.S.

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science
in Dentistry at Virginia Commonwealth University.

Virginia Commonwealth University, 2010

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Purpose: to assess the retentive strengths of passive fit esthetic anterior restorations using three commercially available cements.

Methods: Three resin dies were fabricated from the intaglio surface of each restoration type. Each die was prepared following the current accepted guidelines on primary anterior tooth crown preparation. The three prepared teeth were replicated to produce 30 dies for each of the three restoration types. The prepared teeth were further separated into nine groups of 10 teeth each. Thirty EZ Pedo Crowns, 30 NuSmile Primary Crowns and 30 Unitek crowns were cemented using hand pressure employing the luting cement assigned to the corresponding group. The units were allowed to cure for 7 days. The force required to dislodge the restoration was tested using the Instron Universal Testing Machine. The data was statistically analyzed using a two-way ANOVA to analyze the force required to dislodge the restorations. A two-way logistic regression was used to analyze the failure types.

Results: There were no significant differences in restoration retention rates between restoration types ($P = 0.4412$) but there were significant differences between types of cements used. ($P < .0001$). The differences with regard to cement types were consistent across the restoration groups ($P = 0.7682$). Tukey's HSD multiple comparison procedure indicated FujiCem was significantly more retentive than either Fuji I or Ketac Cem cements and there were no significant differences in restoration retention rates between the Fuji I and Ketac Cem cements.

Conclusion: The type of restoration did not matter between cements but cement type did matter with FujiCem cement being more retentive than the other types of cements tested.

Introduction

Early childhood caries (ECC) is a disease that continues to challenge the diagnostic, preventive, and restorative skills of pediatric dentists.¹ This condition often manifests itself first in the primary maxillary anterior teeth, followed by the primary molars. Dental caries in the primary incisors may endanger the integrity of both the primary and permanent dentitions and is not esthetically pleasing.¹ Unfortunately, treating dental caries in primary maxillary anterior teeth is difficult due to small tooth size, patient cooperation, and parental expectations.^{1,5} In cases of mild to moderate caries, intracoronal resin restorations or extracoronal resin “strip crowns” may be utilized because minimal tooth preparation is required and enough enamel remains for sufficient bond strength to be achieved.⁵ In cases of severe caries that extend beyond the gingival margin, little enamel remains for bonding and moisture control is difficult. In those situations, it is optimal and recommended to use stainless steel crowns (SSCs) or veneered SSCs.⁵ Stainless steel crowns provide retention, durability, and are easy to place. However, their lack of esthetics due to the metallic color causes them to be less popular when restoring maxillary anterior teeth.⁵

Recently, veneered stainless steel crowns have become a viable option for restoring severely broken down primary incisors. However, since the possibility exists that the metal substructure and veneer could separate, new restorative materials have been developed in an attempt to solve this problem. They are crowns made of zirconia for

the primary dentition that contain no metal. Zirconia restorations are not new to the dental world and are one of the dominant types of ceramics used for a variety of computer aided design /computer aided manufacturing restorations, including framework/hand veneer, framework/milled veneer, full-contour fixed prosthodontics, implant abutments, and large implant-supported substructures.¹⁸ Zirconia is currently the strongest dental ceramic available¹⁸, and are also esthetically pleasing. Even though zirconia is widely accepted as a restorative material for the permanent dentition, it is a relatively new restorative material for the primary dentition. According to a recent study by Ortorp et al., the five year retention rates for single unit zirconia crowns on permanent molars and premolars are as high as 88%.¹⁹ Although these retention rates are high, they are based on custom crowns where cement space ranges from 84-134µm.¹⁹ In addition, the crown preparation itself provides a resistance form that aids in the overall retention of the restoration.

Current research on passive fit prefabricated zirconia crowns for primary anterior teeth is limited. A recent PubMed search using terms “primary anterior zirconia,” “deciduous teeth zirconia,” “deciduous anterior teeth zirconia,” and “primary anterior teeth zirconia” yielded no current research on the topic. Retention rates of different types of cements used with zirconia crowns in the primary dentition is also currently unknown. Advantages of the traditional veneered stainless steel tooth-colored crowns include esthetics, retention rates comparable to that of traditional SSCs¹, and less chair time required to place than open-faced SSCs.⁵ The disadvantages are also known, including problems with crimping the crowns, higher cost, and inability to heat sterilize because of the veneer.¹ Nevertheless, veneered crowns still may be the treatment of choice because

they can be placed in the presence of blood contamination without compromising final esthetics.^{5,9}

Very little research has been conducted to explore the failure rate of veneered SSCs.¹ In 2003, Guelmann et al. assessed three brands of commercially available veneered SSC's (Dura Crown, Kinder Krown, and NuSmile Primary Crown) and Unitek stainless steel crowns in an effort to determine which crown exhibited better retention based on crimping and the use of cement.⁵ The results of that study supported previous studies in that SSC retention is, for the most part, dependent upon cement. Moreover, the crowns with veneer facings were more retentive than the non-veneered ones when using both cement and crimping.⁵ This study was limited in that only one type of cement (glass ionomer) was utilized. Further information is needed to determine which cement will provide higher retention rates when restoring primary teeth with veneered SSCs and new prefabricated zirconia crowns.

