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REMOVAL OF PREFABRICATED ZIRCONIA CROWNS FROM PRIMARY ANTERIOR TEETH WITH Er,Cr:YSGG LASER COMPARED TO A HIGH-SPEED HANDPIECE: AN IN- VITRO STUDY

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Removal of prefabricated zirconia crowns from primary anterior teeth with Er,Cr:YSGG laser compared to a high-speed handpiece: an *in-vitro* study

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

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Purpose: The aim of this study was to compare the time and pulpal temperature changes associated with the removal of prefabricated zirconia crowns from primary anterior teeth using an Er,Cr:YSGG laser compared to a rotary handpiece.

Methods: This *in-vitro* study was conducted using extracted primary incisors. Teeth were prepared and restored with prefabricated zirconia crowns (NuSmile®, Houston, TX, USA) sizes 4 and 5 cemented with resin-modified glass-ionomer cement. Restored teeth were stored in a humidor for at least 48 hours prior to removing crowns from the teeth using either an air-rotary handpiece (HG, N=17) or erbium, chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser (LG, N=18). Pulpal temperature was measured inside the pulpal chamber and recorded in 30-second intervals. Removal times and pulpal temperature changes were compared between the two groups. Following crown removal, one tooth and crown from each group was submitted for SEM examination to assess morphological changes.

Results: The average time for crown removal for HG was 80.9 seconds (SD=19.36); and 353.3 seconds (SD=110.6) for LG. Removal with the laser took significantly longer by an average of 272.4 seconds (95% CI: 216.8-328.0, p-value<0.0001) and had higher variability than the rotary handpiece. The maximum observed temperature for HG was 22.2ºC (SD=0.85) compared to 27.7ºC (SD=1.60) for LG. Laser-assisted crown removal was associated with a maximum temperature of 5.5ºC (95% CI: 4.6-6.4) higher than the handpiece (p-value<0.0001).

Conclusions: Er,Cr:YSGG laser and rotary handpiece can both be used predictably to remove zirconia crowns from primary anterior teeth. While a rotary handpiece presents a more efficient method of removal, Er,Cr:YSGG laser offers a viable alternative method.

Introduction

Early childhood caries (ECC) is one of the most common chronic childhood diseases.[1] The ECC most commonly begins progressing on maxillary primary incisors, originating as white spot lesions along the gingival margin and progressing into caries.[1] If in a timely manner dietary changes are not made and the caries lesions are not removed and restored, ECC will quickly lead to teeth becoming non-restorable. Premature primary tooth loss can result in loss of space maintenance for the erupting permanent dentition.[1] ECC can not only affect a child's primary and permanent dentition but can also have negative consequences on a child's life due to missed school days, malnutrition, and a child's psyche.[2] Nutritional counseling, oral hygiene instruction, and fluoride exposure are all important for reducing caries risk. When preventative methods are not adequate, treating ECC consists of caries removal and replacing lost tooth structure with fillings, crown restorations or extraction of teeth that are deemed non-restorable.[3,4]

Stainless Steel Crowns (SSC) have been the treatment of choice for restoring carious lesions on primary teeth.[5] Cementing SSCs is achieved with glass ionomer cements to provide fluoride release and bonding to dentin. The SSCs have proven to have higher survival rates compared to amalgam and composite restorations due to full crown coverage leading to a decrease in bacterial exposure.[5,6] Studies have reported high success rates of around 97% after placement of SSCs, with the main causes of failure attributed to pathological tooth mobility or perforation of the crown.[7] A three-year analysis of 6,288 teeth reported a replacement rate of 1.5% for SSCs compared to 21% for composite restorations.[6] SSCs feature strong retention and durability and can be placed using minimal chair time creating a positive patient experience.[8]

Although primarily indicated for restoring primary teeth, due to good long-term stability, SSC's have become a viable treatment option even for permanent teeth, especially as a restorative option in the adult population with special needs.[9] Permanent molars with developmental defects, traumatic fractures, large carious lesions, or pulp therapy may also be treated with an SSC prior to the completion of a child's growth and development.[5] Children and adolescents with disorders that affect tooth development, such as amelogenesis imperfecta, dentinogenesis imperfecta, and hypomineralized or hypoplastic permanent molars can be covered by an SSC as early as possible to preserve tooth structure.[10,11] Covering defective permanent molars can temporarily help diminish tooth sensitivity, maintain occlusal relationships, and preserve tooth integrity until a child completes pubescent growth, and the permanent molars can be restored with definitive full coverage restorations.[10,11] The main challenge of SSCs is that the esthetic concern frequently outweighs their functionality, especially when used on the anterior dentition.[5] Due to parental concern about the SSC's esthetic disadvantage, more esthetically acceptable SSCs with composite or ceramic facing were introduced. However, there is still an increased risk of fracture, poor gingival health, and unesthetic bulkiness associated with veneered stainless steel crowns.[5] Carious anterior teeth are also commonly treated by bonded composite strip crown restorations with successful esthetic results, but larger carious lesions may lead to a lower retention rate, especially in children with high caries risk.[12]

