Title

Comparing the Survival Outcomes Between Stainless Steel Crowns, Resin Strip Crowns, and Zirconia Crowns When Restoring Maxillary Primary Incisors: A Retrospective Study

Author

Chao, Bryan Lim

Publication Date

2020

Comparing the Survival Outcomes Between Stainless Steel Crowns, Resin Strip Crowns, and Zirconia Crowns When Restoring Maxillary Primary Incisors: A Retrospective Study

by
Bryan Lim Chao

THESIS
Submitted in partial satisfaction of the requirements for degree of
MASTER OF SCIENCE

in

Oral and Craniofacial Sciences

in the

GRADUATE DIVISION
of the
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

Approved:

DocuSigned by:
THUAN QUOC LE
A3AFA95F85E54DE... THUAN QUOC LE
Chair

DocuSigned by:
[illegible]47A... Ling Zhan

DocuSigned by:
Ray Stewart
96F22B264D954A5... Ray Stewart

Committee Members

AUTHOR CONTRIBUTIONS

Committee members: Dr. Thuan Le, DDS PhD (Principal Investigator), Dr. Ling Zhan, DDS PhD, Dr. Ray Stewart, DDS MS

Conceptualization: Bryan Chao, Thuan Le, Ling Zhan, Ray Stewart, Jean Calvo

Investigation: Bryan Chao

Methodology: Bryan Chao, Thuan Le, Ling Zhan, Jean Calvo

Data curation: Bryan Chao, Johanna Tan

Formal analysis: Bryan Chao, Jean Calvo, Ann Lazar

Writing – original draft: Bryan Chao

Writing – review and editing: Bryan Chao, Jean Calvo, Thuan Le, Ling Zhan, Ray Stewart

Abstract

Bryan Lim Chao: Comparing the Survival Outcomes Between Stainless Steel Crowns, Resin Strip Crowns, and Zirconia Crowns When Restoring Maxillary Primary Incisors: A Retrospective Study

The purpose of this study was to evaluate the survival probabilities of stainless steel crowns, resin strip crowns, and zirconia crowns when used to restore the primary maxillary incisors on children diagnosed with early childhood caries at 12, 24, and 36 months. Two hundred and forty-one patients who received either a stainless steel crown, resin strip crown, or zirconia crown under general anesthesia participated in the study (n=241). Data included age, health status, presence of pulp treatment, date of initial treatment, clinical findings, radiographic findings, and type of failure (defined as extraction, or re-treatment of previously treated tooth). Descriptive statistics were performed, and Kaplan-Meier survival curves were used to estimate survival probabilities of each restoration type over time. Cox-proportional hazard ratios were used to compare risk of zirconia crown failure with the other restoration types. The overall survival probabilities for zirconia crowns at 12, 24, and 36 months were 65%, 48%, and 35%, respectively. Zirconia crowns demonstrated lower survival probabilities over 36 months compared with stainless steel crowns and resin strip crowns. These findings prompt our dental team to re-visit how we treatment plan for these restorations, improve our standard operating procedure, and find other ways we can improve their prognosis.

Keywords: Pediatric Dentistry, Restorative Dentistry, Early Childhood Caries, Full Coverage Crowns, Stainless Steel Crowns, Resin Strip Crowns, Zirconia Crowns

TABLE OF CONTENTS

LIST OF FIGURES

Introduction

According to the American Academy of Pediatric Dentistry (AAPD) Guidelines, early childhood caries is defined as the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child under the age of six [1]. The definition of severe early childhood caries (S-ECC) is any sign of a smooth-surface caries in a child younger than three years of age, and from ages three through five, one or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth or a decayed, missing, or filled score of greater than or equal to four (age 3), greater than equal to five (age 4), or greater than or equal to six (age 5) [1].

The etiology of early childhood caries (ECC) is multifactorial. The first contributing factor is of microbial origin. Specific risk markers for ECC include Mutans Streptococci (MS) and Lactobacillus species (LB) [2]. For children, vertical transmission of these microbes play a significant role towards increasing a child's risk for developing early caries [3]. Infants whose mothers have high levels of MS because of untreated caries, are at greater risk of acquiring the organism earlier than children whose mothers have low levels [4]. In addition to vertical transmission, horizontal transmission between other members of the family or children in daycare of these microbes can also take place [4]. Infants with high levels of early transmission of cariogenic bacteria typically have oral environments that are more conducive to caries formation as soon as the teeth erupt into the oral cavity, thereby pre-disposing them to more significant loss of tooth structure from caries.

Another associated risk factor includes dietary habits. Frequent consumption of snacks, particularly ones that are high in sugar content have been shown to increase caries risk [5]. More specifically, studies have shown that an increase in night-time bottle feeding with juice, repeated use of a sippy or no-spill cup, and frequent in-between meal consumption of sugar-added snacks or drinks increase the risk of caries [6]. The mechanism behind this effect can be described by complex interactions between host, diet, and microbes [7]. The process of caries formation is a dynamic process. Stefan's Curve demonstrates that a pH of 5.5 is the critical point at which teeth begin to experience effects of demineralization. The frequent consumption of sugary snacks allows cariogenic bacteria to break down these sugars and produce lactic acid as a byproduct of metabolism. Therefore, more frequent snacking and eating foods higher in sugar content will contribute towards reducing the oral pH below 5.5, which potentiates the caries process. It has been shown that dietary practices which promote caries are established by twelve months of age; this highlights the importance of establishing good dietary habits early [8].

In addition to diet, oral hygiene habits also have a considerable effect on a patient's risk for developing caries. Poor oral hygiene leads to a greater accumulation of plaque and results in an increased amount of cariogenic microbial flora. An increase in each of these factors make teeth more susceptible to developing caries as various sugars are ingested from the diet [7]. Good oral hygiene habits at home help to reduce plaque accumulation and overall bacterial load by mechanically cleansing the teeth. The use of a fluoridated toothpaste also helps to convert carbonated hydroxyapatite into fluorohydroxyappatite (FHA), which is less soluble and more acid resistant. Overall, these habits can help to prevent and reduce the development and subsequent breakdown of teeth from caries.