The authors of this study hypothesized that prefabricated primary zirconia crowns will have a similar failure rate when compared to the other commercially available veneered SSCs and that the prefabricated primary zirconia crowns will share similar advantages when compared to the veneered SSCs. The purpose of this in vitro study was to assess the retentive strengths of passive fit esthetic anterior crowns for primary teeth using three commercially available cements.

Method and Materials

Nu Smile Primary Crowns (NuSmile LTD. Houston, TX), and EZ Pedo Primary Crowns (EZ-Pedo, Inc. Loomis, CA) are two commercially available esthetic primary anterior crowns. Thirty crowns from each of these manufactures, along with 30 Unitek SSCs (3M Dental Products, St Paul, MN), were tested. A plastic typodont (Kilgore International, Inc. Coldwater, MI) consisting of a maxillary right primary central incisor tooth served as a standard tooth size for this study. The typodont tooth shape and size were compared to measurements of natural anterior incisors using the findings of Arnim and Ramer.^{6,7,5} The crown sizes were selected based upon the mesiodistal width of the tooth. Size A3 for Nusmiles, R3 for Unitek, and E3 for EZPedo were selected using the above criteria. To standardize the die space for each crown, Aquasil LV Light body Impression material (Dentsply-Caulk International Inc, Milford, DE) was used to make an impression of the intaglio surface for each of the study crown brands. These models were duplicated in Jeltrate Plus Dutless Alginate impression material (Dentsply-Caulk International Inc,). Pink Orthodontic Resin (Dentsply-Caulk International Inc,) was poured into the alginate impression with the result being negative impressions of the intaglio surface of each of the study crowns.

The Three separate crown dies were prepared according to Helpin⁸ as described below and a high speed, a tapered fissure #169 bur was used for all aspects of the crown preparation.⁵

- 1) The incisal edge of the acrylic die was reduced approximately 2mm.
- 2) The proximal surfaces were reduced approximately 0.5mm per side.
- 3) The labial surface was reduced approximately 0.5mm and the incisal portion of the labial surface was rounded toward the lingual to allow for complete seating of the crown.
- 4) The lingual surface of the tooth was reduced approximately 0.5mm below (gingival to) the cingulum area with the bur parallel to the long axis of the tooth.
- 5) All sharp line angles were rounded.

Three dies were prepared according to the criteria stated above. The three ideally prepared dies, one from each different crown manufacturer, were replicated 30 times using Aquasil Light body impression material and Pink Orthodontic Resin. Hillman group #216 screw eyes (The Hillman Group, Cincinnati, OH) were centered in the bottom of each resin die, parallel to the long axis, for testing in the Instron Universal Testing Machine (Instron Corp, Canton Mass). Test specimens were constructed for use with a Hitachi 1.5 inch 18 gauge electro galvanized pneumatic finishing nail (Hitachi Koki Co, LTD., Norcross, GA). EZPedo crowns were manufactured with an 18 gauge pin hole through the incisal edge, equidistant from the mesial and distal edges so as to direct the forces through the long axis of the crown. It was necessary to prepare a pin hole in each of the incisal edges of the NuSmile and 3M Unitek crowns, because they were

delivered with the incisal edges intact. To accomplish this, a high speed, carbide #4 round bur was used to make a hole through the incisal edge, equidistant from the mesial and distal edges so as to direct the forces through the long axis of the crown. NuSmile crowns were then sent back to the manufacture for final finishing of the intaglio surface.

Ten crowns of each brand were randomly assigned to one of the three test groups. No crimping was performed (Figure 1, Figure 2).

Group 1: Thirty crowns were cemented with FujiCem (resin modified glass ionomer cement) (GC America, Chicago, IL USA)

Group 2: Thirty crowns were cemented with Fuji I (glass ionomer cement) (GC America)

Group 3: Thirty crowns were cemented with Ketac Cem Maxicap (glass ionomer cement) (3M)

After adaptation to the acrylic teeth and 7 days post cementation, Teeth were tested in three groups. Group 1: FujiCem cement; group 2 Ketac Cem cement; and group 3: Fuji I cement. Within each group, teeth were randomly assigned to the three restoration sub groups: Nu Smile, Unitek, and EZ Pedo. Restorations were tested for retention using an Instron machine with a self-centering vice at a crosshead speed of 0.2 inches per minute (Figure 3). The force necessary to dislodge the crowns was recorded in pounds (lbf).