Over the last few years, esthetic zirconia crowns were introduced into dentistry, particularly for the restoration of primary anterior teeth. See Figure 1. Prefabricated zirconia crowns manufactured by NuSmile (NuSmile®, Houston, TX, USA) and Sprig EZ (Sprig®, Loomis, CA, USA) crowns are two common restorative crowns used for both primary and permanent teeth.[13] Resin Modified Glass Ionomer (RMGI) cements are recommended for cementing prefabricated zirconia crowns, with the addition of resin components and light-curing for improved retention and longevity. Zirconia crowns are commonly used in permanent dentition and have recently gained popularity for use in primary dentition due to improved gingival health, decreased plaque accumulation, and popular esthetic appeal among patients and parents.[8] Zirconia crowns are made of a crystal-like dioxide of zirconium and possess mechanical properties similar to metal except they have esthetically pleasing tooth-like coloration.[8] Prefabricated zirconia crowns have proven to be a successful full coverage restoration for patients with ECC, especially in the anterior dentition.[5] They have a smoother surface compared to SSCs, resulting in less plaque accumulation and improved bacterial adhesion properties.[5] Some shortcomings of prefabricated zirconia crowns include the need for significantly more tooth reduction to provide a passive fit for cementation, and more significant wear on the opposing dentition compared to SSCs.[13] However, prefabricated zirconia crowns have been shown to have a smaller internal gap and more accurate internal fit following cementation compared to SSCs and veneered SSCs.[14,15] The esthetic superiority of zirconia crowns has led to increased demand from parents, especially when the anterior dentition has to be restored. Studies have shown comparable success rates for prefabricated zirconia crowns to those of SSC restorations, which has contributed to increased usage among dental providers and becoming a popular treatment modality for pediatric patients.[5]

Figure 1: NuSmile ZR Zirconia Crowns

The removal of a crown can sometimes be indicated due to failures and this may include recurrent caries, and fractured ceramic components, technical errors like inaccurate cementation, or the need for replacement with a custom laboratory fabricated crown. Crown removal can often be a challenging procedure for both the patient and provider.[16] While strong cement retention between the crown and tooth is necessary for longevity, the bond often creates a challenge when removing crowns. Multiple instruments and techniques have been used to mechanically remove a crown from the tooth, with the most commonly used technique sectioning a crown with a high-speed diamond or carbide bur.[16] Removal of a crown with high-speed handpieces can create an unpleasant experience for pediatric patients due to uncomfortable vibration and loud noise. The cements used to cement zirconia crowns are also of similar color to the tooth structure. This can make distinguishing between cement and tooth structure difficult creating a risk of irreversibly damaging the underlying tooth.[16,17,18] To achieve crown removal with a high-speed handpiece, the crown must also be sectioned, which renders it non-reusable.[16]

One of the emerging advantages of prefabricated zirconia crowns over SSCs is the ability to remove the crowns with erbium lasers in an atraumatic manner. Laser irradiation offers a predictable method for debonding zirconia crowns creating minimal to no damage to the tooth or crown surfaces, and provides a more positive patient experience.[19] Erbium family lasers which are: erbium-doped yttrium, aluminum garnet (Er:YAG) and erbium-doped yttrium scandium gallium garnet (Er, Cr:YSGG), are the two most commonly used erbium lasers. They have been shown to produce less odors, vibration, and noise compared to air rotary instrumentation, and can be used without the need for a local anesthetic.[20] Er, Cr:YSGG and Er:YAG lasers have emission wavelengths of 2780 nm and 2940 nm respectively, both of which are absorbed by chromophores including water, hydrated tissues, residual monomers, and bonding cement containing water.[21] Erbium lasers have multiple functions in the dental setting, including both hard and soft tissue ablation. (Figure 2) Through a process of thermomechanical ablation, laser energy light is transmitted through the ceramic crown and is absorbed by water molecules within the glass ionomer cement resulting in reduced bond strength between the crown and tooth resulting in a hydrodynamic ejection.[22] The benefit of removal with laser ablation compared to a high-speed handpiece is that the zirconia crowns are retrieved undamaged and can be utilized again if necessary. Studies have shown laser irradiation can be an efficient and predictable removal method for prefabricated zirconia crowns in primary and permanent molars, however, to date, no studies have been conducted on primary anterior teeth. [23]

The aim of this *in vitro* study is to analyze and compare the removal time required, pulpal temperature changes during the procedure, and differences in ceramic and tooth structure integrity for removal of prefabricated zirconia crowns from primary anterior teeth using an Er,Cr:YSGG laser and air rotary high-speed handpiece.

Figure 2: Biolase Waterlase iPlus

Methods

This *in-vitro* study was conducted based on eighteen (N=18) primary anterior incisors. The teeth were extracted due to normal physiological resorption in the Virginia Commonwealth University (VCU) Pediatric Dentistry clinics. To qualify for inclusion in the study, each tooth had to be deemed restorable with adequate remaining tooth structure following caries removal and crown preparation. A sample size of 15-18 in each group has 80% power to detect an effect size of 1 using a two-group t-test with a 0.05 significance level. Teeth were selected for appropriate size to accommodate a size 4 or 5 prefabricated zirconia crown on the tooth. Availability of size 4 and 5 crowns guided that decision but it also provided an experimental sample of teeth of similar size. Prefabricated zirconia crowns for this study were provided by the crown manufacturer (Nusmile®, Houston, TX, USA). This indicates that a difference between the laser and the drill of at least 1 standard deviation would be determined to be statistically significant.

Teeth were prepared based on the crown manufacturer's instructions (NuSmile®, Houston, TX, USA). Tooth preparation was accomplished with an 850012-C tapered-diamond bur (Premier®, Plymouth Meeting, PA, USA) using an Adec TG-97L air-driven handpiece (Henry Schein®, Melville, NY, USA). To allow the crown to seat passively, approximately 1mm of tooth structure was removed from the incisal surface, the tooth was further reduced circumferentially creating a feather edge margin, and all line angles were rounded off with no sharp edges remaining.[23] Each tooth was then given a number one through eighteen. Teeth were separated into three groups of six teeth each. Two different sizes (4 and 5) of prefabricated zirconia NuSmile crowns (Nusmile®, Houston, TX, USA) were used. Size 4 crown dimensions are: width 6.87mm, height 6.60mm, and diameter 7.61mm. Size 5 crown dimensions are: width 7.22mm, height 6.93mm, and diameter 8.05mm. The NuSmile (NuSmile®, Houston, TX, USA) zirconia crown system provides pink try-in crowns that are used to check the fit of the crown and reduce contamination with blood or saliva prior to cementing the permanent crown.[24] This study was *in vitro* so did not require the need for pink try-in crowns. Clean, non-contaminated crowns provide adequate phosphate bonds, which react with the cement on the intaglio surface of the crown, an important property for retention and prevention of microleakage.[24] Prefabricated zirconia crowns cannot be crimped and therefore depend on the cement to seal off the open margins and prevent microleakage.[24]

