Orthodontic band retention on primary molar stainless steel crowns

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Abstract

The retention of orthodontic bands cemented on primary molar stainless steel crowns (SSC) was studied in vitro. Unitek maxillary and mandibular 1st and 2nd primary molar SSC were fitted with one of four commonly used orthodontic bands (Unitek regular, Unitek narrow, Rocky Mountain, or custom bands made from SSC) using glass ionomer cement. The cemented samples were tested for their resistance to dislodgment on the Instron® Universal Testing Machine (Instron Engineering Corp., Canton, MA) in tensile mode. Alpha level for statistical significance was set at $\alpha = 0.05$. Unitek regular bands cemented on the 2nd molar crowns and Unitek narrow bands cemented on the 1st molar crown samples had equivalent or superior resistance to dislodgment compared with the other bands in the study. When the inside of the band and the outside band-bearing surfaces of selected crowns were lightly scored with a diamond bur prior to cementation, samples exhibited significantly superior retention. Subgroup means increased from 107 to 330%, compared to the values obtained in their preroughened state. The mean values obtained using the roughened band/crown interface technique (range 52.9 ± 7.6 to 73.6 ± 8.4 lbs) compared favorably with retention values from the literature for orthodontic bands cemented on permanent molar and premolar teeth. (Pediatr Dent 15:408–13, 1993)

Introduction

The rationale for, use of, and design of the fixed unilateral space maintainer are well established in the practice of pediatric dentistry when a primary molar is prematurely lost. A space maintainer prevents migration of adjacent teeth, thus holding space in the dental arch for the succedaneous tooth to erupt. Fixed unilateral space maintainers may be of two types according to the current clinical guidelines of the American Academy of Pediatric Dentistry: band and loop and crown and loop.[1]

The crown and loop inherently has the advantage of superior retention, but takes two appointments to fabricate and is difficult to adjust intraorally if deformed or rotated. If broken or if replacement is required, the crown must be removed and a new crown and loop appliance fabricated. Placing a band and loop on a primary molar stainless steel crown is a simpler and less time-consuming procedure. Only one crown need be placed at the initial appointment and administration of local anesthetic is not usually required for the band cementation appointment. If the need arises, the band and loop can be removed, adjustments made or a new appliance fabricated, and recemented without removal of the abutment stainless steel crown. Christensen and Fields[2] advise that the crown and loop is not a recommended technique. Fields[3] states that it is no longer considered advisable to use the crown-loop appliance because it precludes simple appliance removal and replacement. He recommends that teeth with SSC should be banded like natural teeth. McDonald et al.[4] state that a primary first molar stainless steel crown provides a desirable retentive contour for placing a stainless steel band.

The retention of stainless steel orthodontic bands cemented on primary molar stainless steel crowns has not been reported in the pediatric dental literature. The retention of stainless steel bands cemented to permanent molar and premolar teeth has been quantified by in vitro analyses.[5,6]

The purpose of this laboratory study was to quantify and compare retention of four different types of orthodontic bands commonly used in fabricating fixed unilateral space maintainers cemented on SSC.

This investigation attempted to determine if there were significant differences in the retentive abilities of the different band types selected for study. Second, the influence of roughening the band/stainless steel crown interface was analyzed to determine if cement bond strength was improved, and if so by how much. Third, a chart was formulated matching Unitek primary 1st and 2nd molar stainless steel crowns of the various sizes with corresponding orthodontic bands in order to facilitate selection of the appropriate band in the clinical setting.

Methods and materials

To evaluate the retention of stainless steel orthodontic bands cemented with glass ionomer to primary molar stainless steel crowns, this investigation used 120 Unitek (3M/Unitek Corporation, St. Paul, MN) right primary 1st and 2nd molar size #4 crowns. All stainless steel crowns used in this study were trimmed, crimped, and polished. All samples of like crowns (UR 2nds, LR 2nds, UR 1sts, and LR 1sts) were made as similar as possible and "typical" of crown restorations placed clinically. The similarity of trim and crimp of sample crowns within like crown groups was studied. Forty randomly selected samples, 10 from each crown group, were weighed on an electronic laboratory scale in the untrimmed and trimmed state to the nearest 0.001 g. Samples then were crimped. Again, 10 samples from each of the four crown groups (40 total) were selected randomly for measurement. Using a Boley gauge, the greatest transverse inside diameter dimension from mesial-buccal (MB) to distal-lingual (DL), and from mesial-lingual (ML) to distal-buccal (DB) was recorded to the nearest 0.1 mm.

