Failure strength of four veneered primary stainless steel crowns

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Abstract

The purpose of this study was to determine the amount of shear force required to fracture or dislodge the veneered facings of four commercially available veneered primary incisor stainless steel crowns (SSC) and to characterize the veneer failures. Forty Unitek SSCs (#4 left central incisor) were shaped to fit a master die and then 10 each were mailed to four commercial dental laboratories that produce veneered SSCs. The resulting four types of crowns tested were: Cheng Crowns (CC), [Peter Cheng Orthodontic Laboratory]; Kinder Krowns (KK) [Mayclin Dental Studio, Inc]; NuSmile™ Primary Crowns (NC), [Orthodontic Technologies, Inc]; and Whiter Biter Crown® II (WB), [White Bite Inc]. Each crown was cemented onto a standardized die and then thermocycled at 4°C and 55°C for 500 1-min cycles. Each die was then placed into a custom holder on the Instron (Model 4204) testing machine. A force was applied at the incisal edge of the veneer at 148°, (the primary inter-incisal angle), with a crosshead speed of 1 mm/min until the veneer fractured or was dislodged. The mean force (N) required ± SD to produce failure was, respectively: KK (397.2 ± 53.0); NC (447.2 ± 78.5); CC (511.9 ± 83.4); WB (686.5 ± 181.4). Analysis of variance (ANOVA) indicated significance at $P < 0.0001$. A Scheffe's post hoc comparison demonstrated that the Whiter Biter (WB) group required significantly ($\alpha = 0.05$) more force for failure than the other three groups. Additionally, the veneers of the NuSmile, Cheng, and Kinder Krowns demonstrated a mixed adhesive/cohesive failure and all failed by breaking and chipping in pieces from the stainless steel. The Whiter Biter Crown II veneers did not break. They were dislodged intact due to an adhesive failure. We conclude that the Whiter Biter veneered crown is significantly better able to resist a shearing force on the veneer than the other crowns tested. (Pediatr Dent 17:36–40, 1995)

One of the most challenging restorative tasks is the esthetic restoration of badly decayed primary incisors, particularly in the very young child. Baby bottle tooth decay can cause extensive damage of the teeth of infants and toddlers, especially incisors when the bottle is used as a pacifier or for other non-nutritive reasons.[1] The challenge to the clinician is to restore the teeth with a durable, retentive, and esthetic restoration. Primary teeth have a definitive life span of only 6–8 years so a restoration should last at least that long without requiring significant maintenance.

Over the past several years dentists have been limited primarily to four types of full coronal coverage for primary incisors: preformed polycarbonate crowns,[2] acid-etched resin crowns,[3–5] stainless steel crowns,[6] and stainless steel crowns with chair-side veneer placement.[7,8] All of these have limitations and none of the four provides the ideal coverage.

Polycarbonate crown retention is poor and placement is difficult, so these crowns are rarely used today. Acid-etched resin crowns or "strip crowns," provide the most esthetic restoration, however their retention depends upon the amount of tooth structure — especially enamel — remaining after caries removal, and this is also a very technique-sensitive procedure. Stainless steel crowns are very durable, easy to place, and can be used on teeth with little remaining tooth structure, but the esthetics of these metal crowns are a significant concern to most parents. The fourth type of crown, the open-face stainless steel crown, has had the stainless steel on the facial surface removed by a high-speed bur to create a window, which is then filled with a tooth-colored resin. These open-face crowns combine durability and esthetics, but are the most time consuming of the crowns to complete. Often the esthetics of these crowns are still not optimal because metal may be left showing around the resin, and poor gingival health and hemorrhage can further compromise esthetics during placement of the resin window. In summary, none of the traditional methods of coronal coverage for primary incisors is ideal, and in fact, all suffer from either lack of durability, poor esthetics, or being very time consuming to complete.