It is recommended by the crown manufacturer (Nusmile®, Houston, TX, USA) to cement NuSmile zirconia crowns with a resin-modified glass ionomer (RMGI) cement called BioCem cement (BioCem Universal BioActive Cement; NuSmile: Houston, TX, USA).[23] BioCem has been shown to have high washout resistance at the margins and it contains unique bioactive properties including fluoride, calcium, and phosphate release, which initiates hydroxyapatite formation.[24,25] Finger pressure was used to stabilize the crown on the tooth during tack curing with a curing light (800–1200 mW/cm^2) for five seconds on both the buccal surface and 5 seconds on the lingual surface. Excess cement was removed around the crown margin with gauze followed by curing for 20 seconds circumferentially for definitive cementation. To prevent desiccation and to ensure the cement was cured, teeth were stored in a specimen container separated by soaked gauze (humidor) in 0.9% normal saline for 48 hours prior to crown removal.

Crown Removal Methods

Two different methods were used for crown removal: laser irradiation and air rotary handpiece. Laser ablation was performed using an Er,Cr:YSGG laser (Waterlase iPlus®, Biolase®, CA, USA) using settings: 5.0 Watts, 15 Hertz, 50 water, and 50 air with the Turbo handpiece and MX9 laser tip at a distance of approximately 5mm. The range of settings and handpiece followed manufacture instructions for the crown removal protocol. Laser irradiation was performed in 30-second intervals in a sweeping motion on buccal and lingual surfaces. Crown removal was attempted following three minutes of laser irradiation and thereafter every 30 seconds. Crown removal was achieved by placing gauze over the crown to prevent external damage and performing rotational movement of the crown using a hemostat.

Air rotary handpiece removal was achieved using an Adec TG-97L air-driven high-speed handpiece (Henry Schein®, Melville, NY, USA) at 400000rpm with water spray using a friction grip 850012C Course flame diamond bur (Premier ®, Plymouth Meeting, PA, USA). Crown removal was achieved by cutting the crown in the middle from buccal to lingual surface until it was split in half and fell off the tooth or was able to be removed with gauze and hemostat. Crown removal time was recorded for each crown.

Pulpal Temperature Measurements

Pulpal temperature was measured in order to analyze and compare any changes in temperature that may occur during crown removal using both the laser and air rotary handpiece technique. A size 330 carbide bur (Henry Schein®, Melville, NY, USA) using an air rotary handpiece was used to drill a hole through the root of the tooth and directly into the pulp chamber. The temperature probe (Sper Scientific® 800008, Scottsdale, AZ, USA) was inserted into the pulpal chamber through an access hole to measure changes in pulpal temperature throughout the crown removal process. Temperature readings were taken at baseline prior to crown removal and then recorded every 30 seconds throughout the duration of crown removal.

Crown Removal Groups

In total, 18 crowns were removed with laser irradiation (group LR, N=18) and 17 crowns removed with an air-rotary handpiece and tapered diamond bur (group HR, N=17).

Teeth 1-6

Size 5 NuSmile zirconia crowns (Nusmile®, Houston, TX, USA) were cemented using BioCem cement on all six teeth and stored in the humidor at room temperature for at least 48 hours. Laser irradiation on the surface of zirconia crowns was performed using an Er,Cr:YSGG laser (Waterlase iPlus®, Biolase®, CA, USA) on all six teeth. Following the removal of all size 5 crowns, teeth were cleaned for any residual cement. Size 4 crowns were then cemented using BioCem cement on the same teeth and removed by laser irradiation following the same protocol. Size 4 and 5 crowns were selected to compare if the differences in the crown surface area and amount of cement under the crown have any impact on the removal time. Following the removal of crowns, teeth were cleaned of any residual cement and prepared for recementation. Teeth 1-3 received size 4 crowns and teeth 4-6 size 5 crowns cemented with BioCem cement. This group of crowns was removed with an air-rotary handpiece (Henry Schein®, Melville, NY, USA) and tapered-diamond bur (Premier®, Plymouth Meeting, PA, USA). The time required to achieve crown removal and temperature were monitored and recorded at 30 second intervals. Removal time and temperature changes were compared between laser and air-rotary handpiece removal techniques.

Teeth 7-12

This experiment followed the same protocol as experiment 1 but used only size 4 crowns for laser irradiation. Crowns were cemented on teeth 7-12 with BioCem cement, stored in Humidor for 48 hours, and removed by laser irradiation. Following laser-assisted crown removal, tooth 12 was put in a separate moist saline specimen container for scanning electron microscopy (SEM) (JEOL 6610LV, JEOL, Tokyo, Japan) analysis. SEM was used to evaluate the structural integrity or damage of the tooth and zirconia crown following laser irradiation. Teeth 7-9 had size 4 and teeth 10-11 had size 5 crowns cemented and removed via air rotary handpiece (Henry Schein®, Melville, NY, USA) and tapered-diamond bur (Premier®, Plymouth Meeting, PA, USA) measuring the time required for removal and intrapulpal temperature every 30 seconds.

