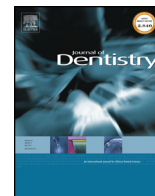




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## Dentist material selection for single-unit crowns: Findings from the National Dental Practice-Based Research Network

Sonia K. Makhija<sup>a,\*</sup>, Nathaniel C. Lawson<sup>a</sup>, Gregg H. Gilbert<sup>a</sup>, Mark S. Litaker<sup>a</sup>,  
Jocelyn A. McClelland<sup>b</sup>, David R. Louis<sup>c</sup>, Valeria V. Gordan<sup>d</sup>, Daniel J. Pihlstrom<sup>e</sup>,  
Cyril Meyerowitz<sup>f</sup>, Rahma Mungia<sup>g</sup>, Michael S. McCracken<sup>a</sup>, National Dental PBRN  
Collaborative Group<sup>1</sup>

<sup>a</sup> Department of Clinical and Community Sciences, School of Dentistry, University of Alabama at Birmingham, Birmingham, AL, United States

<sup>b</sup> Private Practice of General Dentistry, Alabaster, AL, United States

<sup>c</sup> HealthPartners Dental Group, Woodbury, MN, United States

<sup>d</sup> Department of Restorative Dental Sciences, Operative Dentistry Division, University of Florida, Gainesville, FL, United States

<sup>e</sup> Kaiser Permanente, Portland, OR, United States

<sup>f</sup> University of Rochester, Eastman Institute for Oral Health, Rochester, NY, United States

<sup>g</sup> Department of Periodontics, University of Texas Health Science Center at San Antonio, United States

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### ABSTRACT

**Objectives:** Dentists enrolled in the National Dental Practice-Based Research Network completed a study questionnaire about techniques and materials used for single-unit crowns and an enrollment questionnaire about dentist/practice characteristics. The objectives were to quantify dentists' material recommendations and test the hypothesis that dentist's and practice's characteristics are significantly associated with these recommendations.

**Methods:** Surveyed dentists responded to a contextual scenario asking what material they would use for a single-unit crown on an anterior and posterior tooth. Material choices included: full metal, porcelain-fused-to-metal (PFM), all-zirconia, layered zirconia, lithium disilicate, leucite-reinforced ceramic, or other.

**Results:** 1777 of 2132 eligible dentists responded (83%). The top 3 choices for anterior crowns were lithium disilicate (54%), layered zirconia (17%), and leucite-reinforced glass ceramic (13%). There were significant differences ( $p < 0.05$ ) by dentist's gender, race, years since graduation, practice type, region, practice busyness, hours worked/week, and location type. The top 3 choices for posterior crowns were all-zirconia (32%), PFM (31%), and lithium disilicate (21%). There were significant differences ( $p < 0.05$ ) by dentist's gender, practice type, region, practice busyness, insurance coverage, hours worked/week, and location type.

**Conclusions:** Network dentists use a broad range of materials for single-unit crowns for anterior and posterior teeth, adopting newer materials into their practices as they become available. Material choices are significantly associated with dentist's and practice's characteristics.

**Clinical significance:** Decisions for crown material may be influenced by factors unrelated to tooth and patient variables. Dentists should be cognizant of this when developing an evidence-based approach to selecting crown material.

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**Abbreviations:** PBRN, practice-based research network; PFM, porcelain-fused-to-metal.

\* Corresponding author at: Department of Clinical & Community Sciences, UAB School of Dentistry, SDB Room 111, 1919 7th Avenue South, Birmingham, AL 35294-0007, United States.

E-mail address: [smakhija@uab.edu](mailto:smakhija@uab.edu) (S.K. Makhija).

<sup>1</sup> The National Dental PBRN Collaborative Group includes practitioner, faculty, and staff investigators who contributed to this activity. A list is available at <http://nationaldentalpbrn.org/collaborative-group.php>.

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### 1. Introduction

Dentists have a wide variety of options when selecting a material to fabricate a single-unit crown [1]. The dentist's choice and recommendation to the patient can depend on various patient and tooth factors, such as tooth location, esthetics, patient desires, masticatory factors, and patient finances [2–4].