The first eight primary teeth to erupt into the oral cavity are the mandibular and maxillary incisors. These teeth erupt as early as six months, and the eruption of these anterior incisors are typically completed by eighteen months. It is noteworthy that the timing of the eruption of these teeth along with early inoculation by cariogenic bacteria, poor dietary and hygiene practices render these teeth very susceptible to the effects of demineralization and caries formation at a young age. When the maxillary incisors experience early exposure to known risk factors they typically present with the earliest signs of decay and experience the most severe loss of tooth structure, requiring full coverage restorations to restore form, function, and esthetics. Unlike permanent teeth, class III and class IV composite restorations are not commonly used in primary incisors due to technique sensitivity [9]. These teeth have small clinical crowns, large pulp chambers which are close in proximity to interproximal surfaces, and thin enamel [9]. Furthermore, lack of remaining sound tooth structure increases restorative challenges and often results in poor retention, recurrent caries, and dental infection. In pediatric dentistry, the use of full coronal coverage restorations is a superior option for restoration of maxillary primary incisors.

Common full coverage restorations for anterior primary teeth include stainless steel crowns (SSC), resin strip crowns (RSC), pre-veneered stainless steel crowns and zirconia crowns (ZC). SSCs represent an excellent restorative option with many associated benefits. These crowns are primarily used to restore teeth with large caries, cervical decalcification, developmental defects, teeth receiving a pulpotomy/pulpectomy procedure, and for patients who are at high caries risk. SSCs are recognized for being fracture resistant, durable, and retentive [10]. Other benefits include a conservative tooth preparation as well as the ability of the crown to be adjusted to fit the tooth while also being unaffected by surrounding sources of moisture contamination during crown delivery [11]. However, SSCs do present with several limitations. According to Roberts et al., the main reasons SSCs fail are due to crown loss and perforation [12]. Furthermore, due to their metallic appearance, SSCs present with a notable esthetic limitation when restoring maxillary anterior teeth.

Pre-veneered stainless steel crowns represent another restorative option when restoring the primary maxillary incisors. These have similar strengths and benefits as SSCs, and utilize a facial tooth colored veneer to improve esthetics. Limitations of these restorations include increased cost, limited range of adjustment, increased risk of fracture of the veneered portion of the crown, and significantly more tooth reduction for proper cementation and alignment [14]. A retrospective, cross-sectional study demonstrated 1.5-year average success rate with 100% retention of the crown, 13% complete loss of facings, and high parental satisfaction with appearance, color, shape, and size of the restoration [13]. Pre-veneered SSCs were not included in this study due to limited use of these crowns in our clinic.

Resin strip crowns (RSC) are an additional option that provide pediatric dentists with an acceptable esthetic full coverage restoration. These restorations can be color-matched to adjacent teeth by utilizing different shades of composite material. They require conservative tooth preparations to preserve enamel for strong bonding, good marginal gingival adaptation, and allow for marginal polishing and more manipulation during the restoration process. The drawbacks with these types of restorations include discoloration of the restoration and associated margins over time, susceptibility to fracture of the restoration, and increased technique sensitivity for inexperienced operators [14]. A retrospective study revealed that RSCs had disadvantages in function especially in marginal adaptation or fracture and retention [15]. However, overall parental satisfaction with RSCs was high and remained so over time [15].

Zirconia crowns (ZC) are the most contemporary of esthetic full coverage restorations available to pediatric dentists. These crowns have been recognized for their biocompatibility, and excellent esthetics [16]. Studies regarding the use of ZCs has been limited, but many studies with a small sample size and short term study periods demonstrate positive results. A retrospective study evaluated ZCs (to restore maxillary primary incisors) over an average time of 20.8 months and demonstrated good retention (96%) and closed margins (86%) [17]. The same study revealed high parental satisfaction and approval of zirconia crowns [17]. A recent split-mouth study comparing ZCs and SSCs demonstrated that zirconia crowns perform similarly to SSCs when restoring primary molars [18]. Furthermore, a retrospective study demonstrated that ZCs exhibit high survival probabilities at 12 (93%), 24 (85%), and 36 (76%) months after treatment [19]. These results are promising when considering ZCs are an alternative to the previously described restorations. However, ZC limitations include the requirement of more tooth reduction for proper fit, and alignment [20]. Furthermore, ZCs are rigid and cannot be modified or contoured to fit unique tooth preparations. Their cementation process is technique sensitive, requiring moisture control for proper bonding and seal [21].

Although some data is available regarding the success rate of different anterior full coverage restorations, the current available literature lacks studies with follow-up time that extends beyond 24 months while simultaneously providing a comparison between stainless steel crowns, resin strip crowns, and zirconia crowns when restoring the primary maxillary incisors.

The purpose of this study was to compare the survival outcomes between stainless steel crowns, resin strip crowns, and zirconia crowns through a retrospective chart review study. Our hypothesis is that there is no difference in survival probabilities between stainless steel crowns, resin strip crowns, and zirconia crowns when restoring the primary maxillary incisors. The goal of this paper is to add to the existing literature regarding zirconia crowns by evaluating these restorations over a longer follow-up period and comparing clinical results between stainless steel crowns and resin strip crowns to help guide future clinical practices.

Materials & Methods

This is a retrospective cohort study that was approved by the Institutional Review Board of University of California, San Francisco (UCSF-18-25895). We conducted a chart review to compare the survival probabilities of SSC, RSC, and ZC when used to restore primary maxillary incisors for patients under general anesthesia between January 2015-January 2018. The final follow-up date recorded was September 2019.