Once the crowns were trimmed, crimped, and polished, a masking tape skirt was placed around the periphery of each crown. A 1.5-in. machine screw was placed into each crown, and self-polymerizing dental acrylic was then salt-and-peppered past the stainless steel crown margins up into the masking tape skirt, forming a solid acrylic lug and mimicking a prepared tooth, which anchored the crown onto the machine screw (Fig 1). The machine screws were placed in the occlusogingival long axes of individual samples. Deviations from the long axis of individual samples occurred and were measured and recorded.

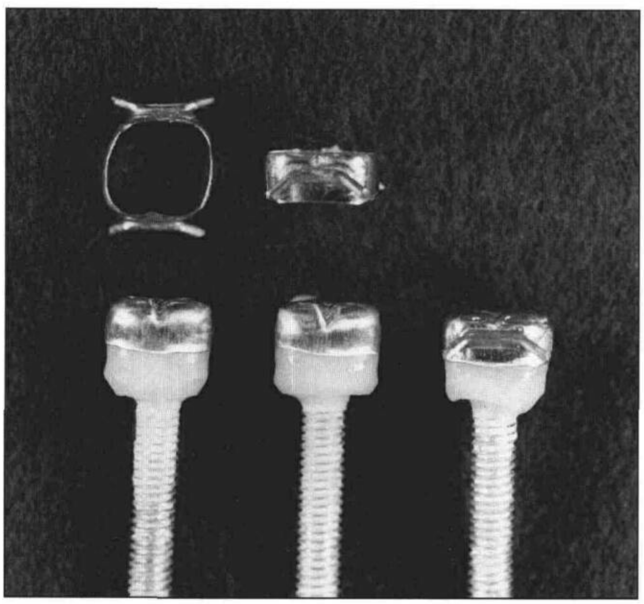

Fig 1. SSC samples and bands.

Band preparation

Unitek regular, Unitek narrow (3M/Unitek Corporation, Monrovia, CA), Rocky Mountain (Rocky Mountain Orthodontics, Denver, CO), and custom bands fabricated from Unitek SSC were selected for study. The factory bands selected exhibited the best clinical fit on their respective crown samples. The bands tested on specific samples are indicated in Table 1. Each band was fitted to and matched with its own crown sample. This mating was maintained throughout the investigation.

Table 1. Mean maximum force in lbs ± 1 SD to dislodge bands from crowns.

Unitek crowns with corresponding bands			*Roughened Band/Crown Interface Study*
Group I (UR2nd#4)			
Unitek U33 (N = 10)	28.3 ±	7.4 lbs /	58.7 ± 12.8 lbs
Unitek NU33 1/2 (N = 10)	25.1	9.9	
Rocky Mtn. U6.5 (N = 10)	22.4	4.1	
Custom (N = 10)	12.3	4.1	
Group II (LR2nd#4)			
Unitek L31 1/2 (N = 10)	15.3	6.2 /	61.0 ± 15.9
Unitek NL31 1/2 (N = 10)	6.4	1.7	
Rocky Mtn. L4.5 (N = 10)	16.8	6.9	
Custom (N = 10)	16.8	4.9	
Group III (UR1st#4)			
Unitek NL26 (N = 10)	17.1	4.2 /	73.6 ± 8.4
Custom (N = 10)	17.8	2.4	
Group IV (LR1st#4)			
Unitek NL25 (N = 10)	20.4	3.4 /	52.9 ± 7.6 lbs
Custom (N = 10)	12.9 ±	4.2 lbs	