Failure Types were recorded as

- 1) Die – Failure at the die/cement interface (Figure 4)
- 2) Crown – Failure at the crown/cement interface (Figure 5)

3) Screw – Failure at the screw/die interface or distortion of the screw (Figure 6, Figure 7)

4) Nail – Failure of nail at crown/nail interface – includes porcelain failure (Figure 8, Figure 9, Figure 10)

The moment any of the above failure types occurred, the experiment for that restoration was discontinued and the force necessary to dislodge the restoration was recorded. Thus only one failure type was recorded per restoration type.

The experimental design was a two-way design, using 2 groups, the restoration group and the cement group. Each classification has three levels. Thus, a two-way ANOVA was used to analyze the force necessary to dislodge the crowns. A two-way logistic regression was used to analyze the failure types. A Tukey's HSD multiple comparison procedure was used to determine significance. All analyses were done using SAS software (JMP, version 9.0.2, SAS Institute Inc., Cary NC).

Results

Analysis of Force

With regard to the force necessary to dislodge the restoration, data was analyzed using two-way ANOVA. There were no significant differences between groups of restorations ($P = 0.4412$). However, there were significant differences between the types of cement used ($P < .0001$). The cement differences were consistent across the restoration groups ($P = 0.7682$). The means for each group and overall for each cement type are shown in Table 1 and Figure 11. Tukey's HSD multiple comparison procedure indicated that the FujiCem was significantly stronger than either Fuji I or Ketac Cem cements and there were no significant differences in strength between the Fuji I and Ketac Cem cements.

Analysis of failure type

The type of failure was recorded for each crown. There were five types of failures recorded and these nominal levels were compared for experimental group differences by logistic regression. Logistic regression indicated that there were no differences between cement groups ($P = 1$) but significant differences existed between restoration groups ($P = 0.0003$). These restoration differences were consistent across the three cement groups ($P = 0.05727$). The failures are summarized in Table 2 and Figure 11. Predictably, the major differences were that porcelain fractures were only seen in the EZ Pedo group,

cement/crown interface separations were relatively common in the Unitek group (n=11), and cement/die interface separations were relatively rare for Unitek (n=7).

Discussion

The results of this study indicate that restoration type does not matter and that restoration retention may depend more on type of cement. This supports previous studies in which the researchers found that crown retention is largely dependent upon cement, (5) even though no restorations in this study were crimped. Guelmann et al. found that crimping the veneered SSC did result in increased retention.⁵ Also, Guelmann et al. theorized that the bond strength to the resin die was weaker than that of natural teeth.⁵

The veneered facing of the NuSmile Primary Crown never became dislodged during preparation of the crown for testing or during the test itself. Although studies report that veneer failures do occur, this was not observed in the present study.^{5, 20}

NuSmile crowns and EZ-Pedo crowns both have visible proprietary internal retention form features (Figure 13, Figure 14). The Unitek crowns did not have these internal retention features, yet showed similar retention rates. The internal retention form feature may have provided additional retention during testing of the Ketac Cem group, where restoration to cement failures were highest among the Unitek restoration group (n=7).

Traditional glass ionomers (Fuji I and Ketac Cem) bond to dentin by an ionic bond with hydroxyapatite, and conventional composite materials bond to dentin through micromechanical interlocking with collagen fibrils and dentinal tubules.²¹ Resin

modified glass ionomers (RMGIs) such as FujiCem contain components of glass ionomer (fluoro-aluminosilicate glasses and polyacrylic acid) as well as resin composites (photo or chemical initiators and methacrylate monomers).²¹ Due to their hybrid nature, RMGIs bond to dentin through both an ionic bond between polyacrylic acid and hydroxyapatite and mechanical interlocking with collagen and the resin monomer.²¹ The addition of resin composite to the glass ionomer cement (FujiCem) may have attributed to the increased bond strength with the resin dies.

The majority of failures occurred at the cement/die interface, indicating that all cements had a high affinity for the crown and a low affinity for the acrylic dies, with the exception of the aforementioned FujiCem.

Nail failures were also relatively uncommon (n=4). When they did occur, they were pulled through the incisal edge. One possible reason for this failure was the variation in nail head length. Porcelain failures were also a type of nail failure, but they were given a separate category in order to distinguish between those porcelain failures and nail failures where the nail passed through the incisal hole. These porcelain / zirconia fractures most likely resulted due to the testing method itself. Since zirconia has high compression strength but low tensile strength, the head of the nail placed increased force on the incisal edge resulting in a point contact where excessive force was located (Figure 9, Figure 10) This excessive force resulted in failure of the zirconia. This failure is unlikely under clinical conditions.

