Scientific Article

Color change and fracture resistance of two preveneered stainless-steel crowns after sterilization

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Abstract

Purpose: This study compared the fracture resistance and color stability of two commercially available, preveneered stainless-steel crowns before and after four sterilization techniques.

Methods: Thirty-five crowns from each of two manufacturers were divided into five groups. Four groups were sterilized twice using one of the following techniques: steam autoclave at both 121° C (15 PSI) for 20 min and 132° C (30 PSI) for 8 min; Chemiclave™ with formaldehyde at 132° C for 20 min; and 2% gluteraldehyde for 10 h. The fifth group from each manufacturer was the control. Color of facings was measured before and after each sterilization in triplicate using a colorimeter, and the variance of each color parameter was analyzed for significance. Fracture resistance was measured for each group and differences between the control and experimental groups analyzed for significance.

Results: The results of this study show that high heat and chemical sterilizations have little effect on color and fracture resistance of the preveneered stainless-steel crowns. Student's t *test analysis revealed a significantly decreased resistance to fracture with Kinder Krowns™ sterilized in 2% gluteraldehyde. Chemiclave™ sterilization caused the most negative color change in all three color parameters measured for both types of crowns.*

Conclusions: As neither steam technique produced significant changes in fracture resistance or color changes that were clinically detectable, the results of this study indicate that the two steam techniques tested can be used by clinicians to sterilize either Kinder Krowns™ or Nu Smile™ preveneered stainless-steel crowns. (Pediatr Dent 20:5 336–340, 1998)

Cosmetically acceptable restoration of grossly decayed primary incisors in young children is an ongoing dilemma for dentists. Cooperation of the young child can be poor, and the procedures are often time consuming. Primary teeth have considerably less enamel than permanent teeth, and caries destruction can be rapid, limiting the amount of tooth structure remaining to retain restorations.

Dentists have proposed several procedures for the restoration of primary incisors. One has been a composite "strip crown" in which a hollow plastic crown form is fitted to the prepared incisor and filled with composite.[1] This procedure is technique-sensitive and requires cooperation from the child, as well as a sufficient amount of tooth structure for composite bonding. The restorations are also fragile and easily fractured. Stainless-steel crowns (SSCs) can be placed on more cariously involved teeth and offer good durability but poor esthetics.[2] A cosmetic solution to the SSC has been the "open face" SSC.[3] This procedure is also technique-sensitive and timeconsuming, sometimes requiring two appointments.

Several companies have recently introduced an SSC in which an esthetic veneer is bonded on the facial surface. This restoration provides the dentist with an easily placed, durable, more esthetic restoration for cariously involved anterior teeth. Few studies have evaluated the durability and color stability of the veneered facing. Waggoner and Cohen determined that the veneer facings of these crowns have a fracture resistance greater than the average bite force of a 5–10-year-old child.[4] Baker et al.[5] found similar resistance to displacement of the veneers for Kinder Krowns™, Nu Smile™, and Cheng™ crowns, but less force was required for dislodgement of the veneers for Whiter Biter™ crowns than those reported by Waggoner and Cohen. Coloma et al. showed that all commercially available veneered facings are capable of staining and color changes.[6]

Another concern is sterilization. In a clinical setting, it may be necessary for the dentist to try on several sizes of crowns to obtain a proper fit, and the crowns not cemented must be sterilized. Preparation of the tooth to receive the crown usually causes gingival bleeding with contamination of crowns during try-in. Heat sterilization is not recommended by the manufacturers because of the possibility that heat could affect the bond of the veneered facing and alter the color (Personal communication). The manufacturers' instructions recommend cold sterilization;[7] however, the amount of microbial killing by this method cannot be verified routinely.[8] Anecdotal reports from practitioners indicate that many of them are unaware of the manufacturers' recommendations for cold sterilization

only or are choosing to use heat sterilization methods.

It would be of value to know whether these heat methods of sterilization are deleteriously affecting the crowns. The purpose of this study was to compare the fracture resistance and color stability of two commercially available preveneered SSCs before and after four sterilization techniques. Additionally, stereomicroscopy before and after each sterilization was used to evaluate surface changes caused by the sterilization procedures.

Methods

Thirty-five preveneered SSCs from two companies were used for a total of 70 SSCs. The crowns were obtained from Mayclin Dental Studio (Kinder Krowns™, Minneapolis, MN) and Orthodontic Technologies, Inc. (NuSmile™ crowns, Houston, TX). Seven of the 35 crowns from each company were used as controls to obtain a baseline fracture resistance value before sterilization. The remaining 28 SSCs from each company were analyzed for surface and color change before and after four different sterilization procedures. These crowns were then subjected to a fracture resistance test. The sterilizers used were steam autoclave (Tuttnauer Company), Chemiclave™ (Harvey Chemiclave 5500™), and 2% gluteraldehyde (Fisher Scientific Company).