Custom bands were fabricated by taking the next larger size Unitek primary molar stainless steel crown and trimming and polishing the gingival portion. The crown's occlusal surface was removed using a wet-belt grinder. The rough occlusal margins were polished. Width measurements were made of the custom and factory bands. Custom and factory bands then were fitted on their respective crowns and burnished to a clinically acceptable fit. The bands were not crimped, and their gingival margins did not extend beyond the host crown's gingival margins. Lugs, 10 mm long, were fabricated from 0.045 stainless orthodontic wire with the distal 2 mm of each wire's ends bent down at an angle of approximately 30° and in the same plane. The lugs were spot welded and soldered onto the midbuccal and lingual surfaces of the bands parallel to their occlusal planes (Fig 1) then cleaned in an acid bath electropolisher to remove flux and oxide coatings.

The bands with lugs attached were cemented on the stainless steel crown samples using glass ionomer cement (Ketac-Cem, ESPE GmbH & Co., Lake Worth, FL). Once cemented, the samples were stored at room temperature in a humidor for a minimum of 24 hr before testing.

The samples with the cemented bands then were pulled using the Instron Universal Testing Machine (Model #TTCL—Instron Engineering Corp., Canton, MA) in tensile mode (Fig 2). A threaded couple adapter was fabricated to accept the machine screws used in the samples. The adapter was attached via a pinion to a

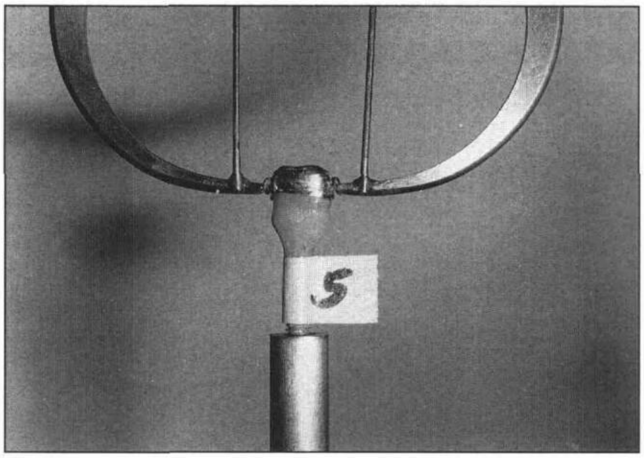

Fig 2. Sample attached to Instron, ready for testing.

universal joint that was connected to the Instron's load cell. To engage the lugs soldered to the buccal and lingual surfaces of the bands, a 6.5-in. outside diameter spring caliper was adapted for this purpose. This caliper easily was adjusted to engage the lugs on an individual band by using the thumb screw. The modified caliper was affixed via a pinion couple to the cross head of the Instron. The Instron was run at a cross-head speed of 0.1 in. per min. The load range set for the recording chart was 0–50 pounds. Chart speed was set at 0.5 in. per min. Each sample was pulled on the Instron until the band was visibly dislodged in an occlusal direction on the crown. After all the samples were tested once, the bands listed in Table 1 with their matching crown samples were cleaned in detergent and water in an ultrasonic cleaner to remove adherent cement.

Roughening band/crown interface

Using a bullet-nose diamond bur (#856-018, Brassler Inc., Savannah, GA) in a high-speed dental handpiece, the inside of the bands and the band bearing buccal, lingual, mesial, and distal surfaces of the 2nd molar crowns, and the buccal, lingual, and distal surfaces of the 1st molar crown samples were scored lightly or roughened up. The mesial surfaces of the 1st molars were not scored because when a band and loop space maintainer is needed on a 1st primary molar abutment, there is almost always a cuspid present blocking access to the mesial surface of the 1st molar. The bands then were recemented on their matching crowns and pulled on the Instron as previously described. The load range of the recording chart was increased to 0–100 lbs. The maximum force recorded on the load-displacement graph required to visibly dislodge a cemented band from its crown was noted.