Screw failures most likely resulted from inconsistent manufacturing techniques. Some screws failed through distortion, while others failed at the screw/die interface. (Figure 6, Figure 7)

As the results indicate, the prefabricated zirconia crowns for primary anterior teeth have similar retention rates when using each of the three types of cements. These crowns share many of the same advantages as the veneered SSC's. In addition, the prefabricated zirconia crowns can be heat sterilized and are a suitable restorative material for children with nickel allergies.¹⁶ The inability to crimp zirconia crowns and the difficulty in adjustment may be seen as potential disadvantages.

Although according to the NuSmile Technical guide, a passive fit is recommended to prevent facing fracture.²² A recent study comparing crimped and non-crimped veneered SSC and the effects of crimping on the veneered facing showed no statistically significant differences between the two groups²⁰

Additional in vitro research is needed to assess the prefabricated zirconia crown. Improved testing methods to limit Screw, porcelain, nail failures to increase the amount of die and cement failures.

Conclusion

In conclusion, with regard to the retentiveness of the three cements tested, restoration type did not matter between cements, but the type of cement did matter with FujiCem being the most retentive. Prefabricated Zirconia primary crowns have similar advantages and disadvantages compared to traditional veneered SSCs and are a viable restorative option for the pediatric patient.

APPENDIX: TABLES AND FIGURES

Table 1: Force in pounds required to dislodge the crowns

Cement	Restoration	Pounds (mean)	SE	95% CI	
FujiCem	EZ Pedo	28.89	2.05	24.81	32.97
	Nu Smile	27.57	2.05	23.49	31.65
	Unitek	27.80	2.05	23.72	31.88
	(all)	28.09	1.19	25.73	30.45
Fuji I	EZ Pedo	15.70	2.05	11.62	19.78
	Nu Smile	19.08	2.05	15.00	23.16
	Unitek	14.84	2.05	10.76	18.92
	(all)	16.54	1.19	14.18	18.90
Ketac	EZ Pedo	16.05	2.05	11.97	20.13
	Nu Smile	16.06	2.05	11.98	20.14
	Unitek	13.73	2.05	9.65	17.81
	(all)	15.28	1.19	12.92	17.64

Table 2: Number of Failure Types by Restoration

Failure type	Restoration			total
	EZ Pedo	Nu Smile	Unitek	
Cement / Die interface	18	23	7	48
Screw / Die interface or Distortion of screw	1	5	8	14
Cement / Crown interface	0	2	11	13
Porcelain Fracture	11	0	0	11
Nail pulled through incisal edge	0	0	4	4
	30	30	30	90