Study Population

Patients who received anterior full coverage restorations on maxillary primary incisors under general anesthesia at UCSF Benioff Children's Hospital between January 2015-January 2018 were included in the current study following the criteria below:

Inclusion criteria:

- Healthy or well-controlled/mild systemic disease patients (ASA I or II)
- Patients who received at least one full coverage restoration (stainless steel crown, resin strip crown, or zirconia crown) on teeth #'s D,E,F,and/or G (primary maxillary incisors)
- Patients with at least one follow-up dental examination in our clinic at UCSF

Exclusion criteria:

- Unhealthy patients (ASA III or higher)
- Patients who received treatment in the dental chair with N2O or oral conscious sedation
- Patients with teeth treated using intra-coronal restorations

- Patients without at least one follow-up dental examination in our clinic at UCSF

Data collection

Electronic charts from January 2015-January 2018 were reviewed to determine if they met the inclusion criteria for our study. Prior to our chart review, our dental IT department helped to select for charts with specific criteria pertaining to our study. Each qualifying patient chart required a hospital general anesthesia code (D2940), and at least one of the following restorative codes: stainless steel crown (D2930), resin strip crown (D2336), or zirconia crown (D2929) on either teeth #'s D, E, F, and/or G. After applying these filters, the initial database consisted of 459 charts of active and inactive patients who received at least one full coverage restoration (stainless steel crown, resin strip crown, zirconia crown) under general anesthesia. Patient charts were reviewed by two persons, the author and his research assistant. Upon completion of the data collection, all qualifying charts and associated data inputs were reviewed by the author to ensure accuracy.

Charts were opened in Axium, and completed dental codes, progress notes, odontograms, and available radiographs were reviewed at each follow-up visit (post-GA check, periodic oral exam, caries risk assessment visits, and emergency visits). A customized qualtrics survey was created, and questions were written to assist in organizing and collecting data from the reviewed charts. Chart numbers and date of dental treatment under general anesthesia were recorded. For this study, initial crown placement was defined as the date of treatment under general anesthesia as recorded in the patient's electronic dental record. The following dental variables were extracted from the patient's dental electronic record: patient age, health status, tooth number receiving treatment (#D, #E, #F, #G), pulp treatment (i.e. none, pulpotomy, pulpectomy), type of restoration (zirconia, stainless steel crown, resin strip crown), and the dates of follow-up appointments at UCSF Pediatric Dental Clinic. The following variables were recorded at each subsequent follow-up visit: clinical findings (within normal limits (WNL), fractured crown, missing crown, abscess, recurrent caries, perforated crown, mobile crown, trauma, exfoliated), radiographic findings (WNL, external resorption, internal resorption, periapical radiolucency, recurrent caries, exfoliated, root fracture, no radiographs), and follow-up procedure (re-cementation of crown, re-treatment – pulp treatment/new crown, extraction, restoration repair, none).

Clinical Protocols and Defined Outcomes:

Stainless steel crowns were prepared according to recommended guidelines and cemented with Fuji I glass ionomer cement. Resin strip crowns were performed with rubber dam isolation using floss ligatures, and were prepared according to recommended guidelines. Following preparation, teeth were etched with 35% phosphoric acid then rinsed and dried. Opti-bond (Kerr Dental) was then placed on the teeth, gently dried, and cured. Resin strip crowns were fabricated using polycarboxylate molds and a combination of flowable and packable composites (Helio). Zirconia crowns were prepared according to the manufacturer (NuSmile) guidelines. After preparation, various sized try-in crowns were sampled for proper fit. Upon achieving hemostasis, the crowns were cemented using BioCem cement utilizing an initial tack cure step, followed by removal of excess cement, and then a final complete cure of the cement.

Definition of success:

- Natural tooth exfoliation: The dental record indicated that the treated tooth had exfoliated naturally since the previous appointment.

- Presence of the restored tooth without any follow-up treatment (extraction due to infection, re-prep/delivery of new crown, pulp therapy, repair/re-cementation of existing full coverage restoration).

Definition of failure:

- Pre-mature extraction: The dental record indicated that the treated tooth was extracted due to infection. The date of extraction was recorded as indicated in the patient chart.
- Follow-up restoration: Re-cementation of existing crown, re-prep and delivery of new crown, repair of existing full coverage restoration as indicated by the dental record.

Data analysis:

After the data was collected, qualifying patient charts were followed through their furthest follow-up date if there was no indication of failure as defined above. The date of placement, and the last follow-up date was recorded and the total number of elapsed days was calculated. However, if there was a failure as defined above, the initial date and the earliest date of failure of any one of the restorations was recorded and the total number of elapsed days was calculated for that specific patient. This was organized and analyzed on a subject level. For example, if a patient received 4 stainless steel crowns on the date of treatment under general anesthesia, if one failed in the future, the entire SSC sample (n=1 patient receiving SSCs) would be considered a failed restoration. For each patient, we calculated days to the first observed sign of failure (completion of a subsequent procedure on a previously restored tooth).

Descriptive statistics were performed for all variables. Survival probabilities were calculated using a Kaplan-Meier survival curve at the subject level. This method was selected because of its ability to compute a survival estimate over time despite losing patients to follow-up. For the Kaplan-Meier and Cox model procedures, time to crown failure was defined as the time from crown placement to time of failure. A Cox proportional hazard was calculated to compare the relative risk of failure between groups. Furthermore, a log rank test was used to determine statistical significance of collected data.

Results

A total of 459 eligible patient charts were reviewed. 83 patients were excluded due to patients having an ASA status greater than 2, leaving 376 eligible charts for review. After reviewing these charts, an additional 135 patients were excluded due to lack of follow-up data. There were 241 qualifying patient charts with 689 total treated teeth for our final analysis. Of the 241 patient charts reviewed, 124 patients received resin strip crowns (349 RSC), 91 patients received stainless steel crowns (254 SSC), and 26 patients received zirconia crowns (86 ZC). These findings are summarized by a flow chart depicted in Figure 1.