The 28 experimental crowns from each manufacturer (size 4) were randomly assigned to four groups and subjected to the sterilization techniques (Table 1).

Surface changes of the crowns were determined using stereomicroscopy at 10 x magnification before and after each sterilization. The surface of each crown was examined for the presence or absence of three defined types of surface change—crazing, fracture, and contour alteration. Crazing was defined as internal cracks visible under 10 x magnification, but not detectable with an explorer gently moved over the surface. The degree of crazing was assigned according to the amount of the surface involved as 1, 2, or 3 with 1 equal to a few, isolated cracks involving less than one-third of the surface, 2 equal to cracks involving one-third to one-half of the surface, and 3 equal to cracks involving greater than one-half of the surface. Fractures were defined as cracks detectable both visually under 10 x magnification and manually when the tine of an explorer moved gently over the surface detected roughness. The degree of fracture involvement was assigned a value of 1, 2, or 3 according to amount of surface involvement using the same criteria as for crazing. Changes in surface contour were defined as deformation consistent with melting or flow of the surface veneer and visible as flattening or dipping-in of the surface relative to the contour of the crown. Changes in contour were assigned a value of 1, 2, or 3 according to amount of surface involvement using the same criteria as used for crazing and fractures. The surface assessments of the veneers were performed before sterilization and again after each run through the assigned sterilization procedure. A paired *t* test was used to compare pre- and poststerilization values and significance was determined at $P < 0.05$ for all data.

TABLE 1. STERILIZATION TECHNIQUES

Group	*Sterilization Method*	*Sample Size*
A	Steam autoclave, 121°C, 15 PSI, 20 min	7
B	Steam autoclave, 132°C, 30 PSI, 8 min	7
C	Chemiclave with formaldehyde vapor, 132°C, 20 min	7
D	2% Gluteraldehyde solution, 75°F, 10 h	7

The color stability of the facings was assessed using the Minolta CR300 Chroma Meter™ which produces color parameters based on average daylight illumination. The color parameters were recorded in the L*a*b* color space as established by the CIE (Commission Internationale de L'Eclairage) in 1978.[9] The L* value is the difference in white and black, and the higher the number, the more white the color. The a* value represents the red/purple–blue/green axis, and the higher the number, the more red/purple the color. The b* value represents the yellow–purple/blue axis, and the higher the number, the more yellow the color.[10] This system is related to human color perception in all three dimensions, or directions of color space. Equal distances in the color space represent approximately equally perceived steps.

Each SSC was mounted on a composite jig to ensure precise placement on the CR300™ for each reading. All readings were in constant controlled lighting in order to maintain the accuracy of the CR300™. The readings on the veneers were taken before sterilization and again after each run through the assigned sterilization procedure. Three readings were taken each time for each facing and the average of these numerical readings was used. A paired *t* test was used to compare pre- and poststerilization L*a*b* values. Significance was determined at $P < 0.05$ for all data.

The fracture resistance test was conducted as follows. A NiCr™ master die was cast from a duralay pattern of the inside of each of the manufacturers' SSCs. The die was placed in the SSC to prevent any distortion during testing. The die and SSC were placed in a holder

for use in the hydraulic testing machine (Instron Model 1125). A force was applied with the 90° edge of a precision bolt at 180° to the incisal edge at the interface of the veneer and SSC at a speed of 0.01 in/min until the facing fractured or dislodged. The force required for fracture was determined numerically in pounds per inch squared by the Instron. An independent *t* test was used to determine significance in fracture resistance ($P < 0.05$) between control crowns (no sterilization) and crowns subjected to each of the sterilization procedures. The same examiner conducted all surface and color evaluations and fracture resistance testing and was blind as to the assigned group of each crown.

Results

Surface changes

All crowns were analyzed under stereomicroscopy at 10 x before and after each sterilization procedure, and no fracture or craze lines were evident in the surface of any of the samples. Additionally, no flattening or concavity in the surfaces of the veneers following any sterilization procedure was observed.