All-zirconia crowns have gained popularity due to their high strength [1] and toughness [2], wear compatibility with natural dentition [3] and low cost. However, some dentists may decide against this material due to its relative opaqueness and fear of long-term strength degradation from low temperature degradation [5]. Zirconia layered with a translucent ceramic, such as porcelain, is considered a more esthetic crown option, but the relatively low coefficient of thermal expansion and thermal diffusivity of zirconia compared to traditional metal coping materials led to laboratory complications. These manifested as veneer chipping and delamination [6–8] over time [9].

Lithium disilicate is another popular material choice for single-unit crowns. It is more translucent than zirconia [4], and can be used in the anterior region without adding a layer of veneering porcelain, which reduces the risk of porcelain chipping. Additionally, the glass matrix of lithium disilicate can be etched with hydrofluoric acid and chemically bonded to tooth structure with a silane primer and adhesive resin cement [10]. Lithium disilicate is not as strong as zirconia, with approximately 40% of its strength [1] and 57% its fracture toughness [2]. A review done by Pieger reported that 5–10 years after cementation, the majority of failures of lithium disilicate crowns occurred in the posterior region [11].

Leucite-reinforced glass ceramic is more translucent than lithium disilicate [12]; however, it is more limited in use and is only recommended as a single-unit in the anterior region [13]. In order to gain sufficient strength for function, leucite-reinforced glass ceramic should be bonded to tooth structure [14].

Porcelain-fused-to-metal (PFM) has been used for many years and studied extensively. Studies have demonstrated a 94% success rate over a 10-year period [15] and good long-term clinical reliability [16].

Although chipping of veneering porcelain is a possible complication, fracture of the metal framework is uncommon [17]. PFM restorations require sufficient tooth reduction to allow space for at least 0.3 mm of metal coping and 0.7 mm of veneering porcelain, and a minimum facial reduction of 1.2 mm according to Hobo and Shillingburg [18]. When comparing PFM crowns to zirconia crowns, several points are noteworthy. Laboratory testing has determined that the fracture strength of a PFM crown using 1.5 mm reduction is similar to zirconia crowns with only 1 mm of reduction [19]. Some manufacturers have even suggested a 0.6 mm minimum reduction for posterior zirconia crowns, which has led some dentists to prescribe all-zirconia restorations to preserve tooth structure [20].

Metal crowns are among the strongest options, although their major disadvantage is esthetics. Full-metal restorations are often considered the gold standard in dentistry due to their excellent biocompatibility and strength. However, the increasing price of precious metals and patients' demands for esthetics have limited the use of both PFM and full metal restorations [7], which could make profitability an important aspect in the dentists' decision on crown material.

Previous studies have investigated the role that patient and dentist factors may have on material longevity [21–23], but none have focused on single-unit crown material selection and dentist characteristics. Therefore, the objectives of this study were to: (1) quantify dentists' material recommendations; and (2) test the hypothesis that dentist/practice characteristics are significantly associated with these recommendations.

## 2. Materials and methods

This study is based on a questionnaire completed by dentists in the National Dental Practice-Based Research Network (PBRN; "network"). The network is a consortium of dental practices and dental organizations focused on improving the scientific basis for

clinical decision-making [24]. Detailed information about the network is available at its web site [25]. The network's applicable Institutional Review Boards approved the study; all participants provided informed consent after receiving a full explanation of the procedures.

### 2.1. Enrollment questionnaire

As part of the enrollment process, practitioners complete an Enrollment Questionnaire that describes themselves, their practice (s), and their patient population. This questionnaire, which is publicly available at <http://nationaldentalpbrn.org/enrollment.php>, collects information about practitioner, practice and patient characteristics. Questionnaire items, which had documented test/re-test reliability, were taken from our previous work in a practice-based study of dental care and that PBRN ultimately led to the development of the National Dental PBRN [26,27].