The average age of patients receiving treatment was 40 months (3.3 years), with an age range of 2-6 years old. The earliest recording of the placement of a ZC was in May 2015 and the last recorded placement was in October 2017. Follow-up ZC data was collected through June 2019. The earliest recording of the placement of a SSC was in February 2015 and the last recorded placement was in November 2017. Follow-up SSC data was collected through September 2019. The earliest recording of the placement of a RSC was January 2015 and the last recorded placement was in November 2017. Follow-up RSC data was collected through August 2019.

The overall survival probabilities of SSCs at 12, 24, and 36 months were highest at 98%, 98%, and 90% respectively (Figure 2). In comparison, the overall survival probabilities of ZCs at

12, 24, and 36 months were the lowest at 65%, 48%, and 35% respectively (Figure 2). Survival probabilities for RSCs were in-between those of stainless steel crowns and zirconia crowns at 93%, 86%, and 79% respectively (Figure 2). Survival probabilities at each time point are summarized in Figure 3. This study revealed that there is a statistically significant (Log rank test: P value < 0.00001) difference between the survival probabilities of stainless steel crowns, resin strip crowns, and zirconia crowns.

The types of failure for zirconia crowns were further investigated and revealed that the two most prominent reasons for failure were due to dental abscess (42%), and missing crown (25%) as seen in Figure 4. Other reasons for zirconia crown failure are described in Figure 4. Dental abscess was the singular reason for observed failures of SSCs (Figure 6). However, dental abscess, recurrent caries, and fractured restorations were the reasons for reported failures of RSCs (Figure 5). Our Cox proportional hazard ratio revealed that ZCs were eight times more likely to fail compared to RSCs, and sixteen times more likely to fail compared to SSCs.

Discussion

Our study aimed to compare the survival probabilities between stainless steel crowns, resin strip crowns, and zirconia crowns placed on primary maxillary incisors at 12, 24, and 36-month follow-up visits at UCSF Pediatric Dentistry dental clinics. This study uniquely provides comparison data of survival probabilities between SSCs, RSCs, and ZCs. We hypothesized that there would be no difference in survival outcomes between the three types of anterior restorations. However, our results did not support our hypothesis, but instead revealed that at 12, 24, and 36 months, zirconia crowns demonstrated the lowest survival probabilities when compared to stainless steel crowns and resin strip crowns (Figure 2,3). Stainless steel crowns demonstrated the most consistent and highest survival probabilities over time (Figure 2,3).

Our results indicated that SSCs demonstrated the highest survival probability when compared to RSCs, and ZCs at 12, 24, and 36 months post-treatment. Stainless steel crowns are still considered in pediatric dentistry as the gold standard for restoring teeth with large multi-surface caries. They are durable, fracture resistant, retentive, and provide excellent coronal seal. Lopez-Loverich, Garcia, and Donly performed a retrospective study evaluating the retention of SSCs placed on 154 primary maxillary incisors [22]. After a mean follow-up time of 27 months, only 7% of the SSCs failed [22]. Our results are in range with these findings with a survival probability of 98% at a 24-month follow-up. Despite the biological and functional success of SSCs, parental preferences and self-awareness of school aged children have driven an increased demand for more esthetic restorations when restoring anterior teeth [19].

Resin strip crowns have demonstrated slightly mixed results according to previous studies. One retrospective study by Manmontri et al. demonstrated that resin strip crowns were acceptable esthetically and biologically, yet had issues with function due to issues with marginal adaptation, fracture, and retention [15]. Another retrospective study by Ram et al. studied resin strip crowns over the course of 24 months and revealed an 80% success rate [23]. Furthermore, an additional retrospective study by Kupietzsky et al. observed an 83% retention rate at 1.5 years, and a 78% retention rate after 3 years [24]. This study also found that RSCs had few negative effects on pulpal health [24]. The findings in our study agree with these previous studies. Overall, RSCs demonstrated survival probabilities above 79% over the course of 36 months, and failures were primarily due to fractured restorations or recurrent caries around the margin. RSCs remain an excellent restorative option to satisfy the esthetic demand of children and their parents while also demonstrating good long-term clinical success.

Multiple existing studies have demonstrated that zirconia crowns are a suitable alternative to traditional restorative approaches. However, these studies were short-term studies with small sample sizes. For example, Donly et al. conducted a split mouth study that revealed no differences between SSCs and ZCs when restoring posterior primary molars in a randomized clinical trial and found no difference in success rate between the two types of restorations over 24 months [18]. It is important to note that two different types of cements were used for each restoration type in this study. Stainless steel crowns were cemented using resin modified glass ionomer cement, while zirconia crowns were cemented using bioceramic cement which requires stricter moisture control [18]. Furthermore, Seminario et al. demonstrated that anterior ZCs exhibited survival probabilities of 93%, 85%, and 76% at 12, 24, and 36 months respectively [19]. This is one of the few existing studies with a longer follow-up study period.

The results from our study do not agree with these previous studies done on zirconia crowns, but instead demonstrate a contrast. Our study revealed a significantly reduced probability of survival of zirconia restorations compared to other traditional types of anterior restorations. Based on these results, zirconia crowns may have less predictable clinical outcomes compared to traditional full coverage restorations.

There are three important reasons that may have contributed to the lower survival probabilities observed with zirconia crowns in our study. First, multiple and inexperienced providers may have reduced the survival probability of ZCs. In our residency program, residents are given opportunities to complete full mouth cases under general anesthesia. Residents enter the program with varying levels of dental experience and skill. In general, pediatric dental residents have less clinical experience and skill compared with pediatric dentists who have already completed their residency training. This difference may translate to less than ideal tooth preparations (over-preparation, over-taper, etc.), improper crown sizing, and improper cementation of zirconia crowns. It is important to note that the limitation of provider inexperience was also applied to the stainless steel crowns and resin strip crowns that were completed in this study. Despite the same exposure to operator inexperience, each of these restorations types boasted higher survival probabilities compared to zirconia crowns. The first explanation for this finding may be that zirconia crowns may procedurally have less margin for error resulting in a greater response to operator inexperience. In contrast, stainless steel crowns and resin strip crowns are more amenable to operator inexperience resulting in more successful cases despite the inexperience. Another explanation may be that due to the recent addition of zirconia crowns to our restorative options, an overall lack of experience may have resulted in more failed cases.