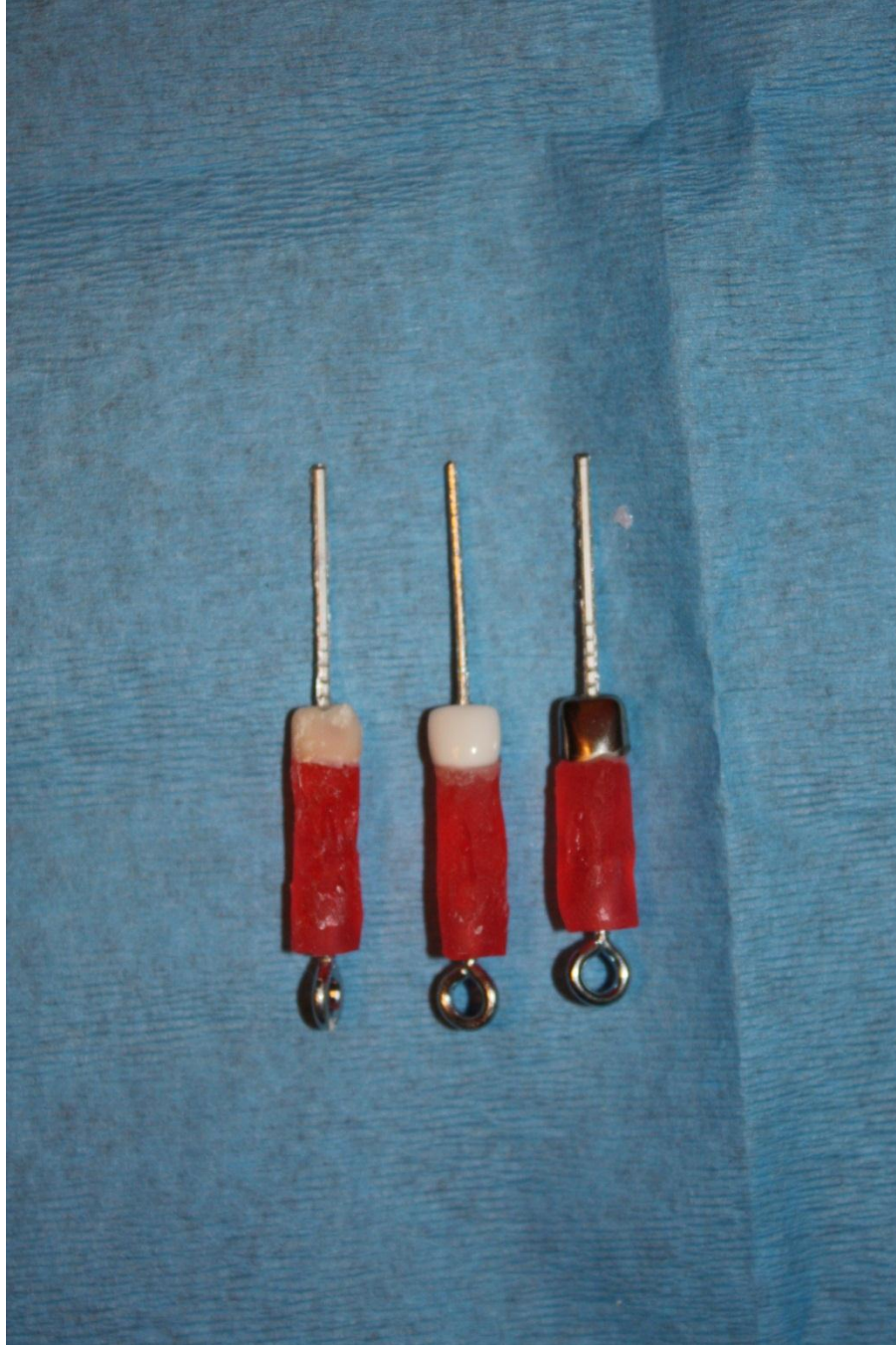


Figure 1: Facial View of Die with Restorations cemented with GC FujiCem



Figure 2: Lingual View of Die with Restorations cemented with GC FujiCem

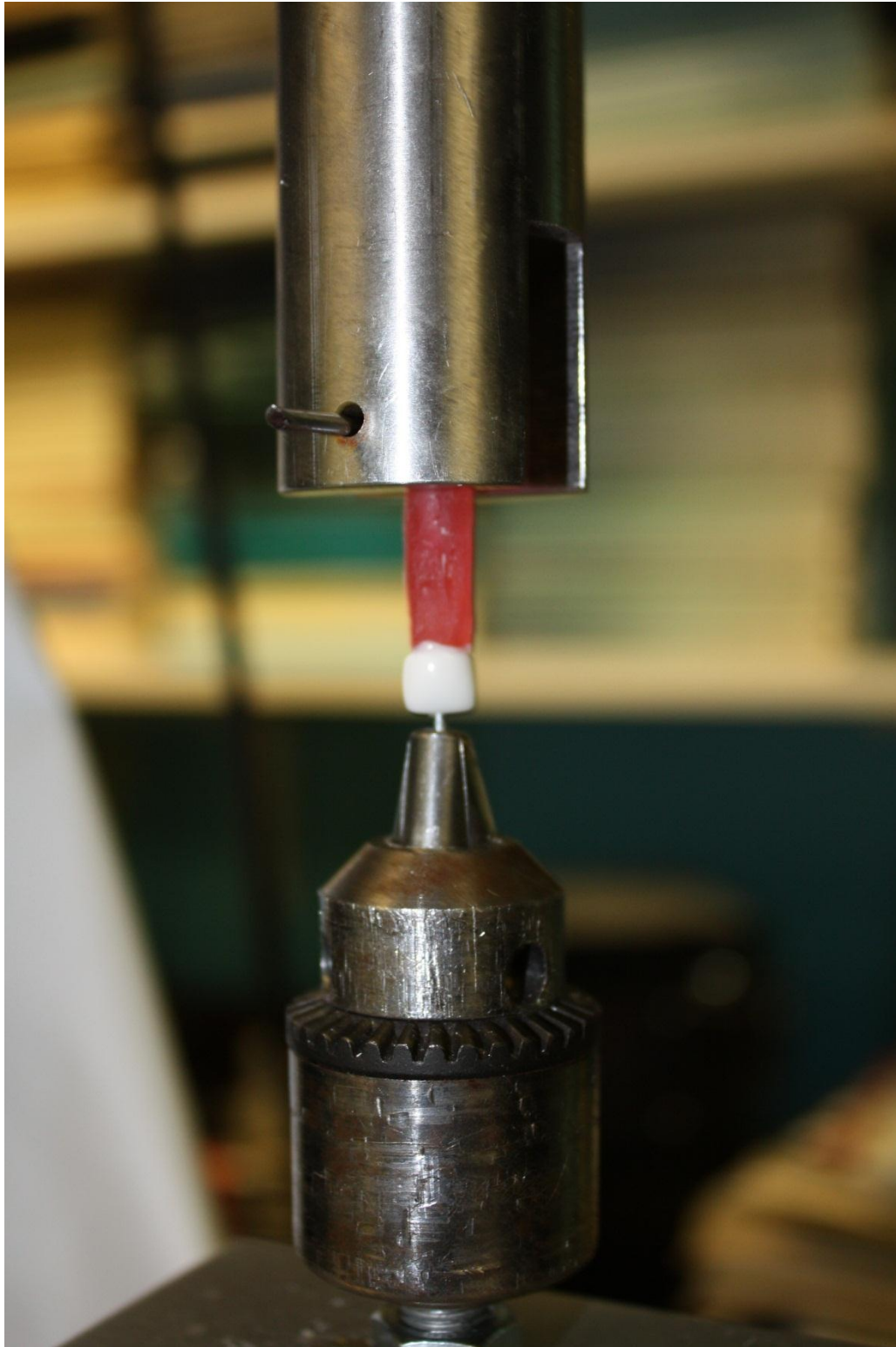


Figure 3: NuSmile Crown prepared for testing in the Intron Machine



Figure 4 – EZ-Pedo – GC Fuji I – Die Failure



Figure 5 – 3M Unitek – Ketac Cem – Crown Failure