### 2.2. Study questionnaire development

The questionnaire for this study was developed by a study team composed of the authors, dentists with clinical expertise, statisticians, and laboratory technicians. Its purpose was to measure current practices in fabricating crowns, and making treatment recommendations for single-unit crowns. The questionnaire was reviewed by Instrument Design, Evaluation, and Analysis Services (IDEA Services), a group with expertise in questionnaire development and implementation, as well as National Institute of Dental and Craniofacial Research (NIDCR) program officers and practitioners with prosthodontic content expertise. After extensive internal review, IDEA Services pre-tested the questionnaire via cognitive interviewing by telephone with a regionally diverse group of eight practicing dentists. Cognitive interviewers probed the dentist's comprehension of each question. The interviewers also asked dentists to identify items of clinical interest that were not addressed in the questionnaire. Results from the pretest prompted further modification of the questionnaire.

Dentists enrolled in the network were eligible for the study if they met all of these criteria: (1) completed an Enrollment Questionnaire; (2) were currently practicing and treating patients in the United States; (3) were in the network's "limited" or "full" network participation category; and (4) reported on the Enrollment Questionnaire that they currently do at least some restorative dentistry in their practices. A total of 2299 dentists met these criteria.

Pre-printed invitation letters were mailed (postal) to eligible dentists, informing them that they would receive an email with a link to the electronic version of the questionnaire. At the time of the email, dentists were given the option to request a paper version of the questionnaire, as this has been shown to improve response rates [28]. Dentists were asked to complete the questionnaire within two weeks. A reminder letter was sent after the second and fourth weeks to those who had not completed the questionnaire. After six weeks, email and postal reminders were sent with a printed version of the questionnaire and dentists were offered the option of completing the online or paper versions. After eight weeks, a final postal questionnaire attempt was made with a letter that also encouraged the dentist to complete the questionnaire online. If a response was not received within two weeks, these dentists were considered non-respondents and were followed up by a Regional Coordinator to ensure that the network communications had been received and that the dentist was not interested in participating. Data collection was closed after 12 weeks from the original email invitation. Dentists or their business entities were remunerated \$75 on completion of the questionnaire. Data were collected from February 2015 to August 2015.

### 2.3. Questionnaire content

The first question confirmed that the invited clinician did at least one crown in a typical month. The Questionnaire is publicly available (<http://www.nationaldentalpbrn.org/study-results/2016/#1>) under the heading “Factors for Successful Crowns”. Among other questions, practitioners were asked what crown material they recommended for patients.

### 2.4. Material selection

The authors had a particular interest in learning about material selection for a single-unit crown in the anterior and posterior regions. The two questions of interest for this article were as follows: “Suppose you are doing a routine single-unit crown on tooth #19. What material would you most likely recommend?” and “Suppose you have the same patient as in the previous question, but the single-unit crown is on tooth #8. What material would you most likely recommend?” For both questions the background context was identical: “Assume your patient is a 40-year male who attends his annual recall visits on a dependable basis, has no relevant medical history, is at low risk for dental decay, has satisfactory occlusion with minimal wear, and is financially able to pay for a crown out-of-pocket.”

The responses to these questions and from the network’s Enrollment Questionnaire were tested to determine whether they were significantly ( $p < 0.05$ ) associated with material selection. These were questions relating to dentist gender, race, years since graduation, practice type, region, practice busyness, insurance coverage, hours worked/week, and location type.

### 2.5. Statistical analyses

Power analysis was based on an anticipated sample size of 1500 completed questionnaires. This sample size would provide

sufficient precision to estimate percentages within  $\pm 2.53\%$ , at the 95% confidence level. Analyses were based on two-way frequency tables (with counts and percentages) with significance tests conducted using chi-square tests.

## 3. Results

Of the 2299 dentists invited, 101 were deemed ineligible before beginning the questionnaire (no longer in active practice; deceased, specialists who do not do conventional single-unit crowns). An additional 66 were deemed ineligible once they completed the first question (do not do at least one conventional crown each month). This left a total of 2132 eligible persons, of whom 1777 responded, for a response rate of 83.4% (1777/2132). Among the 47 test/re-test participants, the mean (SD) time between test and re-test was 15.5 (3.0) days. For categorical variables, agreement between time 1 and time 2 showed a mean weighted kappa of 0.62 (IQR: 0.46, 0.79). Mean test-retest reliability for numeric variables was 0.75.