Secondly, excessive tooth reduction may also explain the reduction in survival probabilities of zirconia crowns. Unlike zirconia crowns, stainless steel crowns and resin strip crowns allow the provider to adapt their restorations to fit their unique tooth preparation which may ultimately help to conserve tooth structure. The unmalleable nature of zirconia crowns, its increased marginal thickness and need for a passive fit may contribute to over-preparation of the tooth. Furthermore, improper sizing of zirconia crowns may contribute to further over-preparation of the tooth to make these crowns fit passively. Anatomically, primary maxillary incisors have thinner enamel and larger pulp chambers. Previous studies by Marshall et al. have revealed that dentinal tubule density is highest at the pre-dentin surface (inner dentin) at the junction of the pulp chamber, where the odontoblastic cell processes also lie in a close-packed array [25]. Furthermore, the deeper portion of dentin also contains tubules with large diameters [25]. Therefore, excessive tooth reduction into the dentin results in greater exposure of more dentinal tubules and ones that are larger in diameter. As a result, a greater amount of tooth reduction increases the risk of mechanical and thermal trauma, leading to irritation of the pulp and possible future pulpal necrosis. Our study demonstrated that the greatest percentage of zirconia crown failures were due to pulpal necrosis, which may highlight heightened pulpal sensitivity to zirconia crown procedures.

Thirdly, complications with cementation may have resulted in greater zirconia crown failures. Because zirconia crowns require a passive preparation design, retention relies primarily on the quality of cementation. Many of our patients seen under general anesthesia are children with large, subgingival caries and extremely poor oral hygiene which results in localized inflammation of gingival tissues making it difficult to obtain adequate moisture control. Furthermore, zirconia crowns require preparation of the tooth subgingivally which may potentiate difficulty with achieving adequate hemostasis. In our clinic, zirconia crowns were cemented with Biocem cement. Biocem cement is a resin modified glass ionomer cement, which ideally requires moisture control to ensure ideal function of the material [21]. In our study, the second most common reason for zirconia crown failure was due to a missing crown. This finding may highlight issues with the quality of cementation protocol or may further support over preparation tendencies.

There are notable limitations to this current study. As a retrospective study, we were unable to control for many clinical factors such as standardized case selection, provider type, and how restorative procedures were carried out when performed. Furthermore, descriptions of the observed outcomes in the dental charts varied from provider to provider. While some indicated specifics such as restoration wear, changes in color, site of fracture or recurrent caries, other providers were not as specific in describing follow-up on these restorations. This inconsistency highlights possible overrepresentation or underrepresentation of information collected in our study. Also, the availability of post-treatment radiographs was inconsistent primarily due to patient behavior and inability to take radiographs at follow-up visits. Though radiographic findings were collected when available, our study is unable to speak on radiographic changes that may have taken place in response to the completion of these restorations due to inadequate sample size for analysis.

In addition, many patients included in this study were excluded due to lack of follow-up visits. Of the 376 charts available for review, 135 cases were not included in this study. This equates to approximately 35% of charts rendered unavailable for analysis. Because ZC's have only recently been introduced in the dental market as an esthetic alternative, zirconia crowns had the smallest sample size with only 26 cases (86 zirconia crowns) available for review. That sample size is significantly less than stainless steel crowns (n=91, 254 crowns), and resin strip crowns (n=124, 349 crowns). At UCSF, most patients treated in the pediatric dentistry clinic are referred from other clinic sites. It is common that once patients complete their dental care under general anesthesia, they return to their original providers for follow-up care. Therefore, it is possible that there may be a significant number of SSCs, RSCs, and ZCs that were completed but are unaccounted for in this study because the patients were asymptomatic and never returned to our UCSF dental clinic for follow-up visits. Therefore, the reported survival probabilities for all 3 types of crowns in this study may be different from its true value.

Statistically, calculations were made on a subject level. For example, while a patient may have received multiple zirconia crowns during treatment under general anesthesia, if one failed, the entire sample would be considered a failed restoration. This approach was executed based on the recommendation of the statistician to prevent over-representation of findings if they were analyzed on a tooth level. However, success outcomes for each tooth can be varied due to decay size and other factors within each subject. Conducting the analysis at a subject level may under-represent the success and failure rates for each group. Therefore, we plan to conduct an additional analysis at the tooth level to supplement and compare to our current findings. We will also conduct further analysis to consider possible confounding factors such as pulp therapy, age of the child at crown placement, as well as follow-up length.

To strengthen our findings, we can continue to gather data from January 2018-present, or call patients that were lost to lack of follow-up visits in this group to increase the sample size of each type of restoration analyzed in this study. Ideally, a separate blinded randomized controlled clinical trial study with at least 80% power, and long-term follow-up using calibrated providers should be conducted to compare the performance and survival probabilities for all three groups of restorations.

In conclusion, the survival probabilities of zirconia crowns over 36 months was found to be below 50%, which is clinically unacceptable. Despite our findings, many other studies have demonstrated clinical success with zirconia crowns. Zirconia crowns inherently have many benefits and can be an excellent restorative option for our high caries risk patients. These findings prompt our dental team to re-visit how we treatment plan for these restorations, improve our standard operating procedure, and find other ways we can improve their prognosis.

