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Choice of cement for single-unit crowns

Findings from The National Dental Practice-Based Research Network

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ABSTRACT

Background. In this article, the authors present clinical factors associated with the type of cement practitioners use for restoration of single-unit crowns.

Methods. A total of 202 dentists in The National Dental Practice-Based Research Network recorded clinical details (including cement type) used for 3,468 single-unit crowns. The authors classified crowns as bonded if the dentist used a resin cement. The authors used mixed-model logistic regression to assess the associations between various clinical factors and the dentist's decision to bond.

Results. A total of 38.1% of crowns were bonded, and 61.9% were nonbonded; 39.1% (79 of 202) of dentists never bonded a crown, and 20.3% (41 of 202) of dentists bonded every crown in the study. Crowns with excessive occlusal reduction (as judged by laboratory technicians) were more likely to be bonded ($P = .02$); however, there was no association with bonding and excessive taper ($P = .15$) or axial reduction ($P = .08$). Crowns were more likely to be bonded if they were fabricated from leucite-reinforced glass ceramic (76.5%) or lithium disilicate (70.8%) than if they were fabricated from layered zirconia (38.8%), full-contour zirconia (30.1%), full metal (14.7%), or porcelain-fused-to-metal (13.8%) ($P < .01$) restorative material. There was no significant association between choice to bond and crown margin location ($P = .35$). Crowns in the anterior maxilla were more likely to be bonded ($P < .01$).

Conclusions. Excessive occlusal tooth preparation, anterior location of a crown, and the use of glass ceramic crowns were associated significantly with the decision to bond.

Practical Implications. In this study, the authors identified factors significantly associated with the clinical decision made by practicing dentists when selecting a cement for restoration of single-unit crowns.

Key Words. Resin cements; glass ionomer cements; dental bonding; restorative dentistry; fixed prosthetics; crowns.

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The cements used in dentistry can be characterized as resin-based cements and water-based acid-base cements. Clinicians typically use resin-based cements with a tooth primer that forms a hybrid layer with collagen in dentin. Self-adhesive resin cements constitute a subcategory of resin-based cements capable of partially demineralizing and hybridizing with tooth structure without a separate primer.[1] Therefore, the use of a resin cement is termed *bonding* a crown because there is a hybrid layer formed at the tooth-cement interface.[2]

Water-based acid-base cements include zinc phosphate, glass ionomer, and resin-modified glass ionomer (RMGI) cements. Zinc phosphate cement is not capable of chemically bonding to tooth.[3] Glass ionomer and RMGI cements contain polyacrylic acid, which can form an ionic bond with calcium ions in hydroxyapatite of enamel and dentin.[4] On the basis of results from bond strength studies, the bond of glass ionomer—based materials to dentin is significantly lower than the bond of resin-based materials to dentin.[5] Although there is a chemical bond between glass ionomer and RMGI cements and tooth structure, cementation of crowns with water-based acid-base cements is not termed *bonding*. The clinician's choice to bond a crown may depend on several clinical factors, such as the need for additional retention, the need to improve the strength of the crown, and whether adequate isolation can be achieved.

Investigators in several laboratory studies have determined that bonding crowns with resin cements increases the retention strength of the crown more than does cementing with glass ionomer or zinc phosphate cements.[6,7] The 2 most critical elements of a crown preparation that affect its retentiveness are its taper and its height.[6-10] Clinicians may choose to compensate for nonretentive preparations by selecting materials they believe can be bonded. Although investigators in several systematic reviews have summarized the multitude of laboratory studies with results showing an effective bond to zirconia with resin cements, many clinicians may not bond zirconia because of a lack of clinical evidence.[11-15]