Color analysis

There were significant differences in the color parameters (L*a*b*) for all the sterilization procedures. Kinder Krowns™ showed several significant color changes following three of the sterilization techniques. They became significantly lighter following the first sterilization and significantly more red/purple following the second sterilization with the steam autoclave at 132°C (20 PSI) for 8 min. They became significantly less white, more blue/green, and more yellow following sterilization with the Chemiclave™. They became significantly lighter and less yellow following sterilization with gluteraldehyde. The Nu Smile™ crowns showed several significant color changes following all of the techniques of sterilization. After sterilization with steam at 121°C (15 PSI) for 20 min, they were significantly more blue/green and more yellow. Following sterilization with steam at 132°C (30 PSI) for 8 min, they were significantly less white, and more yellow. After sterilization with the Chemicalve™, they were significantly less white, more blue/green, and more yellow. Following sterilization with gluteraldehyde, they were significantly more blue/green. The mean color values and standard deviations for both manufacturers' crowns are summarized in Tables 2 and 3.

Fracture resistance

The mean shear values and standard deviations for both manufacturers' crowns are shown in Table 4. There was a significant difference between Kinder Krown™ controls and the crowns sterilized by 2% gluteraldehyde. Significantly less force was required to fracture the facings following sterilization in gluteraldehyde. Though not significant, there was a trend toward decreasing fracture resistance values with the steam autoclaving techniques for both manufacturers, and it was greater for the NuSmile™ crowns. No other significant differences between controls and sterilized crowns were seen. All of the crowns examined showed a mixed adhesive/cohesive failure in which part of the veneer fractured and part remained bonded to the crown.

TABLE 2. L*A*B COLOR VALUES FOR KINDER KROWNS

		Steam Autoclave		*Chemiclave*	*2% Glutaraldehyde*
		121°C, 15 PSI, 20 min.	*132°C, 20 PSI, 8 min.*	*132°C, 20 PSI, 20 min*	*75°F, 10 h*
Sterilization					
L*	Pre	73.35 ± 1.43	73.58 ± 2.08	75.16 ± 0.99	73.94 ± 0.75
	First	73.30 ± 1.43	74.41 ± 2.16*	74.93 ± 1.13	74.23 ± 1.20
	Second	73.55 ± 1.43	73.94 ± 2.49	73.27 ± 1.32*	74.43 ± 1.04*
a*	Pre	0.79 ± 0.23	0.88 ± 0.23	0.85 ± 0.12	0.86 ± 0.20
	First	0.72 ± 0.25	0.93 ± 0.15	0.65 ± 0.26	0.81 ± 0.22
	Second	0.86 ± 0.25	0.99 ± 0.15*	0.53 ± 0.32*	0.85 ± 0.20
b*	Pre	10.69 ± 1.16	10.01 ± 1.16	9.58 ± 0.69	10.00 ± 1.45
	First	10.51 ± 1.39	9.85 ± 1.03	12.66 ± 1.00*	9.33 ± 1.56*
	Second	10.69 ± 1.38	10.06 ± 0.99	13.41 ± 0.79*	9.41 ± 1.44*

* $P < 0.05$

TABLE 3. L*A*B COLOR VALUES FOR NEW SMILE CROWNS

		Steam Autoclave		*Chemiclave*	*2% Glutaraldehyde*
		121°C, 15 PSI, 20 min	*132°C, 20 PSI, 8 min*	*132°C, 20 PSI, 20 min.*	*75°F, 10 h*
Sterilization					
L*	Pre	69.52 ± 1.33	69.90 ± 1.21	70.00 ± 0.86	70.19 ± 0.55
	First	69.28 ± 1.52	69.48 ± 1.32	69.39 ± 0.87	69.95 ± 0.61
	Second	69.45 ± 1.26	69.43 ± 1.21*	69.35 ± 0.64*	70.02 ± 0.57
a*	Pre	0.29 ± 0.17	0.19 ± 0.22	0.24 ± 0.17	0.40 ± 0.18
	First	0.29 ± 0.18	0.16 ± 0.25	0.13 ± 0.16*	0.35 ± 0.19*
	Second	0.27 ± 0.17*	0.15 ± 0.24	0.11 ± 0.16*	0.32 ± 0.20*
b*	Pre	9.67 ± 0.66	9.56 ± 0.49	9.47 ± 0.56	9.42 ± 0.63
	First	10.04 ± 0.66*	10.06 ± 0.53*	11.43 ± 0.55*	9.33 ± 0.63
	Second	10.20 ± 0.61*	10.36 ± 0.57	12.00 ± 0.53*	9.34 ± 0.64