Conclusions

1. Zirconia crowns exhibited the lowest survival probabilities at 12 months (65%), 24 months (48%), and 36 months (35%) post treatment at a subject level. Stainless steel crowns had the highest survival probabilities (98%, 98%, 90% respectively), followed by resin strip crowns during the study period (93%, 86%, and 79% respectively).
2. The main causes for failure was dental abscess and missing crowns for ZCs; recurrent caries and fractured crowns for RSCs, and dental abscess for SSCs.
3. Although our retrospective study shows a significantly lower survival probability of 35% up to 36 months, we are not able to definitively conclude that zirconia crowns are a poor restorative choice for primary maxillary incisors due to limitations in our study. Current literature supports the use of zirconia crowns as an esthetic alternative for primary incisors. Future blinded randomized controlled clinical trials are encouraged to better assess the quality and efficacy of zirconia crowns as a restoration.
4. These results demonstrate that our team at UCSF Pediatric Dentistry needs to investigate how we treatment plan for these restorations, and improve our standard operating procedures for zirconia crowns to produce more predictable outcomes and improve overall prognosis.

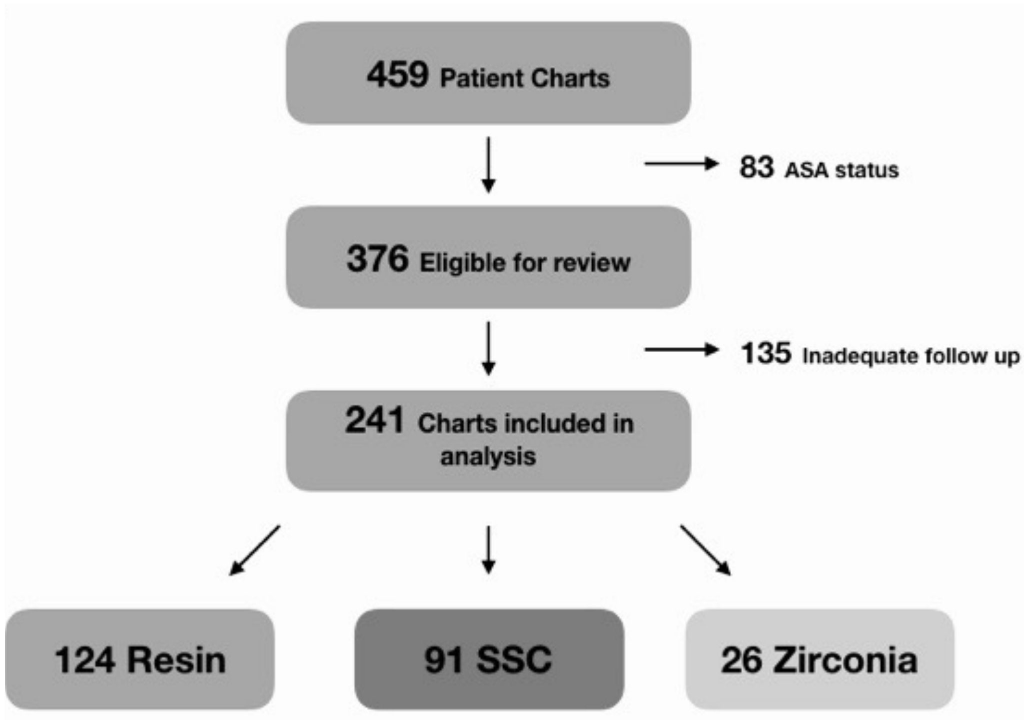

Figure 1: Flow chart depicting the process of selecting charts qualified for study

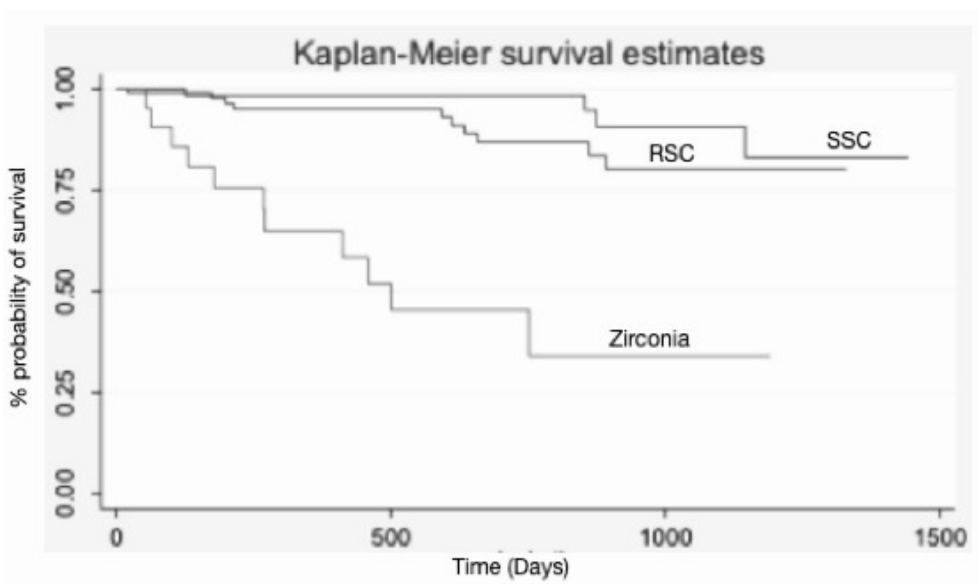

Figure 2: Kaplan Meier Curve comparing the survival probabilities between stainless steel crowns, resin strip crowns, and zirconia crowns at a subject level

Log rank test ($p<0.00001$)

Kaplan - Meier Survival Estimates for all full coverage restorations studied at 12-, 24-, and 36-months

	12 months	24 months	36 months
Stainless Steel Crowns	98%	98%	90%
Resin Strip Crowns	93%	86%	79%
Zirconia Crowns	65%	48%	35%

Figure 3: Survival probability estimates for all full coverage restorations studied at 12, 24, and 36 months at a subject level