Recently, several dental manufacturers have developed and marketed veneered stainless steel crowns for primary teeth (Table 1) using various laboratory bonding processes that allow composite resins and thermoplastics to be attached or bonded to stainless steel. These crowns provide an esthetic restoration that can be placed in a single, short appointment. These veneered crowns use the same stainless steel crowns

TABLE 1. VENEERED STAINLESS STEEL CROWN MANUFACTURERS

Crown Name	*Manufacturer*
Kinder Krowns	Mayclin Dental Studio, Inc. Minneapolis, MN
Whiter Biter Crown II	White Bite, Inc. Exeter, CA
NuSmile Primary Crowns	Orthodontic Technologies, Inc. Houston, TX
Cheng Crowns	Peter Cheng Orthodontic Laboratory Philadelphia, PA

(Unitek, 3M Co, St Paul, MN) dentists have used for years, with proven durability and known handling properties. Hemorrhage and saliva will not affect the esthetics of the crown.

These veneered crowns, however, are not without disadvantages. First, adaptability of the crown to the prepared tooth is limited. Crimping or contouring these veneered crowns can cause some veneers to break. Second, the crowns are more expensive — approximately $18/veneered crown compared with $2/nonveneered crown. Third, the crowns can't be heat sterilized after an unsuccessful try-in because of potential heat damage to the veneer material. Finally, there is a lack of objective data, either clinical or laboratory, evaluating the claims of the manufacturers. A review of the dental literature revealed no articles that evaluate or report any properties or characteristics of these crowns.

A major unknown factor about these crowns is the strength of the veneer attachment to the stainless steel. The purpose of this study was to evaluate the amount of shear force required to fracture or dislodge the veneered facings of four commercially available veneered primary incisor stainless steel crowns. The objective was to determine which of the veneers demonstrate the greatest resistance to dislodgement and to characterize the bond failures.

Methods and materials

Forty size-#4 primary left central incisor stainless steel crowns (Unitek) were obtained and shaped to fit an incisor master die, which had been cast from a wax pattern of the inside of a #4 crown. The die was used to ensure that the mesiodistal and buccolingual shapes of all the crowns were uniform. After fitting all 40 crowns, the metal cast die was then prepared as an incisor that would be receiving a stainless steel crown. Facial reduction of the die was 1 mm, incisal reduction 1.5 mm, lingual and proximal reduction 0.5 mm. A feather-edge gingival margin was created around the preparation. Ten duplicate cast dies were made from this prepared master die.

Ten each of the 40 crowns were mailed to the four commercial manufacturers who were asked to veneer the crowns utilizing their normal veneering process and material with one small exception. Previous evaluation of the four crown types had shown that some manufacturers allowed the veneer to overlap the incisal edge, while others did not overlap the incisal edge. All manufacturers were asked to extend the veneer up to the incisal edge, but not overlap it. All of the companies complied and returned the crowns with the veneers in place.

Each veneered crown was cemented with polycarboxylate cement (Durelon, Espe/Premiere, Norristown, PA) mixed to the manufacturer's specifications onto one of the 10 prepared cast dies. Twenty-four hours following cementation, the crowns were thermocycled at 4°C and 55°C for 500 1-min cycles. Then each die with cemented crown was placed into a custom holder on a servohydraulic mechanical testing machine (Instron, Model 4204, Canton, MA). With the use of a chisel-like rod, 0.5 mm thick at the edge and 8 mm wide, a force was applied on the veneer at the incisal edge at 148° (the primary interincisal angle), with a crosshead speed of 1 mm/min until the veneer fractured or was dislodged. The force required to cause failure of the veneer was recorded, and a one-way analysis of variance (ANOVA) and a Scheffe's post hoc comparison was done to examine differences in failure strength. The fractured test specimens also were examined under a stereomicroscope (10x) to characterize the location of the bond failure; at the steel/resin interface (adhesive failure), within the resin (cohesive failure), or mixed (adhesive/cohesive). An adhesive failure would result in the entire facing being dislodged without breakage. A cohesive failure would result in the veneer remaining bonded to the metal but demonstrating breakage within the resin itself. A mixed failure would result when part, but not all, of the veneer was chipped from the metal-resin interface, leaving other resin still present and bonded.