Analysis

Due to the dissimilarity of the shapes of the crowns in the four different sample groups and the differences in the sizes of the bands that fit these crowns, statistical analysis between groups could not be performed. With respect to statistical analysis, this study is composed of four separate investigations based on the four primary molar crown groups (Groups I–IV) listed in Table 1. The data obtained from the Instron testing were statistically analyzed within groups using ANOVA and Newman-Keuls multiple comparisons tests, and Student's *t*-tests where appropriate. F tests were used to determine homogeneity of variance. Where the assumption of homogeneity of variance for statistical testing was violated, multiple *t*-tests were used with corrected table values[7] where indicated to confirm ANOVA results. Alpha level for statistical significance was set at $\alpha = 0.05$.

Results

Uniformity of the sample material

The uniformity of the sample material was analyzed, and the trim and crimp of the stainless steel crowns was compared within groups. Analyzing trim; 39 of the 40 randomly selected samples weighed fell within ± 2 SD from their respective group means. The range between high and low weights encompassed 2.4%—Group I, 2.6%—Group II, 2.6%—Group III, and 3.3%—Group IV of their corresponding mean values. Analyzing crimp; all 40 randomly selected samples measured fell within ± 2 SD from their respective group means. The range between high and low MB-DL and ML-DB measurements was equal to 4.1 and 2.6%—Group I, 2.0 and 3.5%—Group II, 4.0 and 5.2%—Group III, and 2.5 and 2.8 %—Group IV respectively of their corresponding mean values. This small amount of variation suggests the similarity of the prepared stainless steel crowns within groups. All 40 custom bands were measured with respect to width, at the midbuccal, lingual, mesial, and distal and compared with competing Unitek factory bands used in this study. The custom and factory bands were very similar in their occlusal-gingival dimensions. In many instances, the custom bands were wider than the Unitek bands. The amount of angulation exhibited by the machine screws away from the long axes of the sample crowns for 36 randomly selected samples ranged from 0 to 5 degrees (Mean = 2.9 ± 1.5 degrees). This amount of variation should have been neutralized by the Instron's universal joint. Therefore, the samples exhibited a degree of precision in their fabrication that allows for the following statistical analyses of band retention.

Group I analysis

ANOVA and Newman-Keuls multiple comparisons test indicated that the custom band subgroup ($\bar{x} = 12.3 \pm 4.1$ lbs) had significantly less retention than the Unitek U33 ($\bar{x} = 28.3 \pm 7.4$ lbs), Unitek NU33 1/2 ($\bar{x} = 25.1 \pm 9.9$ lbs), or the Rocky Mountain U6.5 ($\bar{x} = 22.4 \pm 4.1$ lbs) subgroups, the latter three being statistically equivalent.

Group II analysis

ANOVA and Newman-Keuls multiple comparisons test indicated that the Unitek NL31 1/2 subgroup ($\bar{x}$ = 6.4 ± 1.7 lbs) exhibited significantly less retention than the custom band ($\bar{x}$ = 16.8 ± 4.9 lbs), Rocky Mountain L4.5 ($\bar{x}$ = 16.8 ± 6.9 lbs), or the Unitek L31 1/2 ($\bar{x}$ = 15.3 ± 6.2 lbs) subgroups, the latter three being statistically equivalent.

Group III analysis

Student's *t*-test indicated that the Unitek NL26 ($\bar{x}$ = 17.1 ± 4.2 lbs) and the custom band ($\bar{x}$ = 17.8 ± 2.4 lbs) subgroups were statistically equivalent.

Group IV analysis

Student's *t*-test indicated that the Unitek NL25 subgroup ($\bar{x}$ = 20.4 ± 3.4 lbs) exhibited significantly more retention than the custom band subgroup ($\bar{x}$ = 12.9 ± 4.2 lbs).

Roughened groups

Student's *t*-test on repeated measures confirmed that all bands had significantly more retention after roughening. Specifically, the mean retention increased 107% for the UR 2nd-U33 group, 299% for the LR 2nd-L31 1/2 group, 330% for the UR 1st-NL26 group, and 159% for the LR 1st-NL25 group (range = 52.9 ± 7.6 lbs to 73.6 ± 8.4 lbs) as compared with values obtained in the preroughened state.