### 3.1. Material selection for anterior tooth

The top three material choices for anterior teeth were lithium disilicate (54%), layered zirconia (17%), and leucite reinforced glass ceramic (13%) (Fig. 1). The analysis of material selection according to dentist and practice characteristics (Table 1), statistically significant differences were found with dentist gender ( $p = 0.022$ ), race ( $p = 0.014$ ), years since graduation ( $p = 0.022$ ), practice type ( $p < 0.0001$ ), region ( $p = 0.0006$ ), practice busyness ( $p = 0.0005$ ), hours worked/week ( $p = 0.0004$ ), and location type ( $p = 0.002$ ). The only characteristic that was not statistically significant was insurance coverage ( $p = 0.062$ ) (Table 1). Dentists who graduated more than 15 years ago, although half chose lithium disilicate, had a higher percentage who chose PFM (10%) compared to those who graduated between 5 and 15 years ago

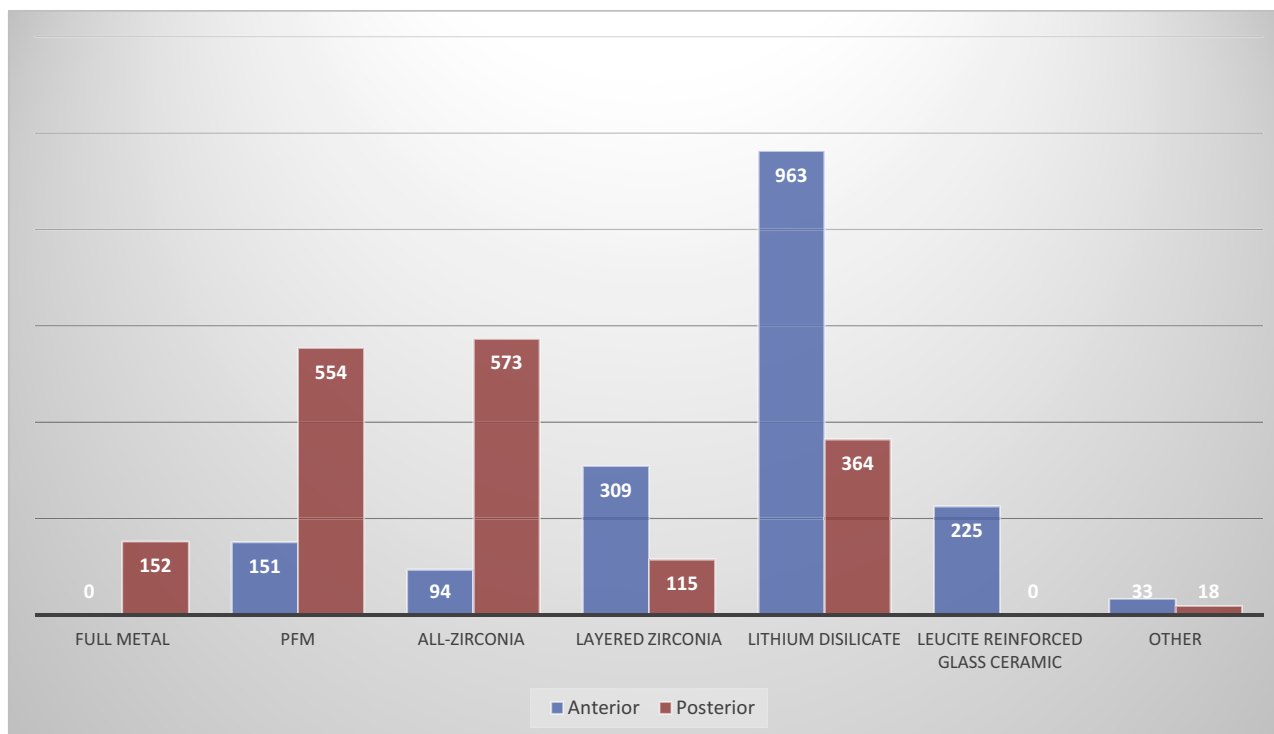


Fig. 1. Frequency distribution of material selection, by tooth\*.

\*For anterior tooth, full metal was not an option. For the posterior tooth, leucite reinforced glass ceramic was not an option.