For some ceramic crown materials, it is necessary to bond the crown to tooth structure to strengthen the restoration. Feldspathic porcelain and leucite-reinforced glass ceramic crowns achieve significantly higher crown fracture strength when bonded with a resin cement than when cemented with glass ionomer or zinc phosphate cements.[15-18] This increase in strength has been credited either to the ability of the cement to fill defects and prevent crack propagation in the ceramic or to the better mechanical properties of the resin cement (increased strength and lower water sorption).[15,19] Lithium disilicate crowns have shown similar[20,21] or higher[18,19] fracture strength when bonded than when not bonded, assuming a thickness of 1.5 millimeters (manufacturer recommended material thickness for nonbonded restorations). If the occlusal thickness of lithium disilicate crowns is less than 1.5 mm, bonding them significantly improves their overall fracture strength.[22] Results from several studies show that zirconia crowns do not have a significantly higher fracture strength when bonded with resin cements than when cemented with glass ionomer or zinc phosphate cements, even at a 0.5-mm occlusal thickness.[21,23] For porcelain-fused-to-metal (PFM) single-unit crowns, the 5-year cumulative fracture rate of the metal coping is low (0.03%) compared with the rates of lithium disilicate (2.3%) and zirconia (0.4%) copings.[14] It is therefore unlikely that the strength of PFM crowns plays any role in cement selection.

Bonding to dentin with a resin-based material in a relatively moisture-controlled field can produce a greater bond of the crown to the tooth structure than can using an RMGI cement; however, if dentin becomes contaminated with saliva, the bond to the resin-based material will be less than that of the RMGI.[24] Therefore, a significant contraindication for the use of a resin cement would be the inability to achieve adequate moisture control. Owing to the proximity to salivary glands and the tongue, as well as gravitational pooling, achieving salivary isolation is often more challenging in the posterior aspect of the mouth, particularly in the mandibular arch. Isolation of subgingival margins is also difficult because it places the crown margin in direct contact with sulcular fluid. Thus, the choice of cement for use when placing a dental crown depends on several variables that the clinician must consider.

Our goal in this study was to record preferences and theorize rationales that clinicians use for cement selection for the restoration of single-unit crowns. We achieved this goal by examining practice, practitioner, and clinical factors for restoration of crowns placed in a practice-based research network and their association with the decision to bond the crown. Our aims in this study were to determine whether factors related to the retention of the crown (preparation taper, occlusal reduction), crown strength (occlusal reduction, axial reduction, material choice), or ability to isolate from saliva (tooth location, margin location) were associated with the use of resin cements (bonding) or water-based acid-base cements (nonbonding).

METHODS

Dentists in The National Dental Practice-Based Research Network ("network") completed this study.[25] This study is based on a prospective cohort study focused on the acceptability of crowns restored in routine clinical practice. We asked network regional coordinators to recruit 200 network dentists to participate in this study. We collected data about each practitioner and practice by using the network's enrollment questionnaire. Network dentists were eligible for this study if they were treating patients in the United States, were in the full network participation category, had completed the stage 1 questionnaire,[26] and had reported placing at least 7 crowns per month. We

ABBREVIATION KEY

NA: Not applicable.
PFM: Porcelain-fused-to metal.
RMGI: Resin-modified glass ionomer.

required practitioners to complete human participants training and asked them to secure the participation of at least 1 dental laboratory for technical evaluation of crown preparations in the study.

The network's applicable institutional review boards approved the study, and all participants provided informed consent. Once a clinician began the study, he or she was trained by the regional coordinators and then asked to enroll 20 total patients within 3 months. We remunerated dentists or their practices $50 per patient for patient enrollment and completion of the study's data forms and $25 per patient for completion of the insertion visit data forms. All data forms are publicly available at http://nationaldentalpbrn.org/study-results/factors-for-successful-crowns.php. We launched the study on March 1, 2016, and patient follow-up closed on February 28, 2017.

Study population

Clinicians recruited patients consecutively from among their pool of patients who needed a crown. Patients were 18 years or older, able to provide informed consent, and in need of a single-unit crown on a natural tooth. Of the 3,883 patients whom the clinicians approached to participate, 3,806 (98.02%) provided informed consent.