Results

Force required for veneer failure

Table 2 depicts the mean force required to produce failure of the 40 veneers. ANOVA indicated significance at $P < 0.0001$. A Scheffe's post hoc comparison demonstrated that the Whiter Biter group required significantly ($\alpha = 0.05$) more force for failure than the other three groups. The Kinder Krowns required the least amount of force, but that was not significantly different from the NuSmile or Cheng crowns.

Characterization of veneer failure

Table 3 demonstrates the type of veneer failure seen with each crown type. There were significant differences between the Whiter Biter crowns and the other three types. All of the Whiter Biter veneers failed adhesively with no breakage or chipping. Instead, as the

Table 2. Force required to dislodge veneers

Crown Name	*Force (Newtons) ± SD*
Kinder Krowns	397.2 ± 53.0
NuSmile Primary Crowns	447.2 78.5
Cheng Crowns	511.9 83.4
Whiter Biter Crown II	686.5* ± 181.4

* *Indicates significant difference ($\alpha = 0.05$).*

Table 3. Type of veneer failure

Crown Name	*No. of Adhesive Failures*	*No. of Cohesive Failures*	*No. of Mixed Failures*
Kinder Krowns	0	1	9
NuSmile Primary Crowns	0	1	9
Cheng Crowns	0	2	8
Whiter Biter Crown II	10	0	0

adhesive spot welds of the underlying meshwork failed, the intact veneer began to separate from the stainless steel (Fig 1). Almost all (87%) the veneers of the other three crown types experienced a mixed, adhesive/cohesive failure, which is demonstrated in Fig 2. A piece of the veneer was chipped off (cohesive failure) separating at the metal-resin interface (adhesive failure). In no instance in any of the 30 NuSmile, Kinder Krowns, and Cheng Crowns was the entire veneer dislodged or completely removed.

Discussion

Preveneered primary stainless steel crowns offer several advantages over other anterior esthetic restorations. They are esthetic, do not require lengthy or multiple appointments to place, and their esthetics are not affected by hemorrhage. However, the stainless steel-veneer bond is extremely important to the success of the crown. If the bond is not strong, veneer loss may

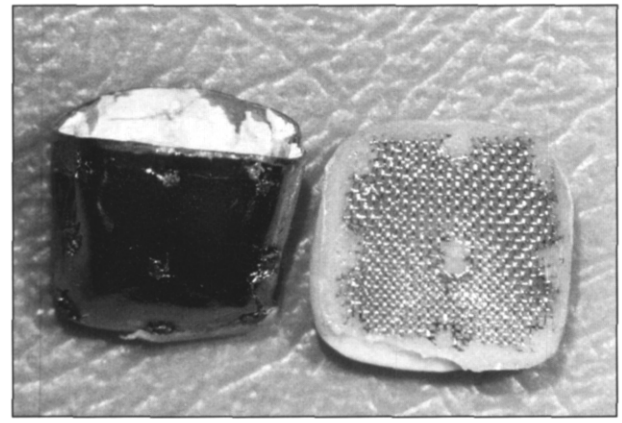

Fig 1. This Whiter Biter II crown is shown after the shearing force caused failure of the spot welds holding the metal meshwork onto the crown. The veneer has separated from the metal, but the thermoplastic material remains embedded in the meshwork.

occur. If the veneer were to become dislodged, the practitioner would be forced to remove the crown and place another or leave the child with an unesthetic tooth. Because the manufacturers do not readily share information regarding their veneering process, it was unclear as to whether any of the veneered crowns would show a superiority in bond strength. The stainless steel is identical for all the crowns but because of differences in veneer material and veneer attachment, one type of facing might be more resistant to dislodgement force than another. This was found to be true, with the Whiter Biter demonstrating the ability to withstand more shearing dislodgement force than the other three crown types. The character of the veneer failure of the Whiter Biter crowns was also markedly different from the other three.