**Table 1**  
Frequency (%) of material selection for anterior tooth (#8), overall and by dentist and practice characteristics.

	PFM	All-zirconia (e.g., Bruxzir)	Layered zirconia (e.g., Lava)	Lithium disilicate (e.g., e-Max)	Leucite-reinforced glass ceramic (e.g., Empress)	Other	P-Value	Total <sup>a</sup>
Overall	150 (9)	94 (5)	307 (17)	956 (54)	223 (13)	33 (2)	--	1763 (100)
Gender								
Male	120 (9)	60 (5)	217 (17)	711 (55)	151 (12)	22 (2)	<b>0.022</b>	1281 (73)
Female	30 (6)	34 (7)	90 (19)	245 (51)	72 (15)	11 (2)		482 (27)
Race								
White/Caucasian	128 (9)	71 (5)	254 (17)	794 (55)	178 (12)	25 (2)		1450 (83)
Black/African-American	7 (9)	10 (13)	16 (21)	27 (36)	15 (19)	2 (2)	<b>0.014</b>	77 (4)
Other	3 (4)	2 (3)	7 (10)	41 (59)	14 (20)	3 (4)		70 (4)
Asian	13 (8)	10 (6)	30 (19)	88 (55)	17 (11)	2 (1)		160 (9)
Years since graduation								
<5	2 (3)	3 (4)	12 (17)	43 (62)	9 (13)	1 (1)	<b>0.022</b>	70 (4)
5–15	24 (5)	21 (5)	76 (17)	266 (60)	54 (12)	3 (1)		444 (25)
>15	125 (10)	70 (6)	221 (17)	651 (52)	162 (13)	29 (2)		1258 (71)
Practice type								
Owner of a private practice	94 (7)	67 (5)	231 (18)	716 (56)	158 (12)	27 (2)		1293 (73)
Associate/employer of a private practice	13 (6)	12 (6)	32 (16)	123 (59)	26 (13)	1 (0)		207 (12)
HealthPartners Dental Group	5 (11)	1 (2)	3 (7)	32 (73)	2 (5)	1 (2)		44 (2)
Permanente Associates Dental Group	15 (21)	0 (0)	14 (20)	33 (47)	6 (9)	2 (3)	<b>&lt;0.0001</b>	70 (4)
Other managed care	0 (0)	0 (0)	2 (20)	6 (60)	2 (20)	0 (0)		10 (1)
Public health practice	13 (20)	12 (19)	10 (16)	22 (34)	5 (8)	2 (3)		64 (4)
Federal facility	5 (21)	0 (0)	3 (12)	5 (21)	11 (46)	0 (0)		24 (1)
Academic institution	4 (8)	2 (4)	12 (25)	17 (36)	13 (27)	0 (0)		48 (3)
Region								
Western	34 (12)	11 (4)	56 (19)	150 (52)	34 (12)	7 (3)		292 (17)
Midwest	11 (6)	4 (2)	26 (14)	124 (69)	12 (7)	3 (2)		180 (10)
Southwest	26 (8)	30 (10)	49 (16)	163 (52)	37 (12)	5 (2)	<b>0.0006</b>	310 (17)
South Central	30 (9)	19 (6)	68 (21)	159 (48)	50 (15)	4 (1)		330 (19)
South Atlantic	15 (5)	16 (5)	54 (17)	191 (58)	43 (13)	8 (2)		327 (18)
Northeast	35 (10)	14 (4)	56 (17)	176 (52)	49 (15)	6 (2)		336 (19)
Practice busyness								
Too busy to treat all	23 (23)	5 (5)	14 (14)	47 (46)	9 (9)	3 (3)		101 (6)
Provided care to all, but overburdened	22 (7)	21 (6)	48 (15)	191 (58)	38 (12)	6 (2)	<b>0.0005</b>	326 (18)
Provided care to all, not overburdened	72 (8)	54 (6)	163 (18)	484 (53)	123 (14)	14 (1)		910 (51)
Not busy enough	34 (8)	14 (3)	83 (19)	241 (55)	54 (13)	10 (2)		436 (25)
Insurance coverage								
<40%	4 (8)	1 (2)	9 (17)	29 (56)	6 (11)	3 (6)		52 (3)
40–79%	66 (9)	26 (3)	131 (17)	425 (56)	96 (13)	12 (2)	0.062	756 (43)
>80%	81 (9)	67 (7)	166 (18)	495 (52)	119 (12)	17 (2)		945 (54)
Hours work/week								
≥32 h	118 (8)	71 (5)	263 (17)	844 (56)	183 (12)	28 (2)	<b>0.0004</b>	1507 (86)
<32 h	32 (13)	23 (9)	45 (18)	108 (43)	39 (15)	5 (2)		252 (14)