Figure 6 – 3M Unitek – GC Fuji I – Screw Failure

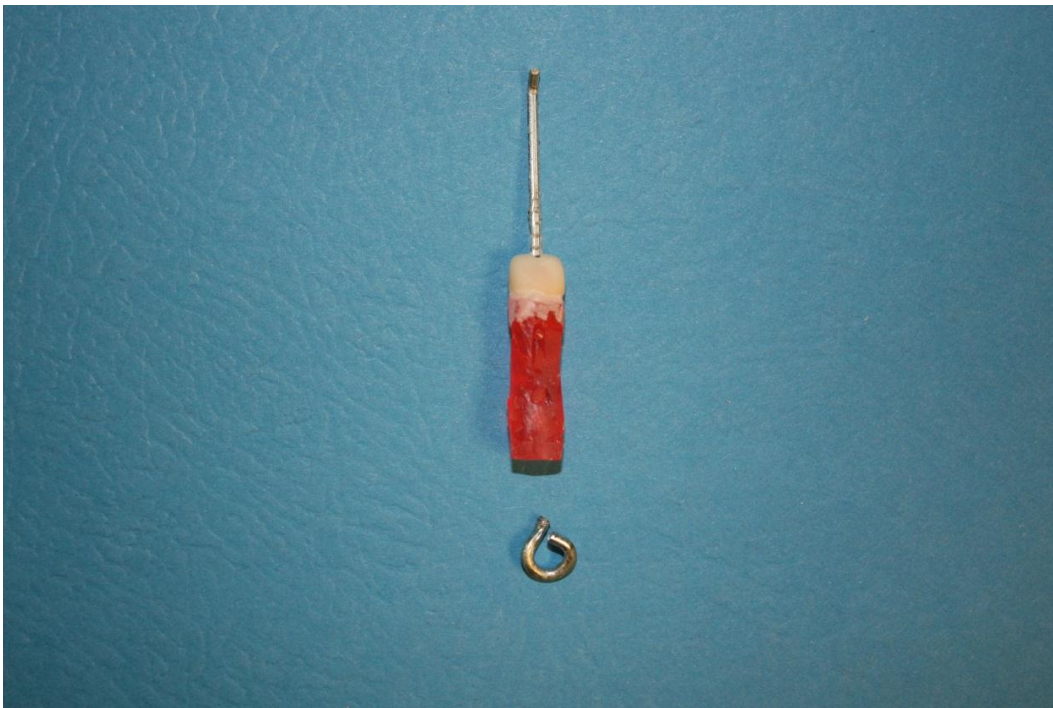


Figure 7 – EZ-Pedo – GC Fuji I – Screw Failure



Figure 8: 3M Unitek – GC Fuji I - Nail Failure



Figure 9 – EZ-Pedo – Ketac Cem – Porcelain Failure



Figure 10 – EZ-Pedo – Ketac Cem – Porcelain Failure

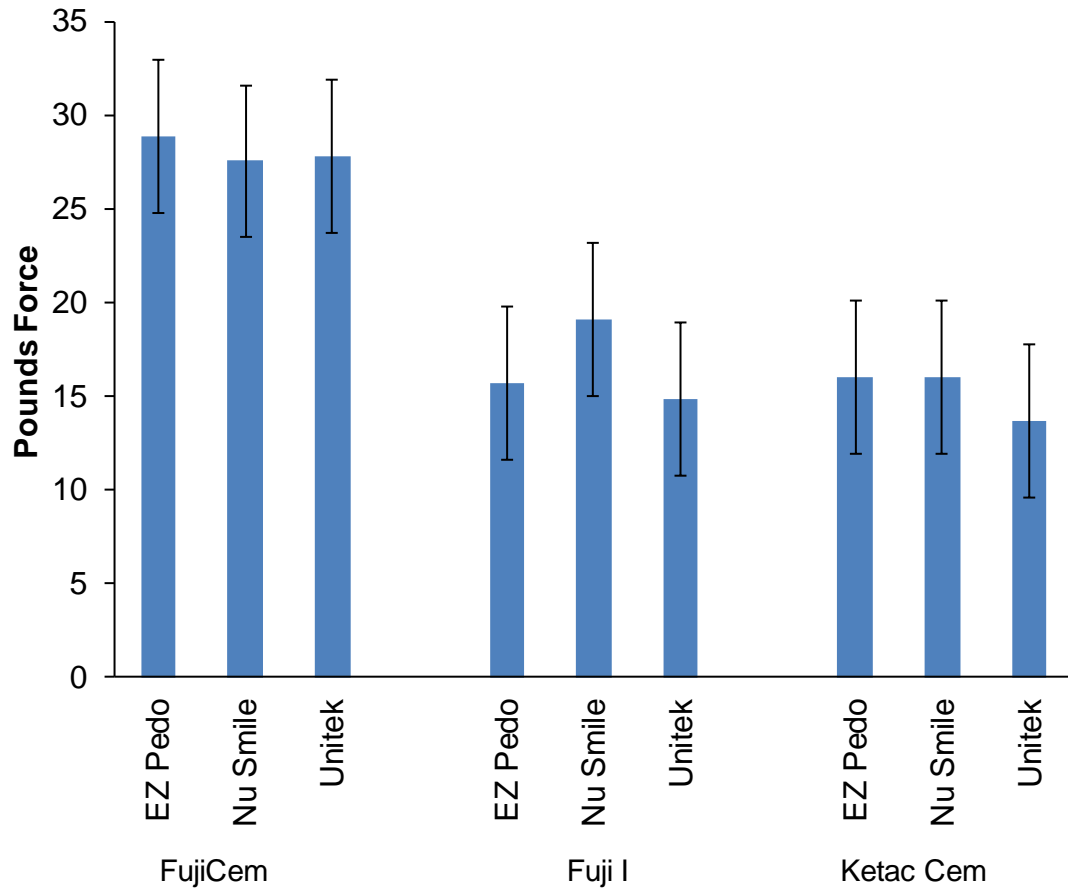