The specific materials and processes utilized for veneer placement on these primary stainless steel crowns are proprietary secrets, which the manufacturers generally were not willing to discuss. However, the results of the testing lead to some discoveries regarding both the materials and the attachment mechanism, which help explain the results. The Whiter Biter crown is different in both material and attachment from the other three crowns. The Cheng, NuSmile, and Kinder

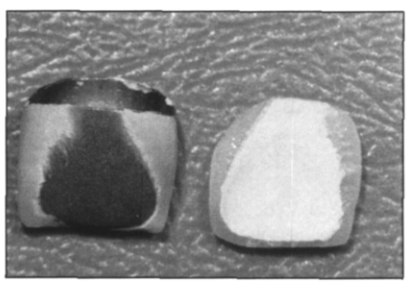

Fig 2A. The veneer of this Kinder Krown broke into pieces with part of it being lost and the remainder staying bonded to the stainless steel of the crown.

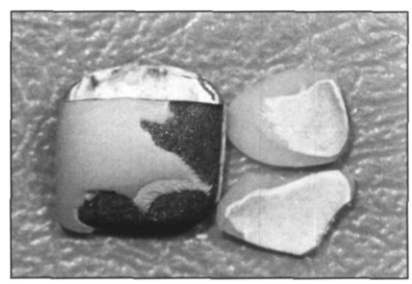

Fig 2B. The veneer of this NuSmile crown shows a similar breakage to the Kinder Krown. Pieces were dislodged, but a portion of the veneer remains bonded.

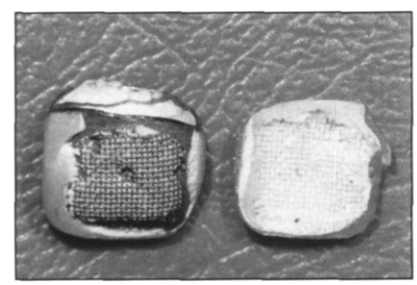

Fig 2C. The veneer of this Cheng crown was dislodged from the underlying meshwork. Note that part of the veneer circumferential to the mesh remains attached.

crowns all utilize a composite resin or a dimethylacrylate resin for their facing material. The Whiter Biter crowns utilize a different, thermoplastic material. The resin materials are relatively inflexible, rigid, and brittle and hence these veneers tend to break when placed under a lot of force. The thermoplastic material of the Whiter Biter, on the other hand, is quite flexible. It is more likely to deform than break when placed under concentrated force. The plasticity of the veneer materials may account for much of the difference in the failure rate and mechanism of failure found in this study.

The method of attachment of the veneers to the stainless steel also varies by crown type. The thermoplastic veneer of the Whiter Biter crown is placed onto the stainless steel by first spot welding a small piece of metal mesh to the facial surface of the crown. The veneer material is then melted onto the mesh where it is mechanically retained via small tags of plastic incorporated into the meshwork. When incisal forces are directed onto these veneers, failure can occur in two adhesive areas, either at the spot welds or at the mesh/plastic interface. In the samples tested, all the failures seen were failures of the spot weld. The veneer stayed embedded in the meshwork and did not break.

Cheng, NuSmile, and Kinder crowns, were not statistically different from one another in their ability to withstand shearing force. All of these use resin veneers that demonstrated breaking and chipping, primarily at the incisal edge, adjacent to the force application. The veneers of the Cheng crown, like the Whiter Biter, are attached primarily to the metal via a meshwork welded to the surface. There may also be some pretreatment of the stainless steel to get an adhesive bond directly to the stainless steel, but this was not readily discernible and the manufacturer would not disclose the veneering process. In spite of a similar attachment mechanism, the Cheng crown was likely to break or dislodge at a significantly lower force rate than the Whiter Biter. Unlike the Whiter Biter crowns, the failures of the Cheng crown were associated with failure of the veneer material and not with the welded meshwork. The failures were mixed adhesive/cohesive failures. Often the veneers would crack circumferentially to the underlying meshwork, but the mesh would stay attached to the crown.