**Table 1** (Continued)

	PFM	All-zirconia (e.g., Bruxzir)	Layered zirconia (e.g., Lava)	Lithium disilicate (e.g., e-Max)	Leucite-reinforced glass ceramic (e.g., Empress)	Other	P-Value	Total*
Location type								
Inner city of urban area	25 (12)	20 (10)	42 (20)	86 (41)	33 (16)	3 (1)		209 (12)
Urban (not inner city)	33 (7)	26 (5)	92 (19)	269 (55)	63 (13)	7 (1)	<b>0.002</b>	490 (28)
Suburban	60 (8)	35 (4)	125 (16)	467 (59)	91 (11)	17 (2)		795 (45)
Rural	33 (12)	13 (5)	48 (18)	135 (49)	38 (14)	6 (2)		273 (15)

Bolded values shows  $p < 0.05$ .

\* Not all columns add to 1763 due to missing values.

(5%), and those who had graduated less than 5 years ago (3%). With regard to practice busyness, almost 25% of dentists who were too busy to treat all their patients chose PFM, compared to less than 10% for dentists in the other categories. Over 50% of dentists in private practice chose lithium disilicate, compared to 36% or less of dentists in public health practices, federal facilities and academic institutions.

### 3.2. Material selection for posterior tooth

The top three material choices for posterior crowns were all-zirconia (32%), PFM (31%), and lithium disilicate (21%) (Fig. 1). The analysis of material selection by dentist and practice characteristics, statistically significant differences were found with dentist gender ( $p = 0.001$ ), practice type ( $p < 0.0001$ ), region ( $p < 0.0001$ ), practice busyness ( $p < 0.0001$ ), insurance coverage ( $p < 0.0001$ ), hours worked/week ( $p < 0.0001$ ), and location type ( $p < 0.0001$ ). Two characteristics were not statistically significant: race ( $p = 0.374$ ) and years since graduation ( $p = 0.2380$ ) (Table 2). For practice type, 55% of dentists from Permanente Associates Dental Group (a large group practice) chose a full metal crown compared to other practice types that varied in range from 4 to 25%. Practices with over 80% insurance coverage were more likely to prescribe PFM crowns. Dentists in rural practices were more likely to prescribe all-zirconia restorations than any other location type.

## 4. Discussion

The results of this study show a high prevalence of prescription of ceramic crowns compared to metal-based crowns. These results are in stark contrast to a study from nearly 30 years ago which reported a higher selection rate of PFM crowns (55% of Swiss and 56% of Canadian dentists) and metal crowns (17% of Swiss and 35% of Canadian dentists) than porcelain jacket crowns (1% of Swiss and 2% of Canadian dentists) [29]. The shift in material choice from metal porcelain is likely due to significant improvements in dental ceramics, patient demands for esthetic ceramics, and the high cost of fabrication of metal-based crowns. The study results also demonstrate that material choice for single-unit crowns is associated with factors other than the clinical presentation of a patient. Generally, these associations are related to practice type, years since graduation, insurance, and practice busyness.