* $P < 0.05$

TABLE 4. SHEAR STRENGTHS (PSI) OF PREVENEERED SSCS

	Kinder Krowns	*Nu Smile*
Controls	86.71 ± 28.86	124.00 ± 22.08
A. Steam autoclave (121°C, 15 PSI, 20 min)	81.87 ± 9.89	109.00 ± 25.26
B. Steam autoclave (132°C, 30 PSI, 8 min)	78.28 ± 22.43	105.71 ± 32.92
C. Chemiclave (132°C, 15 PSI, 20 min)	91.00 ± 29.68	121.71 ± 23.44
D. 2% Glutaraldehyde (75°F, 10 h)	74.00 ± 13.41*	137.57 ± 26.69

* $P < 0.05$

Discussion

The manufacturers' instructions do not specifically warn the user not to subject their crowns to heat sterilization. Rather they "recommend cold sterilization." This project was initiated for two reasons. First, the investigators believed that due to the potential for bloody contamination of these crowns, cold sterilization was insufficient because it cannot be routinely verified for effectiveness. Second, anecdotal reports are that dentists are using heat to sterilize these crowns. They unknowingly might be weakening the facing bond and subsequently using a crown with an increased potential for failure of the facings.

It was surprising to note that the only significant decrease in fracture resistance was in the Kinder Krown™ group subjected to the cold sterilization method recommended by the manufacturer. The chemiclave groups from both manufacturers appear to be the least negatively affected. The fracture resistance values for the Kinder Krown™ actually increased following this procedure. Steam autoclaves use steam at a temperature of 121°C (250°F) at 15 PSI for 20 min or a temperature of 132°C (270°F) at 30 PSI for 8 min for lightly wrapped items.[8] The Chemiclave™ uses a formaldehyde vapor at a temperature of 132°C (270°F) at 20–40 PSI for 20 min. As the levels of heat are very similar between the two methods, heat may not play as large a role in changing the fracture resistance as originally anticipated by the manufacturers. Rather, steam may play some part in changing the fracture resistance. Because the fractures were both adhesive and cohesive, it may be not only the bond interface that is affected, but also some internal components of the veneer as well.

The veneered facings are composite resins and are bonded to the SSC by processes the manufacturers do not reveal. The lower fracture resistance exhibited by the Kinder Krowns™ following soaking in gluteraldehyde could be associated with the manufacturer's veneering process. In preparation of the crown for veneering, a small portion of the metal in the mesial/incisal and distal/incisal of the crown is removed, leaving two small holes. The composite material is placed in these holes during the veneer and bonding process, with the intent that this procedure will strengthen the bond of the material to the metal crown. The effects of gluteraldehyde on the compos-

ite material is unknown. However, it is possible that the gluteraldehyde solution is able to come into contact with both sides of the composite resin, the inner incisal and the outer incisal, somehow affecting the strength of the veneer bond. These Kinder Krowns™ exhibited the same adhesive/cohesive fracture that was observed in the crowns sterilized by the other methods.

The findings of this study agree with those of Waggoner and Cohen, who found adhesive/cohesive failures in nine of the 10 Kinder Krowns™ tested and in all 10 of the Nu Smile™ crowns tested.[4] In the present study, there were no differences in the type of fracture between manufacturer or the different sterilization procedures. However, Nu Smile™ crowns exhibited a higher failure strength in all tests.

The color stability of the crowns varied with the sterilization technique. The only technique that caused color changes of a magnitude noticeable by the human eye was the Chemiclave™. For both manufacturers, this technique caused the crowns to have significant differences in variance of all three color directions. The differences between pre- and poststerilization were greater for the Kinder Krown™ crowns, but both types of crowns became less white, more blue/yellow, and more yellow. Kuehni and Marcus reported that color differences of "less than approximately one" were judged to be a color match by more than 50% of observers.[11] Therefore, if color differences of greater than one can be perceived by the human eye as change, the changes of 1.89 units to less white and 3.83 units to more yellow measured in the Kinder Krowns™ could be observed as being significantly darker as a result of the sterilization procedures. Pre- and poststerilization differences for the other techniques, though significant in a number of color parameters, were not large enough to be noticeable. Even the sterilization technique recommended by the manufacturers caused significant color changes in both crowns.

These results present a dilemma in that Chemiclave™ sterilization, which appeared to cause the least effect on shear strength values, caused the greatest negative change in crown color. Therefore, it is difficult to recommend it over the two steam techniques. However, as the steam techniques produced neither significant changes in fracture resistance nor color changes which were clinically detectable, the results of this study indicate that the two steam techniques tested can be safely used by clinicians to sterilize either Kinder Krowns™ or Nu Smile™ preveneered SSCs. In fact, when considering the adverse effects on fracture resistance and color change, either of these techniques is preferable to the manufacturer's recommended method of cold sterilization in gluteraldehyde.

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