Figure 11: Mean, Standard Deviation lbf required to dislodge the crowns

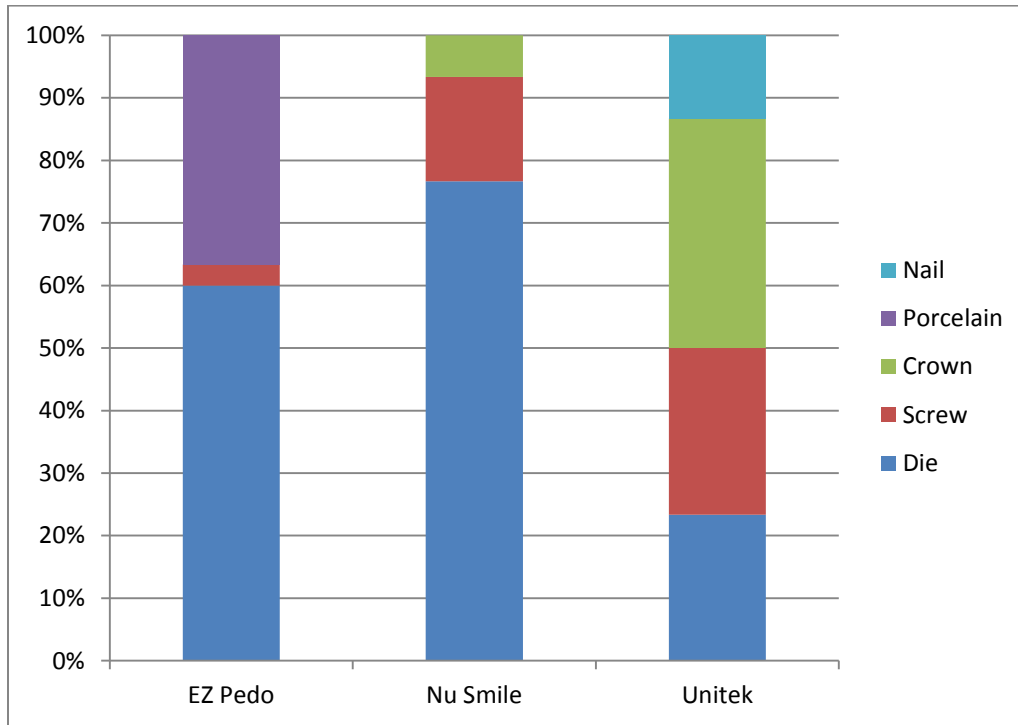


Figure 11: Percentage of Failure Types by Restorations

Note: The mosaic plot shown in Figure 12 shows the type of failures on the right-hand side and the failures within each group on the left. The size of the tile in the mosaic is proportional to the number of failure types.