Discussion

When treating the immature child patient in the office setting or in the operating room under general anesthesia, time is a very valuable commodity. Fabricating a custom orthodontic band used in making a band and loop space maintainer does take more time than selecting a factory band. This investigation set out to determine if custom bands fabricated from the next larger size Unitek primary molar stainless steel crown had any advantage in retention when compared to three types of factory bands. Differences in the inherent retention of the three types of factory bands also were evaluated. Upon statistical analysis of the data from within Groups I, II, III, and IV, the custom bands tested exhibited no statistical advantage in retention, being either equivalent or inferior, compared with Unitek regular bands when cemented on the maxillary and mandibular 2nd primary molar crowns (Groups I and II). Also, custom bands had no statistical advantage over the Unitek narrow bands when tested on maxillary and mandibular 1st primary molars (Groups III and IV). Unitek regular and Rocky Mountain bands did not fit the primary 1st molar crowns well, being too tall when seated. Therefore, they were not tested on these samples in this investigation.

Rocky Mountain bands gave the clinical impression of being stiffer than Unitek bands, which might suggest that they offer some retentive advantage when cemented. However, this was not found to be the case.

The reasons that certain band subgroups exhibited significantly less retention than their counterparts are interesting to contemplate. The Unitek narrow bands performed well on the upper 2nd molar crowns, but gave disappointing results on the lower 2nd molar samples. Custom bands performed equivalent to the Unitek narrow bands on the upper 1st molar samples, but exhibited significantly less retention on the lower 1st molar crowns. Variation in band retention could be explained by differences in band surface area, malleability of band material, band fit, retentive shape of host crown, and cement properties. Although there is no obvious explanation, a combination of crown shape and band fit is the most likely cause for the nonsystematic differences in the results.

Visual examination of the bands dislodged from their respective crown mates prior to roughening revealed that the glass ionomer cement bond failure occurred almost uniformly between the cement and the stainless steel crown. This adhesive failure is most likely explained by the differences in the surface textures of the internal band and the external crown. The internal band surface, having gone through spot welding, heating during soldering, and acid bath electropolishing, appeared to be irregular and exhibited areas with a dull etched appearance. In contrast, the surface of the Unitek stainless steel crown had a highly polished factory finish that contributed little to the mechanical retention of the cement.

The typical dislodged band retained a film of cement around its internal surface while the crown surface was clean with little or no retained cement. The band and cement basically pulled off the crown. Clinical studies of actual orthodontic cases by Maijer and Smith,[8] Mizrahi,[9] and Fricker,[10] and a laboratory study by Norris and associates,[6] concur that glass ionomer cement used to cement orthodontic bands had significantly better retentive strength to enamel than to band material. Thus, when bond failures occurred in these studies, the tendency was for the glass ionomer cement to fail at the cement/band interface, leaving the cement bonded to tooth enamel. It has been reported that the chemical adhesion of glass ionomer to stainless steel is equivalent to approximately 10% of the tensile strength of the cement (0.7 vs. 5.6–8 MPa), and to approximately 13% of the bond obtained between glass ionomer and tooth enamel (0.7 vs. 3.2–7.5 MPa).[11] This evidence might persuade one to argue that orthodontic bands cemented on stainless steel crowns with glass ionomer cement may not have the same inherent potential to be as retentive as similar bands cemented on natural teeth. This may be why some clinicians have reported anecdotal evidence of poor clinical success when placing band and loop space maintainers on stainless steel crown abutments.

Croll,[12] in his 1983 technique article on cementing band and loop space maintainers, advocated roughening the band interior with a coarse diamond bur to aid cement adherence to the stainless steel. For the roughening phase of this analysis, Unitek regular bands were chosen from Groups I and II and Unitek narrow bands from Groups III and IV because these bands performed either superior or equivalent to the others.