Teeth 13-18

Prefabricated zirconia crowns on teeth 13-18 underwent crown removal only with an air rotary handpiece (Henry Schein®, Melville, NY, USA) and tapered-diamond bur (Premier®, Plymouth Meeting, PA, USA). Teeth 13-15 received size 4 and teeth 16-18 size 5 prefabricated zirconia crowns cemented with BioCem cement. Teeth 13-18 were only removed via air rotary handpiece in order to eliminate any changes in tooth integrity or damage that could have resulted from sequential crown removal using the laser irradiation prior to removal with a rotary handpiece, as was the case for teeth 1-12.

Following crown removal, tooth and crown 18 were stored in a separate moist saline specimen container for SEM analysis (JEOL 6610LV, JEOL, Tokyo, Japan) to evaluate the structural integrity or damage of the tooth following air-rotary handpiece removal of the crown.

Scanning Electron Microscopy Analysis (SEM)

SEM analysis (JEOL 6610LV, JEOL, Tokyo, Japan) was performed to determine the structural integrity and potential surface damage that may have occurred to the prefabricated zirconia crowns and the tooth following laser irradiation versus the high-speed rotary handpiece removal technique.

Statistical Methods

Differences in time and temperature were compared based on the method of removal (laser vs. drill) with equal and unequal variance t-tests, as appropriate. The significance level was set at 0.05 level. SAS EG v.8.2 (SAS Institute, Cary NC) was used for all analyses.

Results

A total of 18 crowns were removed with laser (LR) and 17 with the air rotary handpiece (HR). One crown from each group was randomly retained for SEM analysis. Twelve unique crowns were used for laser and air rotary crown removal and six unique crowns were removed only with an air rotary handpiece in this study. During laser-assisted crown removal, three crowns (17%) were non-reusable compared to 100% of crowns that were non-reusable using the air rotary handpiece.

Table 1: Summary of Time to Debond and Changes in Temperature for Debonding with Laser and Drill

		Mean (SD)	
		Laser (n=18)	**Drill (n=17)**
Debonding Time (seconds)		**353.3 (110.61)**	**80.9 (19.36)**
	Size 4	337.5 (120.76)	83.1 (14.91)
	Size 5	385 (87.81)	79 (23.37)
Maximum Temperature Recorded (^{o}C)		**27.7 (1.59)**	**22.2 (0.85)**
Change in Temperature from Baseline (^{o}C)		**2.9 (1.86)**	**0.2 (1.16)**

The average time for zirconia crown removal with the air rotary handpiece was 80.9 seconds (SD=19.36), or 1 minute and 20 seconds. The average time to remove a zirconia crown using the laser was 353.3 seconds (SD=110.6), or 5:53.3 minutes. Removal with the laser was significantly longer by an average of 272.4 seconds (95% CI: 216.8-328.0, p-value<0.0001) and had higher variability than the air rotary handpiece. See Table 1. The time to remove the crown with the laser was not significantly related to the crown size (p-value=0.4068). However, size 5 crowns did require a marginally longer time to debond (385 vs 337.5 seconds; 95% CI on difference: -70.7 to 165.7 seconds).

The maximum temperature recorded during the removal process was also compared between the two removal methods. The maximum observed temperature with the air rotary handpiece was 22.2ºC (SD=0.85) compared to 27.7ºC (SD=1.60) with the laser. Laser use for zirconia crown removal was associated with a maximum temperature of 5.5ºC (95% CI: 4.6-6.4) higher than with the air rotary handpiece (p-value<0.0001). Additionally, the use of the laser was also associated with significantly greater variability (p-value=0.0148). See Figure 3.

The change in temperature from baseline was recorded during the removal process and was compared between the two removal methods. The average temperature change with the air rotary handpiece was 0.18ºC (SD=0.1.16) compared to 2.94ºC (SD=1.86) with the laser. (Figure 5) Laser use for zirconia crown removal was associated with a change in temperature of 2.76ºC (95% CI: 1.69-3.83) higher than with the air rotary handpiece (p-value<0.0001). Additionally, the use of the laser was also associated with marginally significant greater variability (p-value=0.0653). (Figure 4)

SEM analysis was performed on both the zirconia crown and tooth structure following air rotary handpiece and laser removal to compare any differences in structural integrity. Lower magnifications of 500x revealed cutting streaks on a tooth that had crown removed with an air rotary handpiece, indicating contact between tooth structure and the bur during removal of the crown. (Figure 6) Higher magnifications of 5000x or greater, SEM revealed greater opening of dentinal tubules following air rotary removal and more intact smear layers in the laser removal group. (Figures 7, 8). The SEM analysis of both crowns removed showed no differences in crown integrity at low magnifications. Analysis at magnifications 10,000x or more showed greater amounts of crack lines in the air rotary removal sample, indicating more damage to the zirconia crown surface compared to the crown removed with the aid of a laser. (Figures 9, 10)