Regarding the interpretation of years since graduation, the dentist may either have developed preferences for restorative material by gaining exposure to materials in dental school or learning from clinical experience while in practice. The landscape of available dental materials has changed significantly over the past 20 years. A 1997 survey of US dental schools [30], revealed that the most commonly used dental ceramics at the time were the core material In-Ceram Alumina and the glass ceramic Dicor, with flexural strengths of 419 MPa and 108 MPa respectively [31,32]. In

2005, Ivoclar Vivadent released e.max Press, a lithium disilicate material with a flexural strength of 384 MPa that was esthetic enough to be used without veneering porcelain [33]. By 2013, a major US dental laboratory reported that 80% of its crowns and fixed prostheses were fabricated from all-ceramic materials, likely due to the introduction of all-zirconia restorations [34]. In other words, lithium disilicate could have been taught in dental school for all of the graduates of 5 years or less, many of the graduates of 5–15 years, and none of the graduates of >15 years. Similarly, all-zirconia restorations could have been taught in dental school for most of the graduates of 5 years, few of the graduates of 5–15 years and none of the graduates of >15 years. Graduates of >15 years showed a slightly greater tendency to use PFM crowns for anterior teeth, which may be related to less exposure to dental ceramics in dental school or an aversion to ceramics due to the inferior properties of previous generations of materials. Surprisingly, no correlation was observed with years since graduation and prescription of posterior all-zirconia crowns. The penetration of all-zirconia into the market may be the result of its excellent mechanical properties [1–3] and low cost.

Differences in materials selection by practice type may be related to the financial responsibility of the dentist or employer to pay the laboratory costs. For most dental laboratories, all-zirconia or all-lithium disilicate restorations can be offered at a lower price than layered restorations due to the easier fabrication process. Additionally, the price of noble or high-noble PFM restorations will be affected by the price of the precious metals present in the metal coping, which is often more expensive than the cost of purchasing ceramic materials. Likely the group of dentists who would be most directly impacted by the laboratory cost of their materials would be private practice owners. In this group, the most commonly chosen materials were also the most economical materials, which were all-zirconia for posterior crowns and lithium disilicate for anterior crowns. Although dentists in some managed care groups, federal facilities, community health clinics and academic institutions may be responsible for the cost of their laboratory fees, many of their employers will pay some or all of those fees, which could reduce their financial motivations behind material selection. For example, academic dentists selected a high proportion of layered zirconia and leucite anterior restorations, which are typically offered at higher prices than lithium disilicate. Dentists in federal facilities, public health practices, and the Permanente Associates Dental Group chose a higher proportion of anterior PFM and posterior full metal restorations, which are also higher-priced restorative materials. Another financial motivating factor for the approximately 15% of private practice dentists who utilize in-office CAD/CAM systems is that lithium disilicate is the predominant material used for in-office milling and many laboratories offer discounted prices when fabricating all-zirconia or lithium disilicate crowns from digital impressions [35,36]. The bias was difficult to assess based on the methods used for the current study.

**Table 2**  
Frequency (%) of material selection for posterior tooth (#19), overall and by dentist and practice characteristics.