Patient treatment

Once enrolled in the study, clinicians prepared the tooth for a crown and completed a crown preparation data form regarding clinical aspects of the procedure, including the tooth number, an estimate of the deepest margin of the preparation (above the crest of the gingival tissue, at the crest of the gingival tissue, 1 mm below the gingival tissue, 2 mm below the gingival tissue, or $\geq$3 mm below the gingival tissue), and the type of restorative material selected for the crown (leucite-reinforced glass ceramic, lithium disilicate, layered zirconia, full-contour zirconia, PFM, or other). For the study, clinicians recruited only 1 single-unit crown per patient. The clinician then sent the impression to his or her selected dental laboratory, along with an anonymous data collection form for the dental technician to complete. This form included information regarding the taper of the preparation, occlusal reduction, and axial reduction. The technician rated each of these aspects of the preparation as excessive, adequate, or insufficient. Laboratory technicians employed at 155 different locations evaluated the crown preparations. We asked clinicians to insert the crown within 6 weeks of preparation.

Outcomes

At the time of insertion, clinicians reported the type of cement used for the crown on a second data form. The primary outcome for this study was the decision to bond the crown (the use of resin cement or self-adhesive resin cement) or not (use of RMGI cement, glass ionomer cement, or zinc phosphate cement). To test associations between practitioner and practice characteristics and the decision to bond or not, we categorized practitioners as those who never bonded (in the study), sometimes bonded (at least 1 bonded crown in the study), and always bonded (in the study).

Statistical analysis

We evaluated the associations between clinical factors and the decision to bond the crown with mixed-model logistic regression analysis ($\alpha = .05$). The models included a random effect to account for clustering of patients within individual clinicians. Because crowns and patients were clustered within practitioners, we would expect outcomes from patients treated by the same practitioner to be correlated. We recoded the margin location into 1 of 3 categories as follows: at or above, 1 mm below, or 2 mm or more below the gingival crest. We categorized the location of the tooth as posterior maxilla (teeth nos. 1-5 and 12-16), anterior maxilla (teeth nos. 6-11), posterior mandible (teeth nos. 17-21 and 28-32), or anterior mandible (teeth nos. 22-27).

RESULTS

Clinicians cemented 3,468 single-unit crowns in this study. A total of 38.1% of crowns were bonded (29.2% with resin cement and 8.9% with self-adhesive resin cement), and 61.9% were nonbonded (52.2% with RMGI, 8.3% with glass ionomer cement, and 1.4% with zinc phosphate cement). Table 1 presents the percentages and number of crowns.

Table 1. Percentage and number of crowns that were cemented, according to type of cement (N = 3,468).

CEMENT TYPE	CROWNS, NO. (%)
Resin: Bonded	1,321 (38.1)
Resin cement	1,013 (29.2)
Self-adhesive resin cement	308 (8.9)
Acid-Base: Nonbonded	2,147 (61.9)
Resin-modified glass ionomer cement	1,811 (52.2)
Glass ionomer cement	286 (8.2)
Zinc phosphate cement	50 (1.4)

A total of 202 dentists cemented at least 1 crown. Table 2 presents the characteristics of these dentists. Most were owners of a private practice (76.6%) and worked full time (88.4%). Most had been in practice for more than 20 years (59.7%). There were no associations between practitioner or practice characteristics and the decision to bond. Some dentists had no intradentist variability within the study: 39.1% of dentists reported that they never bonded a crown, and 20.3% reported that they bonded every crown. We conducted sensitivity analyses to evaluate the effect of these nonvarying dentists. We conducted analyses that were limited to clinicians who showed variability in their decision to bond. The analyses included 1,462 crowns placed by 82 dentists, and the results indicated little difference in effect sizes or significance levels compared with the results obtained from analyses including all dentists and crowns.

Table 3 presents the number and percentage of bonded crowns for each clinical criterion. There were significant differences in the percentages of bonded crowns on the basis of occlusal reduction ($P = .02$), restorative material ($P < .01$), and the location of the tooth in the arch ($P < .01$) but not for taper ($P = .15$), location of gingival margin ($P = .35$), or axial reduction ($P = .08$). Crowns with an occlusal reduction deemed to be excessive were more likely to be bonded than were those that were adequate or with insufficient reduction. Leucite-reinforced glass ceramic and lithium disilicate crowns were more likely to be bonded than were layered zirconia, full-contour zirconia, full metal, PFM, and other crowns. Materials in the other category included computer-aided design and computer-aided manufacturing resin composites (Paradigm MZ100, 3M ESPE, and CERASMART, GC America). Crowns with subgingival margins of 2 mm or more had a slightly lower likelihood of being bonded (29.7%) than did those at or above the crest (39.9%) or those with subgingival margins of 1 mm (40.4%); however, the differences were not statistically significant. There was a significant association between bonding and the tooth location, with more crowns bonded in the anterior maxilla than in the posterior mandible or maxilla.