Figure 13
NuSmile Crown - Internal proprietary retention form



Figure 14
EZPedo Crown - Internal proprietary retention form "Zir-lock"

Literature cited

Literature Cited

1. Roberts C, Lee JY, Wright TJ. Clinical evaluation of a Parental satisfaction with resin-faced stainless steel crowns. *Pediatric Dentistry*. 2001;23:28-31
2. Subramaniam P, Kondae S, Gupta KK. Retentive strength of luting cements for stainless steel crowns: an in vitro study. *J Clin Pediatr Dent*. 2010 Summer; 34 (4) :309-12.
3. Yilmaz Y, Gurbuz T, Eyuboglu O, Belduz N. The repair of preveneered posterior stainless steel crowns. *Pediatr Dent*. 2008 Sep-Oct; 30 (5) :429-35.
4. Yilmaz Y, Simsek S, Dalmis A, Gurbuz T, Kocogullari ME. Evaluation of stainless steel crowns cemented with glass-ionomer and resin-modified glass-ionomer luting cements. *Am J Dent*. 2006 Apr; 19 (2) :106-10.
5. Guelmann M, Gehring DF, Turner C. Retention of veneered stainless steel crowns on replicated tyodont primary incisors: an in vitro study. *Pediatr Dent*. 2003 May-Jun; 25 (3) :275-8.
6. Arnim S, Doyle M. Dentin dimensions of primary teeth. *J Dent Child*. 1959;26:252-261.
7. Kramer WS, Ireland RL. Measurements of primary anterior teeth. *J Dent Child*. 1959;26:252-261.
8. Helpin ML. The open-face steel crown restoration in children. *J Dent Child*. 1983;50:31-33.
9. Waggoner WF. Restoring primary anterior teeth. *Pediatr Dent*. 2002 Sep-Oct; 24 (5) :511-6.
10. Croll TP. Preformed posterior stainless steel crowns: an update. *Compend Contin Educ Dent*. 1999 Feb; 20 (2) :89-92, 94-6, 98-100 passim; quiz 106.
11. Reddy R, Basappa N, Reddy VV. A comparative study of retentive strengths of zinc phosphate, polycarboxylate and glass ionomer cements with stainless steel crowns--an in vitro study. *J Indian Soc Pedod Prev Dent*. 1998 Mar; 16 (1) :9-11.
12. Croll TP. Primary incisor restoration using resin-veneered stainless steel crowns. *ASDC J Dent Child*. 1998 Mar-Apr; 65 (2) :89-95.
13. Shiflett K, White SN. Microleakage of cements for stainless steel crowns. *Pediatr Dent*. 1997 May-Jun; 19 (4) :262-6.
14. Croll TP, Helpin ML. Preformed resin-veneered stainless steel crowns for restoration of primary incisors. *Quintessence Int*. 1996 May; 27 (5) :309-13.
15. Durr DP, Ashrafi MH, Duncan WK. A study of plaque accumulation and gingival health surrounding stainless steel crowns. *ASDC J Dent Child*. 1982 Sep-Oct; 49 (5) :343-6.
16. Gökçen-Röhlig B, Saruhanoglu A, Cifter ED, Evlioglu G. Applicability of zirconia dental prostheses for metal allergy patients. *Int J Prosthodont*. 2010 Nov-Dec;23(6):562-5.
17. Giordano R 2nd. Zirconia: a proven, durable ceramic for esthetic restorations. *Compend Contin Educ Dent*. 2012 Jan;33(1):46-9.
18. Ortop A, Kihl ML, Carlsson GE. A 5-year retrospective study of survival of zirconia single crowns fitted in a private clinical setting. *J Dent*. 2012 Feb 28.

19. Moldovan O, Luthardt RG, Corcodel N, Rudolph H. Three-dimensional fit of CAD/CAM-made zirconia copings. Dent Mater. 2011 Dec;27(12):1273-8. Epub 2011 Oct 7.
20. Gupta M, Chen JW, Ontiveros JC. Veneer retention of preveneered primary stainless steel crowns after crimping. J Dent Child (Chic). 2008 Jan-Apr;75(1):44-7
21. Lawson N, Cakir D, Beck P, Ramp L, Burgess J. Effect of Light Activation on Resin-modified Glass Ionomer Shear Bond Strength. Oper Dent. 2012 Feb 15. [Epub ahead of print]
22. Technical Guide Instructions for Use and General Information, NuSmile Primary Crowns. http://www.nusmilecrowns.com/pdf/nsc_TechnicalGuide.pdf. 4/15/2012

VITA

Charles Austin Davis, Jr. was born on December 16, 1979 in Tucson, Arizona. He attended the University of Tennessee Health Science Center's College of Dentistry, where he obtained the degree of Doctor of Dental Surgery in 2010. He join the advanced education in Pediatric Dentistry program at Virginia Commonwealth University's School of Dentistry in Fall 2010.