Figure 3: Comparison of Removal Time by Method

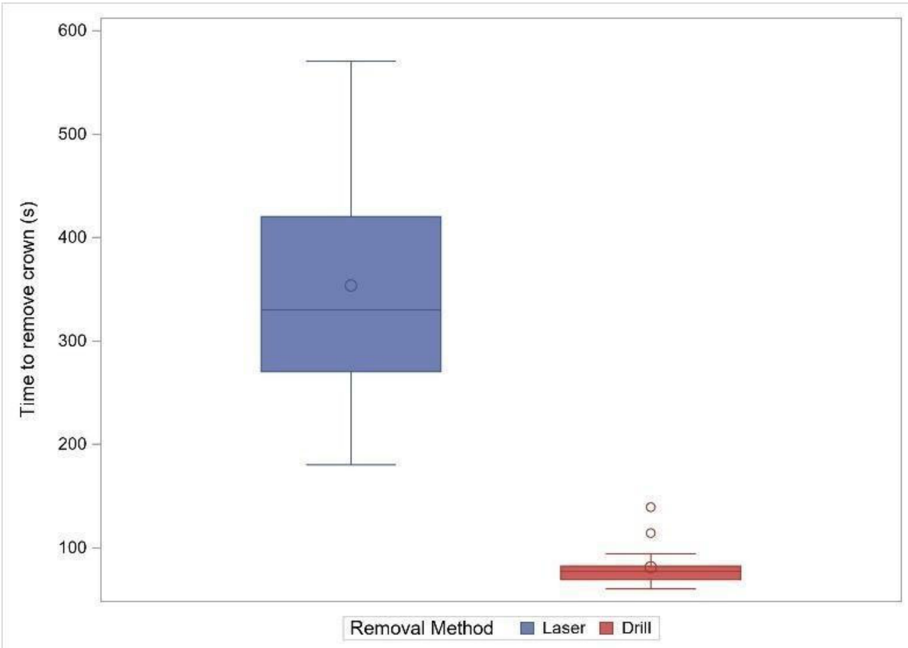


Figure 4: Comparison of Maximum Observed Temperature by Method

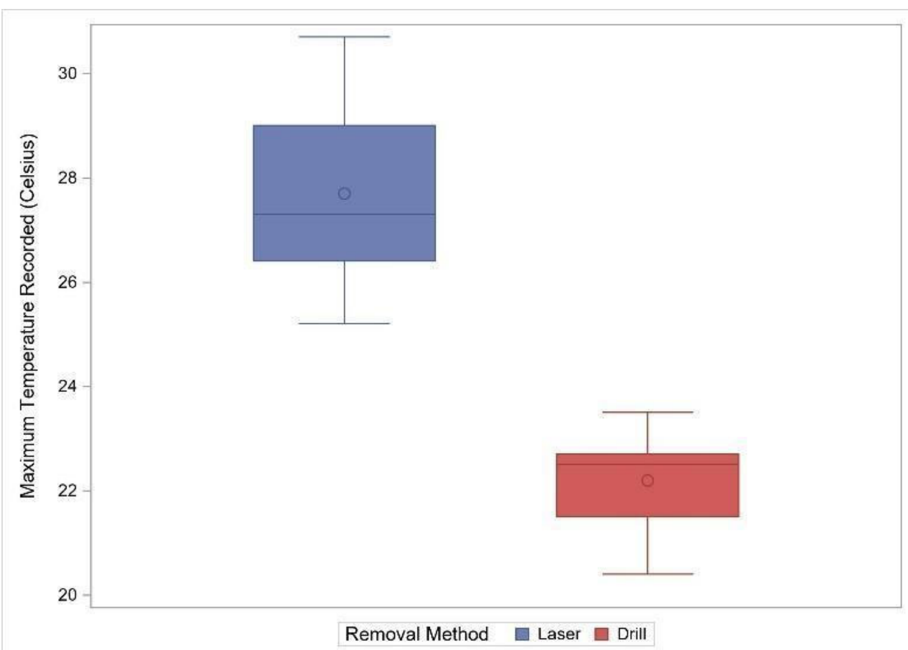


Figure 5: Comparison of Temperature Change by Method

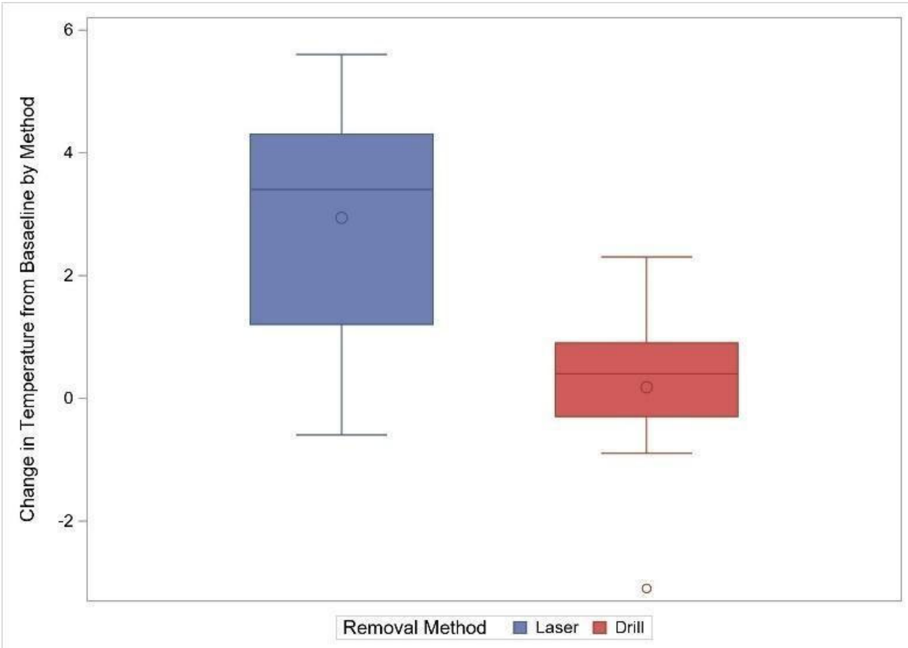


Figure 6: Scanning Electron Microscope Image of the Surface of the Tooth at Magnification 500x Following Crown Removal with Air Rotary Handpiece