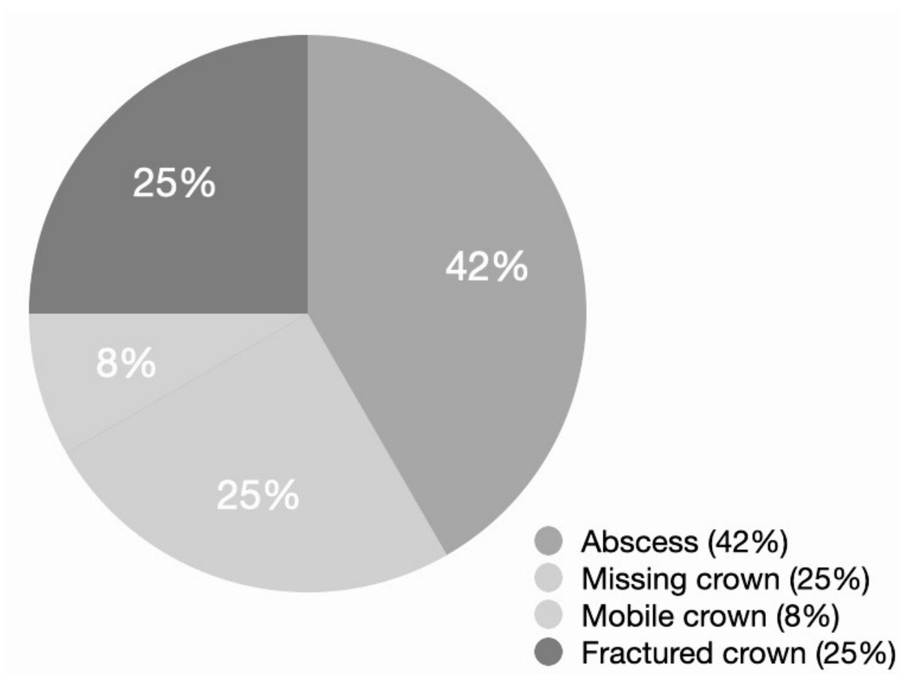

Figure 4: Distribution of causes for failure of zirconia crowns at a subject level

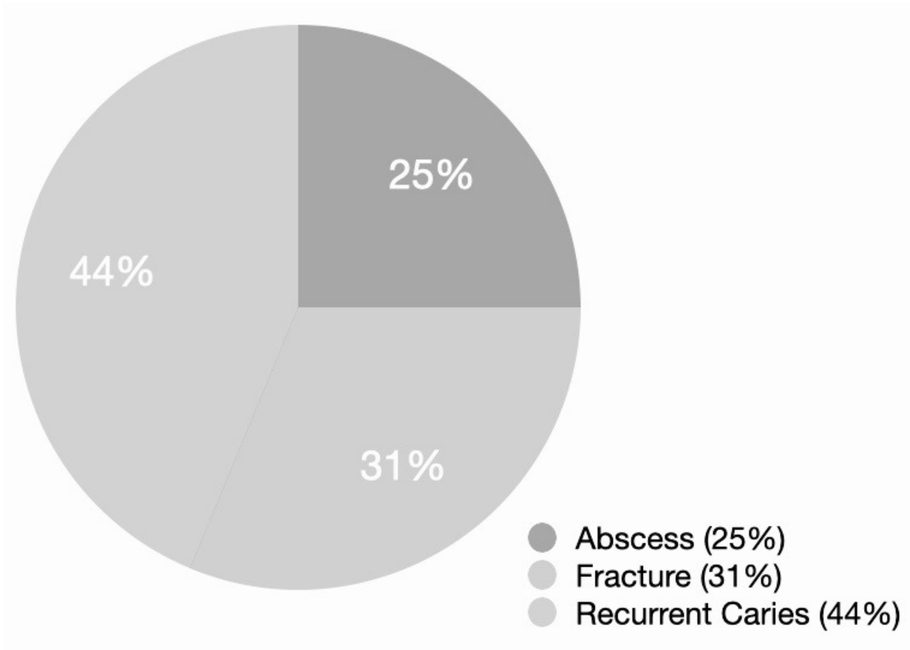

Figure 5: Distribution of causes for failure of resin strip crowns at a subject level

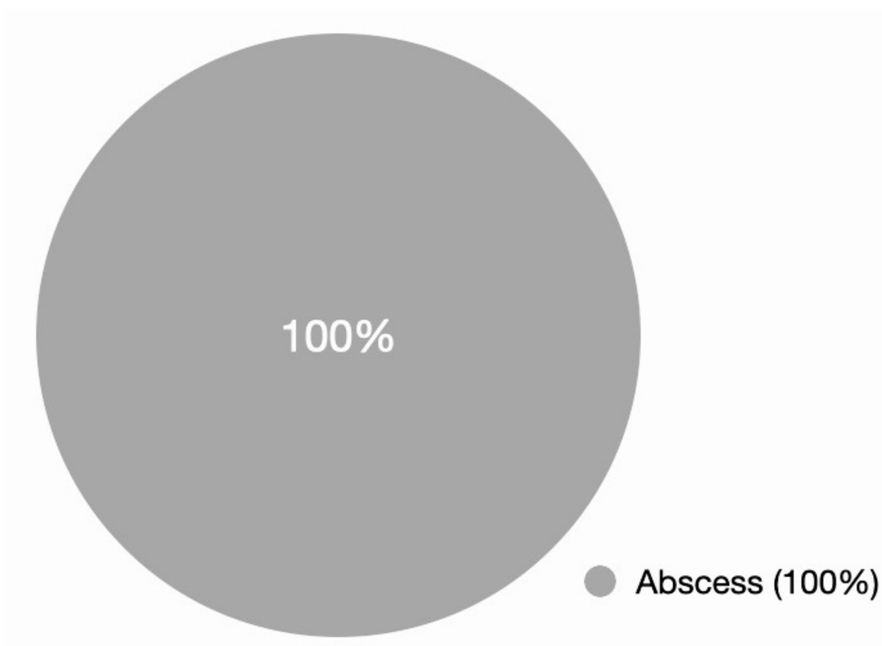

Figure 6: Distribution of causes for failure of stainless steel crowns at a subject level