DISCUSSION

In this study, 38.1% of crowns were bonded with resin cement. Of the crowns bonded with resin cement, 23.3% were bonded with self-adhesive resin cement. This percentage is low compared with the results of a 2013 non—peer-reviewed survey of 907 dentists in which the most commonly used resin cement for PFM, zirconia, and lithium disilicate cements was RelyX Unicem (3M ESPE), which is a self-adhesive resin cement.[27] This discrepancy may be owing to practitioners incorrectly identifying the classification of their resin cement as not self-adhesive, but we have no information about that. Of the crowns cemented with water-based acid-base cements, 84.4% were cemented with RMGI, 13.3% with glass ionomer cement, and 2.3% with zinc phosphate cement. These percentages are in agreement with those in the 2013 survey, in which the author reported the most commonly used product in this category was RelyX Luting Plus (3M ESPE), a RMGI cement.[27]

The first aim of our study was to determine whether there was an association between preparation taper or occlusal reduction and the decision to bond the restoration. Preparations with an increased taper and excessive occlusal reduction were more likely to be bonded, but only excessive occlusal reduction showed a statistically significant association. On the basis of results from laboratory studies, a preparation with a taper greater than 12° and height less than 3 mm may have decreased resistance form that may benefit from bonding.[28,29] Determination of preparation taper and height

Table 2. Percentage and number of dentists who never bonded, sometimes bonded, or always bonded any of the crowns enrolled in the study, overall and according to practice or practitioner characteristic.

PRACTICE OR PRACTITIONER CHARACTERISTIC	NO. OF PRACITIONERS*	NEVER BONDED, NO. (%N)	SOMETIMES BONDED, NO. (%)	ALWAYS BONDED, NO. (%)	COMPARISONS, *P* VALUE
Overall	202	79 (39.1)	82 (40.6)	41 (20.3)	NA†
Dentist Sex					.69
Male	145	56 (38.6)	57 (39.3)	32 (22.1)	
Female	54	23 (42.6)	22 (40.7)	9 (16.7)	
No. of Years Since Dental School Graduation					.37
< 10	28	12 (42.9)	10 (35.7)	6 (21.4)	
10-19	53	17 (32.1)	28 (52.8)	8 (15.1)	
20-29	42	15 (35.7)	15 (35.7)	12 (28.6)	
≥ 30	78	35 (44.9)	28 (35.9)	15 (19.2)	
Network Region					.57
Western	27	9 (33.3)	16 (59.3)	2 (7.4)	
Midwest	33	15 (45.5)	11 (33.3)	7 (21.2)	
Southwest	39	13 (33.3)	16 (41.0)	10 (25.6)	
South Central	45	18 (40.0)	15 (33.3)	12 (26.7)	
South Atlantic	32	13 (40.6)	14 (43.8)	5 (15.6)	
Northeast	25	11 (44.0)	9 (36.0)	5 (20.0)	
Practice Type					.20
Owner of private practice	151	57 (37.8)	60 (39.7)	34 (22.5)	
Associate in private practice	22	8 (36.4)	8 (36.4)	6 (27.3)	
HealthPartners Dental Group‡	8	5 (62.5)	3 (37.5)	0 (0.0)	
Permanente Dental Associates§	8	2 (25.0)	6 (75.0)	0 (0.0)	
Public health, academic, other	8	5 (62.5)	3 (37.5)	0 (0.0)	
Practice Busyness					.19
Too busy	10	6 (60.0)	4 (40.0)	0 (0.0)	
Overburdened	39	12 (30.8)	21 (53.8)	6 (15.4)	
Not overburdened	117	50 (42.7)	42 (35.9)	25 (21.4)	
Not busy	35	11 (31.4)	14 (40.0)	10 (28.6)	
Employment Time Commitment					.36
Full time	176	66 (37.5)	72 (40.9)	38 (21.6)	
Part time	23	12 (52.2)	8 (34.8)	3 (13.0)	