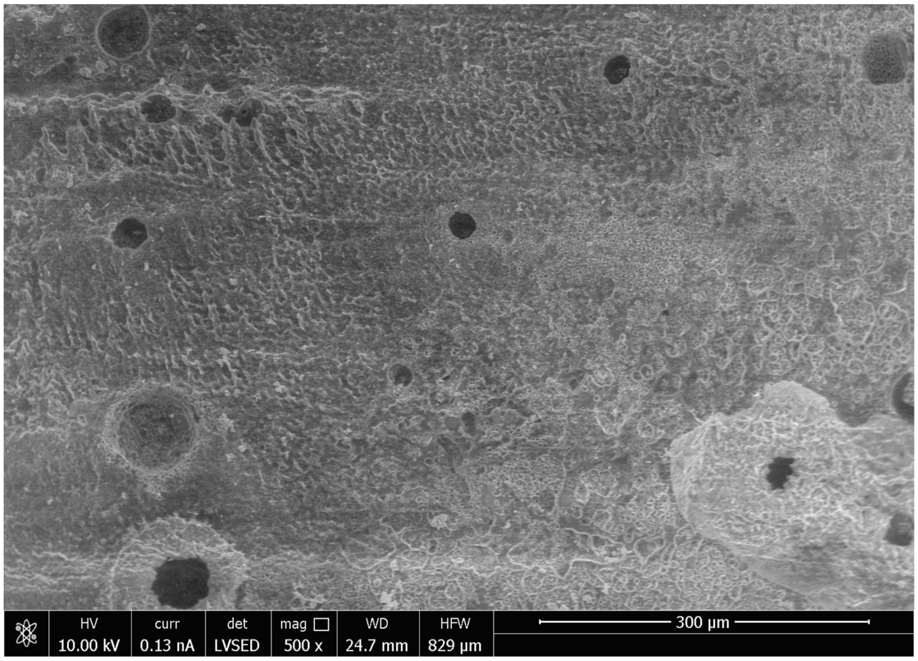


Figure 7: Scanning Electron Microscope Image of the Surface of the Tooth at Magnification 5000x Following Crown Removal with Air Rotary Handpiece

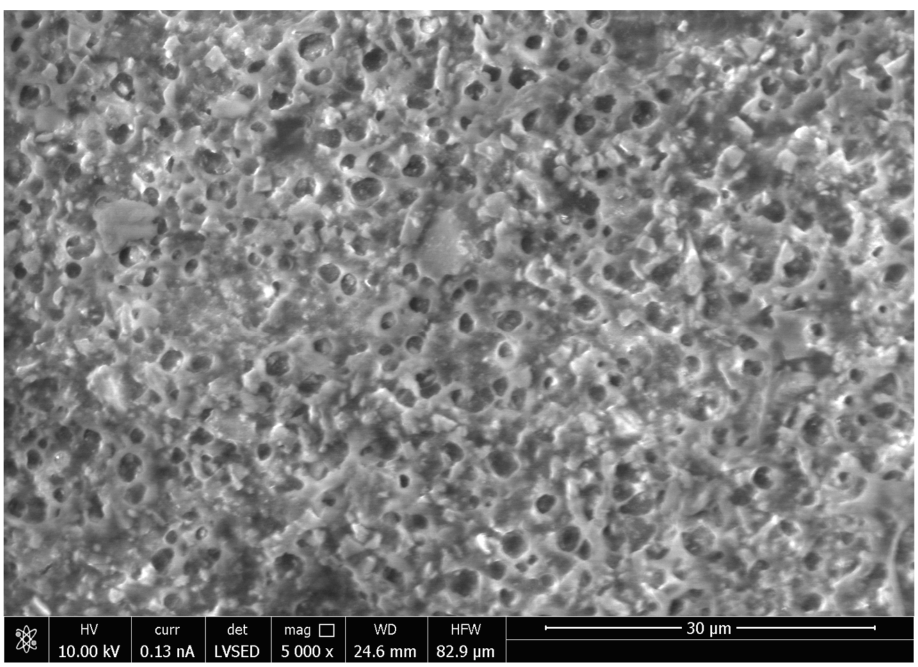


Figure 8: Scanning Electron Microscope Image of the Surface of the Tooth at Magnification 5000x Following Crown Removal with Laser Irradiation using an Er,Cr:YSGG Laser

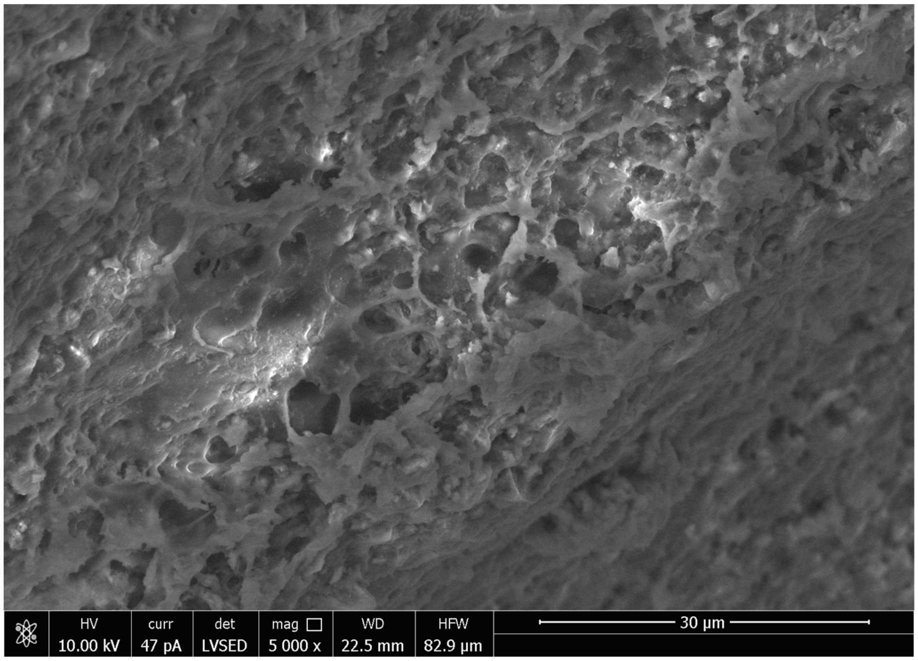


Figure 9: Scanning Electron Microscope Image of the Surface of the Zirconia Crown at Magnification 10,000x Following Crown Removal with an Air Rotary Handpiece