The attachment to the stainless steel of the veneers of the NuSmile and Kinder crowns differs from the Cheng and Whiter Biter crowns. No metal meshwork is utilized to hold the veneers. Instead, the veneers are bonded directly to the stainless steel. A pretreatment of the metal helps create an adhesive bond that allows the resin material to be applied directly onto the metal. (Due to the proprietary nature of the process, exact detail on the bonding is not available.) When shearing forces are applied to the incisal edge of these veneers they are likely to fail by chipping or loosing pieces of the veneer, but not the entire veneer. As with the Cheng crown, only small pieces of the veneer were broken and lost, while much of the veneer remained intact and attached to the crown. Most (90%) of the veneer fractures of both these crowns were mixed adhesive and cohesive failures. The veneer separated at the metal-resin interface, but the entire veneer never was dislodged completely. In every instance, some of the resin remained bonded to the metal, even though the incisal resin had been broken or dislodged.

Before this experiment it was postulated that it might be possible to break or dislodge a veneer from one of these crowns if a child bit down with great force and incised directly on the veneer material. To simulate oral forces for this study, the force applied by the Instron machine was directed at 148° which is the average primary interincisal angle. Data regarding the biting force of preschoolers is not available, but it is safe to assume that their biting force is less than or equal to that of 5- to 10-year-old children, for whom data are available. Bakke et al.[9] reported average biting force of 5- to 10-year-old children to be 357 N ± 64. The average force required to break one of these veneers was greater than this for all four types of crowns tested, ranging from 397 N (Kinder Krowns) to 687 N (Whiter Biter), which makes it unlikely that a child would crack or break a veneer through normal incisive function. Clinical experience has demonstrated, however, that these crowns do occasionally chip or lose parts of the veneer. Based on the results of this in vitro study, it is probably more likely that the breakage occurs as a result of traumatic forces, not incisive forces.

It is unclear what effect water sorption might have on the veneer strength. Composites tend to absorb water over an extended period of time but in this study the crowns were immersed in water for only about 24 hr. It is possible that increased water sorption might change the strength of the material and/or bond to some degree.

It is important for the reader to note that since completion of this study, the manufacturer of Kinder Krowns has attempted to improve the strength of their veneers. Kinder Krowns that are now available are a second-generation crown with a different veneer material and an increased mechanical retention in the incisal portion of the crown. However, it is not clear to what degree these changes would affect the results found in this study.

Though in this study the Whiter Biter crown was able to withstand more incisal shearing force than the other crowns, this is just one of several characteristics of these crowns that must be considered and should not be taken as a strong endorsement of this crown over all others. The shade of veneers and adaptability of crown during placement, the natural esthetics of each material, its ability to resist staining, and the possibility of microleakage between the veneer and stainless steel also should be considered. Additionally, the ease of repairing small chips or recontouring the shape

of the veneers are other important considerations. Objective evaluation of these characteristics has not yet been reported in the literature.

Conclusions

1. The Whiter Biter II veneered primary stainless steel crown is significantly better able to resist a shearing force on the veneer than the other three commercial crowns tested.
2. The mechanism of veneer loss is different for Whiter Biter II from the other crowns tested. The Whiter Biter veneers exhibited adhesive failures and were dislodged in one piece while the other three crowns experienced a mixed adhesive/cohesive failure that resulted in pieces, but not the entire veneer, being dislodged.

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From The Archives

Folkestoneians fight sissification

Not all Britons have surrendered to the sanitary and hygienic fads of our times. A noble little band in Folkestone, England, we are informed by cable dispatches in the August 28th, Record-Herald, stands out resolutely against tooth brushes. It refuses to yield to the subtle influences that are refining the Britishers into a race of weaklings. At a meeting of a board of guardians of children's cottage homes a member of the board had the temerity to advocate the purchase of tooth brushes for the children under their care. He even went so far as to declare that tooth brushes were as necessary as soap and water. The motion to supply tooth brushes was vigorously opposed. The mayor of the town attacked the idea with great vehemence, declaring that the stamina of Englishmen was being ruined by such fads. He ventured the opinion that many of those present at the board meeting had not used tooth brushes for the greater part of their lives. And the board agreed with him, for it promptly voted down the tooth brush proposition. The children in the cottage homes at Folkestone may not have any teeth at forty-five, but they will have preserved their stamina. "Back to Nature" is the stirring slogan of the sturdy stalwarts of Folkestone.

The Dental Summary, 1904