* Total sample sizes vary owing to missing values for some characteristics, and percentages do not necessarily add up to 100% owing to rounding. † NA: Not applicable. ‡ Greater Minneapolis, MN. § Greater Portland, OR.

is often easier to achieve with direct vision in the dental laboratory. In our study, laboratory technicians reported that 6.0% of crown preparations had excessive taper and 9.7% of crown preparations had excessive occlusal reduction. Therefore, to optimize cement selection, it may be beneficial for laboratories to alert the practitioner of issues with preparation taper and height.

Insufficient occlusal and axial reduction was not associated with the decision to bond. Possibly, clinicians compensated for insufficient restorative space by choosing a crown material that they did not believe benefited from adhesive bonding. Of the preparations with insufficient occlusal reduction, 39.3% were restored with zirconia, 31.5% with PFM, and 6.7% with all metal, whereas only 19.7% were restored with lithium disilicate and none with leucite-reinforced glass ceramic.

Table 3. Raw percentage and number of crowns that were bonded or not, overall and according to crown or preparation characteristic.

CROWN OR PREPARATION CHARACTERISTIC	NO. OF CROWNS*	BONDED CROWNS, NO. (%)	NONBONDED CROWNS, NO. (%)	COMPARISONS, *P* VALUE†‡
Overall	3,468	1,321 (38.1)	2,147 (61.9)	NA§
Preparation Taper¶				.15
Excessive	194	122 (62.9)	72 (37.1)	—
Adequate	2,924	1,025 (35.1)	1,899 (64.9)	—
Insufficient	92	30 (32.6)	62 (67.4)	—
Occlusal Reduction¶				.02
Excessive	310	235 (75.8)	75 (24.2)	a
Adequate	2,734	901 (33.0)	1,833 (67.0)	b
Insufficient	165	40 (24.2)	125 (75.8)	b
Axial Reduction¶				.08
Excessive	202	136 (67.3)	66 (32.7)	—
Adequate	2,920	1,008 (34.5)	1,912 (65.5)	—
Insufficient	87	33 (37.9)	54 (62.1)	—
Restorative Material				< .01
Leucite reinforced	17	13 (76.5)	4 (23.5)	a
Lithium disilicate	1,012	717 (70.8)	295 (29.2)	a
Layered zirconia	268	104 (38.8)	164 (61.2)	b
Full-contour zirconia	1,131	340 (30.1)	791 (69.9)	b
Full metal	177	26 (14.7)	151 (85.3)	c
Porcelain-fused-to-metal	856	118 (13.8)	738 (86.2)	c
Other	2	2 (100)	0 (0)	—
Location in Arch				< .01
Anterior maxilla	228	98 (43.0)	130 (57.0)	a
Posterior maxilla	1,609	605 (37.6)	1,004 (62.4)	b
Anterior mandible	39	16 (41.0)	23 (59.0)	a,b
Posterior mandible	1,585	599 (37.8)	986 (62.2)	b
Crown Margin Location				.35
At or above gingival crest	1,432	572 (39.9)	860 (60.1)	—
1 millimeter below gingival crest	1,344	543 (40.4)	801 (59.6)	—
2 mm or more below gingival crest	688	204 (29.7)	484 (70.3)	—

* Numbers of crowns in row category. Total sample sizes vary owing to missing values for some characteristics. † *P* values reflect adjustment for clustering within clinician by means of mixed-model logistic regression. ‡ Categories with the same letter are not significantly different. § NA: Not applicable. ¶ Based on assessment of the crown impression by the laboratory technician who made the prosthetic crown.