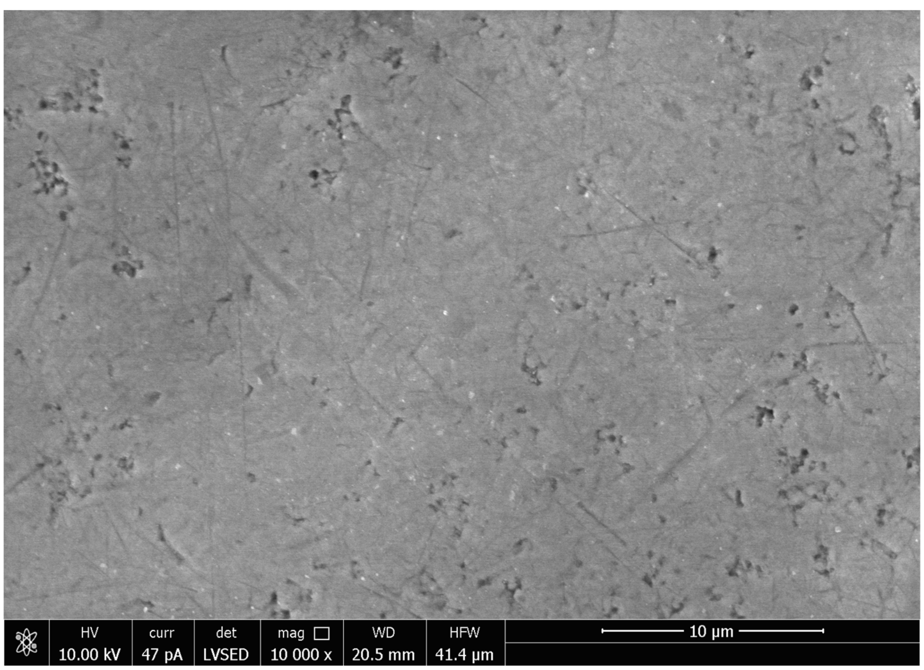
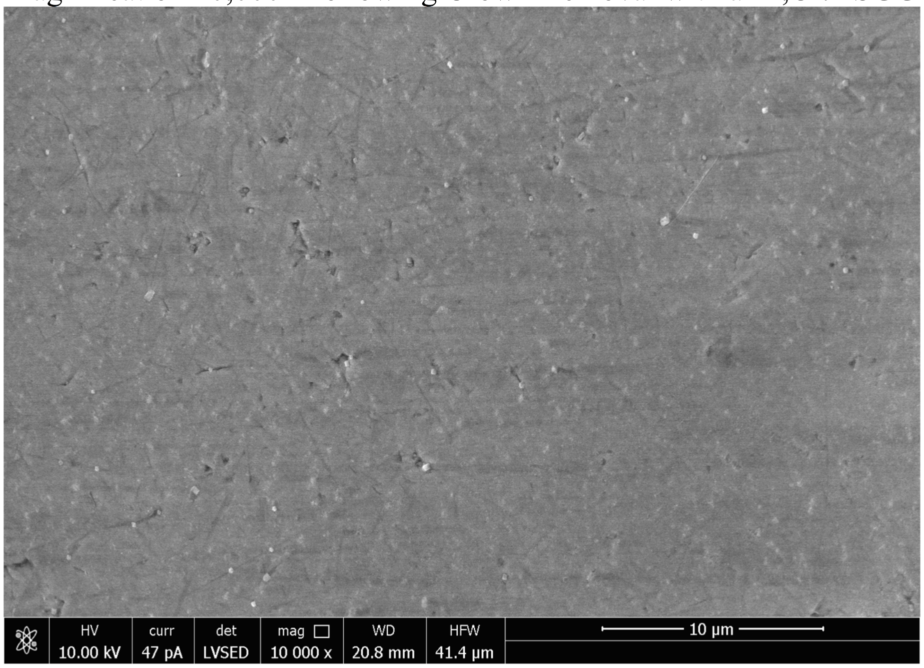


Figure 10: Scanning Electron Microscope Image of the Surface of the Zirconia Crown at Magnification 10,000x Following Crown Removal with a Er,Cr:YSGG Laser



Discussion

This study compared the length of time for removal, changes in pulpal temperature, and potential underlying tooth damage for both the laser and air rotary handpiece to determine any differences between removal methods for prefabricated zirconia crowns from primary anterior teeth. There are currently no published studies that have examined the removal of anterior prefabricated zirconia crowns with laser debonding, or compared removal methods between laser debonding and air rotary handpiece techniques. Our results proved that anterior primary zirconia crowns can be successfully removed and reused using laser debonding, and showed significant differences compared to the removal with an air rotary handpiece.

Conventional zirconia crown removal is usually accomplished using an air rotary handpiece and a flame diamond bur in a buccal-lingual motion to section the crown in two pieces, rendering it non-reusable and creating an added risk of damaging the underlying tooth structure.[26] Lasers are becoming increasingly popular in dentistry with an array of functions.[27] Lasers are often a less invasive option for a variety of dental treatments, including composite resin removal, veneer removal, and ortho bracket removal.[28,29,30] Recent studies have also shown the benefit of removing crowns from implant abutments or natural tooth structure, with the ability to preserve the crown for potential reuse without any underlying damage to the crown or tooth structure.[23,31] Erbium lasers have the ability to cut hard tissue, including enamel, dentin, cementum, or bone, and soft tissue.[32] Erbium lasers produce energy of wavelengths 2,780nm to 2,940nm depending on the model.[33] The wavelength produced by the Er,Cr:YSGG laser used in this study was approximately 2,780nm. The laser beam travels through the translucent ceramic crown and the laser energy is absorbed by the target chromophore water and residual monomers in the luting cement bonding the crown to the underlying tooth surface.[33] Through a process of thermomechanical ablation, micro explosions of water molecules occur and weaken the bond strength of the cement leading to the debonding of the crown with a low risk of damaging the underlying tooth structure and integrity of the crown.