References

1. American Academy of Pediatric Dentistry. Policy on Early Childhood Caries (ECC): Classifications, Consequences, and Preventive Strategies. *Pediatric Dentistry* – **2016**, 71
2. Kanasi, E.; Johansson, I.; Kressin, N.R.; Nunn, M.E.; R. Kent, Jr.; Tanner, A.C.R. Microbial risk markers for childhood caries in pediatricians' offices. *Journal of Dental Research* – **2010**, 89 (4): 378-83
3. Li, Y.; Caufield, P.W.; The fidelity of initial acquisition of mutans streptococci by infants from their mothers. Journal of Dental Research – **1995**, 74(2):681-5
4. Berkowitz, R.J. Mutans streptococci: acquisition and transmission. *Pediatric Dentistry* – **2006**, 28(2): 106-9
5. Moynihan P.J.; Kelly, S.A.M. Effect on caries of restricting sugars intake: Systematic review to inform WHO guidelines. *Journal of Dental Research* – **2014**, 93(1):8-18
6. Tinanoff, N.T.; Kanellis, M.J.; Vargas, C.M. Current understanding of the epidemiology mechanism, and prevention of dental caries in preschool children. *Pediatric Dentistry* – **2002**, 24(6): 543-51
7. Hajishengallis,E.; Parsaei, Y.; Klein, M.I.; Koo, H. Advances in the microbial etiology and pathogenesis of early childhood caries. *Molecular Oral Microbiology* **– 2017,** (24-34)
8. Kranz, S.; Smiciklas-Wright, H.; Francis, L.A. Diet quality, added sugar, and dietary fiber intake in American preschoolers. *Pediatric Dentistry* – **2006**, 28(2): 164-71
9. Waggoner, W. Restoring primary anterior teeth. *Pediatric Dentistry* – **2015**, (163-170)
10. Seale, N.S. The use of stainless steel crowns. *Pediatric Dentistry* – **2002**, Sept-Oct;24(5):501-5

11. Pinkham, J., Casamassimo, P., Fields, H., McTigue, D., Nowak, A. Pediatric Dentistry Infancy Through Adolescence 4th edition – **2005**, 357-362

12. Roberts J.F.; Attari N.; Sherriff M. The survival of resin modified glass ionomer and stainless steel crown restorations in primary molars, placed in a specialist paediatric dental practice. *Br Dent J* – **2005**, 198(7): 427-31

13. Shah, P.V.; Lee, J.Y.; Wright, T.J. Clinical success and parental satisfaction with anterior preveneered primary stainless steel crowns. *Pediatric Dentistry – 26:5,* **2004***,* 391-95

14. Pinkham, J., Casamassimo, P., Fields, H., McTigue, D., Nowak, A. Pediatric Dentistry Infancy Through Adolescence 4th edition – **2005**, 367

15. Manmontri, C.; Sirinirund, B.; Langkapint, W.; Jiwanarom, S.; Kowan, V.; Tantayanusorn, S.; Nirunsittirat, A. Retrospective evaluation of the clinical outcomes and patient and parental satisfaction with resin strip crowns in primary incisors. *Pediatric Dentistry – V40/NO7*, **2018**, 425-32

16. Taran, P.K., Kaya, M.S. A comparison of periodontal health in primary molars restored with prefabricated stainless steel and zirconia crowns – **2018**, V40/NO5, 334-339

17. Holsinger, Daniel.; Wells, M.; Scarbecz, M.; Donaldson, M. Clinical evaluation and parental satisfaction with pediatric zirconia anterior crowns. *Pediatric Dentistry – V38/NO3,* **2016**, 192-97

18. Donly, K.J.; Sasa, I.; Contreras, C.I.; Mendez, M.J.C. Prospective randomized clinical trial of a primary molar crowns: 24-month results. *Pediatric Dentistry* – V40NO4, **2018**, 253-258

19. Seminario, A.L.; Garcia, M.; Spiekerman, C.; Rajanbabu, P.; Donly, K.J.; Harbert, P. Survival of zirconia crowns in primary maxillary incisors at 12-, 24-, and 36-month follow-up, *Pediatric Dentistry V41/NO5*, **2019**, 385-90
20. Clark, L.; Wells, M.; Harris, E.; Lou, J. Comparison of amount of primary tooth reduction required for anterior and posterior zirconia and stainless steel crowns. *Pediatric Dentistry – V38/NO1*, **2016**, 42-46
21. NuSmile Crowns. Biocem White Paper Booklet V2. Page 2, Accessed April 23, 2020 at https://www.nusmile.com/biocem
22. Lopez-Loverich A.; Garcia, Maria,; Donly, K. Retrospective study of retention of stainless steel crowns and pre-veneered crowns on primary anterior teeth. *Pediatric Dentistry – V37/NO7*, **2015**, 530-534
23. Ram, D.; Fuks A. Clinical performance of resin-bonded composite strip crowns in primary incisors: a retrospective study. *International Journal of Paediatric Dentistry* – **2006**, 16:49-54
24. Kupietzsky, A.; Waggoner, W.; Galea, J. Long-term photographic and radiographic assessment of bonded resin composite strip crowns for primary incisors: results after 3 years. *Pediatric Dentistry* – **2005**, 27:3
25. Marshall GW Jr. Dentin: microstructure and characterization. *Quintessence Int.*; 24 (9): **1993**; 606-617

Publishing Agreement

It is the policy of the University to encourage open access and broad distribution of all theses, dissertations, and manuscripts. The Graduate Division will facilitate the distribution of UCSF theses, dissertations, and manuscripts to the UCSF Library for open access and distribution. UCSF will make such theses, dissertations, and manuscripts accessible to the public and will take reasonable steps to preserve these works in perpetuity.

I hereby grant the non-exclusive, perpetual right to The Regents of the University of California to reproduce, publicly display, distribute, preserve, and publish copies of my thesis, dissertation, or manuscript in any form or media, now existing or later derived, including access online for teaching, research, and public service purposes.

DocuSigned by:

AE247F05E706476...

Author Signature

5/28/2020

Date