The second aim of our study was to determine whether there was an association between the crown material and the choice of the cement. In this study, there was a considerable preference to bond crowns fabricated from leucite-reinforced glass ceramic and lithium disilicate, whereas bonding was less common for crowns fabricated from full-contour zirconia, layered zirconia, and PFM. These findings are consistent with those of a non—peer-reviewed 2015 survey of 1,394 dentists in which the author reported that 39% of dentists typically used a resin cement and 55% used RMGI cement with zirconia crowns and that 63% used resin cement and 32% used RMGI cement with lithium disilicate crowns.[30] There are several possible explanations for these preferences. Zirconia has twice the strength of lithium disilicate[31]; therefore, many clinicians may choose not to bond zirconia crowns because it is not necessary for strength improvement. The same justification would be used for PFM and full-metal crowns. Some clinicians may choose not to bond to zirconia because they do not believe it is possible to bond reliably to this material. This opinion is not found in the scientific literature because authors of review articles have summarized laboratory studies with results indicating effective methods for bonding to zirconia[11-15] and the chemical basis of the bond between zirconia and methacryloyloxydecyl dihydrogen phosphate.[32-35] Clinicians may be more likely to use resin cement with leucite-reinforced glass ceramic and lithium disilicate crowns because these materials are translucent and may require a more esthetic resin cement.

The final aim of our study was to determine whether the choice to bond a restoration was related to a clinician's ability to achieve isolation, specifically based on the location of the prepared tooth and the location of the margin of the crown relative to the crest of the gingival tissue. A higher percentage of restorations were bonded in the maxillary anterior portion of the mouth than in the posterior portion. This association could be due to the challenge in achieving isolation in the posterior part of the mouth and the clinician's awareness of the literature reporting the significant reduction in bond strength that occurs with salivary contamination.[36-38] This trend also may be due to increased use of lithium disilicate and leucite-reinforced restorations for anterior teeth or the choice to use esthetic shaded resin cements for anterior teeth. In this study, clinicians placed 19.9% of crowns on preparations that had at least a portion of the subgingival margin of 2 mm or more. Although a lower percentage of these crowns were bonded with resin cement, this finding was not significantly different from those in crowns with margins located more coronally.

There was a large degree of interdentist variability in the decision to bond; 39.1% of dentists never bonded a crown, and 20.3% of dentists bonded every crown in this study. We examined several practice and practitioner characteristics for an association with the decision to bond; however, we found none. In the 1970s, zinc phosphate cement and other water-based cements were favored for luting restorations, but by the 1990s, glass ionomer and adhesive resin cements were replacing them.[39,40] Despite differences in the cement materials that may have been taught during their training, practitioners had no trend in bonding preference when we considered years since graduation from dental school. There were no regional differences in the preference to bond restorations despite possible differences in clinical techniques at different centers of clinical education. There was a slight trend, although not statistically significant, for practitioners in less busy practices always to bond. Because bonding is often more technique sensitive, practitioners who are less busy may have more time to use resin cements.

This study has several limitations. A major assumption of the analysis was that all crowns that were placed with a resin cement were bonded. A dentist may have used a resin cement without the intention of bonding the crown, forgoing the steps of priming the ceramic surface and achieving adequate isolation. In addition, there exists a level of subjectivity in the evaluation of the crown preparations and location of gingival margin because different clinicians and technicians performed the evaluations, and these evaluators may have had different interpretations of these categories. A weakness of this method is that it involves using the technicians' assessment of the crown preparation to infer the causes of the practitioners' decision making. As we noted previously, there also may be errors from clinicians incorrectly categorizing their cements.

Although network practitioners have much in common with dentists at large,[41,42] their crown procedures may not be representative of those of a wider representation of dentists. Network members are not recruited randomly, so factors associated with network participation may make network dentists unrepresentative of dentists at large. Although we cannot assert that network dentists are entirely representative, we can state that they have much in common with dentists at large, while also offering substantial diversity in these characteristics as shown in previous studies.[43-46]

CONCLUSIONS

A total of 38.1% of single-unit crowns were bonded with resin cement. Excessive occlusal tooth preparation, anterior location of a crown, and the use of glass ceramic crowns were associated significantly with the decision to bond single-unit crowns. ■

SUPPLEMENTAL DATA

Supplemental data related to this article can be found at https://doi.org/10.1016/j.adaj.2019.01.021.

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The National Dental Practice-Based Research Network Collaborative Group includes practitioner, faculty, and staff investigators who contributed to this activity. A list is available at http://www.nationaldentalpbrn.org/factors-for-successful-crowns-1.php.

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