Prefabricated anterior zirconia crowns are becoming more prevalent in the field of pediatric dentistry due to the efficiency of placement and esthetic appeal. They are commonly indicated in pediatric patients until a definitive permanent crown can be placed following pubescent growth. Prefabricated crown retrieval may be indicated prior to placing a definitive crown, or in instances of needing endodontic therapy, recurrent caries, and fractured restorations. If placement during cementation of the zirconia crown is suboptimal, a laser can be used to remove the crown and recement it back into a more ideal position. Laser-assisted crown retrieval offers to reduce the waste of material that would otherwise occur with air rotary handpiece removal. Previous studies have shown that laser debonding prefabricated zirconia crowns from primary and permanent posterior molars can be successfully accomplished without damaging the underlying tooth structure and preserving the crown.[23]

Removal times with the laser were significantly slower and showed greater variation compared to the air rotary handpiece. Longer laser removal times could have been related to cement thickness, and more energy required to ablate the thicker volumes of cement. Previous studies have shown that greater cement thickness relates to longer debonding times.[23] This was further confirmed in this study with size 5 crowns requiring longer debonding times compared to size 4 crowns. Larger teeth were selected for size 5 crowns, but tooth size in relation to crown size was not standardized in this study, which could have created greater variances in laser removal times.

No external physical changes could be visualized following laser irradiation procedures compared to evident crown destruction during air rotary handpiece removal. The inability to observe changes in crown structure during laser removal makes it difficult to determine when the crown releases from the tooth and could skew the time necessary for crown retrieval. Anterior prefabricated zirconia crown removal for both laser and air rotary handpiece techniques was efficiently accomplished in six minutes or less. While air rotary handpiece removal featured faster retrieval times, this study did not take into consideration the additional time needed for local anesthetic delivery for pain management. Compared to air rotary handpiece removal, laser irradiation offers the benefit to deliver pre-emptive analgesia and painless treatment, without the added time and dental fear associated with a needle-injected local anesthetic.[34] Removal of crowns was standardized with a single provider. It should be noted that removal times of zirconia crowns with air rotary handpiece could vary depending on the provider's experience, whereas removal time with the laser is more dictated by laser settings and cement thickness.[23]

Thermal stimulation of pulp tissue can occur during crown removal using both laser and air rotary techniques. Increases in pulpal temperature greater than 5.5°C create an increased risk for irreversible pulpitis.[35] In our study neither technique resulted in temperature increases that exceeded 5.5°C, confirming that both methods can safely remove crowns without creating irreversible pulpal damage to primary anterior teeth. On average pulpal temperature increased 2.76ºC during laser irradiation, while the air rotary handpiece caused an increase of 0.18ºC from baseline temperatures. Laser irradiation also showed more variation in temperature and higher temperature readings compared to air rotary removal. Differences in pulpal temperature increases could be attributed to the functionality of each device. Higher temperature readings associated with laser irradiation could be attributed to longer procedure times, less water spray for cooling, and higher energy needed for crown removal. When crowns are removed with an air rotary handpiece the energy is absorbed on the surface of the crown and further away from the pulp. Laser energy is absorbed by the underlying chromophore (cement) which is closer in proximity to the pulp tissue, and thus contributes to a greater increase in pulpal temperature during crown removal. Pulpal temperature is an important factor to consider when removing crowns from primary anterior teeth due to the thin layer of remaining dentin that overlies the pulp chamber following tooth preparation. Adequate water spray is essential to prevent overheating of pulpal tissues.

The SEM analysis proved that prefabricated zirconia crown removal can be achieved while maintaining tooth integrity using both air rotary handpiece and laser removal. Laser irradiation of zirconia crowns on primary anterior teeth showed no underlying tooth damage and fewer surface irregularities of the crown surface compared to air rotary removal. Evidence of changes in tooth structure at low magnification following removal with an air rotary handpiece proves there is a risk of damaging the tooth during crown removal. The air rotary abutment also revealed more and larger openings of the dentinal tubules compared to laser removal. Greater amounts of open tubules could result in more post-operative sensitivity following crown removal. Removal of the crown with an air rotary handpiece is still a proven successful method for crown removal. Operators must use extra caution while drilling off a crown with an air rotary handpiece to prevent irreversible damage.

This study includes some limitations that should be addressed with future research on anterior prefabricated zirconia crown removal. This study was a benchtop experiment, lacking the variables that would occur in a clinical practice setting treating pediatric patients. Baseline pulpal temperatures were dependent on the room temperature, which had slight daily variations. The lack of vital pulpal tissues and blood circulation with protective cooling mechanisms present in human subjects could also alter temperature values. Teeth were selected to best fit the available crowns, sizes 4 and 5. Future studies should standardize the exact tooth structure remaining following tooth preparation and various prefabricated zirconia crown sizes should be fitted to ensure consistency and standardization in cement thickness. Forces used to remove the crowns with the hemostat could have varied depending on cement thickness, size and shape of the tooth, operator strength, and differences in opposing forces that would be present in a human mouth. Future experiments should be performed with teeth stabilized in a typodont or with human subjects to better replicate accessibility with adjacent teeth and oral anatomical structures.

Conclusion

Anterior prefabricated zirconia crowns can be removed by Er,Cr:YSGG laser irradiation with underlying RMGI cement. Laser irradiation took a longer time compared to air rotary handpiece removal, but renders the prefabricated zirconia crown reusable following retrieval. The laser settings in this study were able to successfully and safely remove anterior prefabricated zirconia crowns without compromising tooth structure integrity.

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