Table 2. Unitek crowns matched with corresponding Unitek bands

Maxillary 2nd Primary Molars			*Maxillary 1st Primary Molars*		
U1	-	U29	U1	-	Custom
U2	-	U29 1/2	U2	-	Custom
U3	-	U31 1/2	U3	-	NL25
U4	-	U33	U4	-	NL26
U5	-	U35	U5	-	NL27
U6	-	U37	U6	-	NL28
Mandibular 2nd Primary Molars			*Mandibular 2nd Primary Molars*		
L1	-	NL27	L1	-	Custom
L2	-	L29	L2	-	Custom
L3	-	L29 1/2	L3	-	Custom
L4	-	L31 1/2	L4	-	NL25
L5	-	L33 1/2	L5	-	NL26
L6	-	L35 1/2	L6	-	NL27

Visual examination of the roughened, dislodged bands and crowns revealed that cement adhered to both the internal band and external crown surfaces where scored. This indicates that a partial cohesive failure of the cement had occurred. Roughening the band/crown interface greatly enhanced the mechanical retention of the glass ionomer cement. The cemented, roughened samples had statistically greater mean retention values than when cemented and tested in their original state. Mean retention values increased from 107 to 330% for the subgroups tested.

Bills et al.,[5] in their 1980 laboratory study, evaluated the retention of stainless steel orthodontic bands cemented with four commonly used dental cements on 120 extracted human premolar teeth. An Instron Universal Testing Machine was used with a technique similar to our investigative procedure. At the 24-hr postcementation time period, their mean results ranged from 38.5 ± 12.85 lbs for zinc phosphate to 27.0 ± 8.87 lbs for polycarboxylate. Glass ionomer was not tested.

Norris et al.,[6] in their 1986 in vitro investigation, quantified the retention of stainless steel bands cemented with three commonly used dental cements on 180 extracted human molar teeth. The technique was also similar to the one employed in this study. At the 24-hr postcementation period, their mean results for glass ionomer cement were 0.99 MN/m^2 (range = 0.31–1.90 MN/m^2). These results are given as force per surface area of the bands, but the surface areas were not given. This corresponds to an approximate mean value of 28.0 lbs (range = 8.8–53.7 lbs) if the assumption is made that an average molar band is 10 mm in diameter and 4 mm high. The standard deviations published in the Bills et al. study, and the ranges given in the Norris et al. article are similar to those found in this investigation.

Cementing band and loop space maintainers on primary and permanent molars is an accepted clinical procedure. From the retention values given in the literature for orthodontic bands cemented to extracted posterior teeth, and from the data presented in this study, it would seem logical to conclude that a clinician would be justified in cementing a band and loop type space maintainer on a primary molar stainless steel crown with glass ionomer cement utilizing the roughened band/crown interface technique. One could speculate that using crimped bands seated just below their SSC gingival margins with this technique would result in even better retention values. Clinically it would be advisable to have both narrow and regular factory bands available for use in fabricating fixed space maintainers cemented on primary molar SSC so that the widest band, occlusal gingivally, exhibiting a clinically acceptable fit can be utilized.

When it becomes clinically appropriate to remove a band and loop space maintainer from a roughened stainless steel crown, a clinically acceptable surface finish can be easily achieved with common dental finishing/polishing burs and devices.

When a factory band cannot be found to fit the smaller sizes of 1st molar crowns, fabricating a custom band using the technique previously described is a practical alternative.

Table 2 may serve as a quick reference guide to match Unitek primary molar stainless steel crowns with corresponding Unitek orthodontic bands.

Dr. Beemer is a commissioned officer in the USPHS and is practicing with the Indian Health Service in Warm Springs, Oregon. This paper was submitted in partial fulfillment of the requirements for a certificate in Pediatric Dentistry from the Oregon Health Sciences University, School of Dentistry. Dr. Ferracane is associate professor and chair, Department of Dental Materials Science; and Dr. Howard is associate professor and director, both at Oregon Health Sciences University. The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the Indian Health Service.

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