	Full metal	PFM	All-zirconia (e.g., Bruxzir)	Layered zirconia (e.g., Lava)	Lithium disilicate (e.g., e-Max)	Other	P-Value	Total <sup>*</sup>
Overall	151(9)	550 (31)	571(32)	112 (6)	362 (21)	18 (1)	---	1764 (100)
Gender								
Male	111 (9)	360 (28)	446 (35)	79 (6)	274 (21)	12 (1)	<b>0.0001</b>	1282 (73)
Female	40 (8)	190 (40)	125 (26)	33 (7)	88 (18)	6 (1)		482 (27)
Race								
White/Caucasian	123 (9)	442 (30)	467 (32)	96 (7)	309 (21)	13 (1)		1450 (83)
Black/African-American	5 (6)	34 (44)	25 (33)	5 (6)	6 (8)	2 (3)	0.374	77 (4)
Other	8 (11)	18 (26)	23 (33)	5 (7)	15 (22)	1 (1)		70 (4)
Asian	16 (10)	53 (33)	51 (31)	9 (6)	31 (19)	1 (1)		161 (9)
Years since graduation								
<5	8 (11)	23 (36)	17 (24)	4 (6)	14 (20)	2 (3)		70 (4)
5–15	36 (8)	122 (28)	154 (35)	26 (6)	104 (23)	2 (0)	0.2380	444 (25)
>15	107 (9)	407 (32)	400 (32)	85 (7)	246 (19)	14 (1)		1259 (71)
Practice type								
Owner of a private practice	57 (4)	397 (31)	455 (35)	84 (6)	293 (23)	8 (1)		1291 (73)
Associate/employer of a private practice	18 (9)	52 (25)	71 (34)	17 (8)	45 (22)	4 (2)		207 (12)
HealthPartners Dental Group	10 (22)	18 (41)	10 (23)	3 (7)	3 (7)	0 (0)		44 (2)
Permanente Associates Dental Group	39 (55)	21 (30)	2 (3)	4 (6)	2 (3)	2 (3)	<b>&lt;0.0001</b>	70 (4)
Other managed care	1 (10)	3 (30)	5 (50)	0 (0)	1 (10)	0 (0)		10 (1)
Public health practice	10 (16)	29 (45)	15 (23)	3 (5)	7 (11)	0 (0)		64 (4)
Federal facility	4 (17)	10 (42)	3 (12)	1 (4)	5 (21)	1 (4)		24 (1)
Academic institution	12 (25)	18 (38)	8 (17)	3 (6)	5 (10)	2 (4)		48 (3)
Region								
Western	60 (21)	92 (32)	56 (19)	14 (5)	63 (21)	7 (2)		292 (16)
Midwest	26 (14)	52 (29)	50 (28)	11 (6)	41 (23)	0 (0)		180 (10)
Southwest	26 (8)	97 (31)	118 (38)	18 (6)	52 (17)	0 (0)		311 (18)
South Central	17 (5)	95 (29)	137 (42)	19 (6)	58 (17)	4 (1)	<b>&lt;0.0001</b>	330 (19)
South Atlantic	12 (4)	80 (24)	123 (38)	30 (9)	77 (24)	5 (1)		327 (18)
Northeast	11 (3)	138 (41)	89 (26)	23 (7)	73 (22)	2 (1)		336 (19)
Practice busyness								
Too busy to treat all	20 (20)	43 (42)	24 (24)	6 (6)	7 (7)	1 (1)		101 (6)
Provided care to all, but overburdened	42 (13)	95 (29)	104 (32)	24 (7)	57 (18)	4 (1)	<b>&lt;0.0001</b>	326 (18)
Provided care to all, not overburdened	63 (7)	282 (31)	198 (33)	59 (7)	196 (21)	13 (1)		911 (51)
Not busy enough	27 (6)	132 (30)	147 (34)	26 (6)	104 (24)	0 (0)		436 (25)
Insurance coverage								
<40%	3 (6)	14 (27)	20 (38)	4 (8)	11 (21)	0 (0)		52 (3)
40–79%	47 (6)	226 (30)	228 (30)	53 (7)	196 (26)	7 (1)	<b>&lt;0.0001</b>	757 (43)
>80%	100 (10)	309 (33)	319 (34)	58 (6)	148 (16)	11 (1)		945 (54)
Hours work/week								
≥32 h	113 (7)	458 (30)	492 (33)	102 (7)	329 (22)	13 (1)	<b>&lt;0.0001</b>	1507(86)
<32 h	38 (15)	91 (36)	74 (29)	13 (5)	32 (13)	5 (2)		253 (14)
Location type								
Inner city of urban area	21 (10)	86 (41)	58 (28)	14 (7)	28 (13)	2 (1)		209 (12)
Urban (not inner city)	49 (10)	137 (28)	167 (34)	31 (7)	100 (20)	6 (1)	<b>0.016</b>	490 (28)
Suburban	54 (7)	246 (31)	246 (31)	55 (7)	186 (23)	9 (1)		796 (45)
Rural	27 (10)	81 (30)	100 (37)	15 (5)	49 (18)	0 (0)		273 (15)

Bolded values shows p < 0.05.

\* Not all columns add to 1764 due to missing values.

Practice busyness was also shown to correlate with material selection. The trend in the data indicates that the busiest dentists were more likely to select PFM materials and less likely to select lithium disilicate and leucite based restorations for anterior restorations. This preference may be related to the increased time required to use these ceramic materials clinically. The relative translucency of leucite and lithium disilicate materials requires that dentists adequately communicate the shade of the prepared tooth to the laboratory and select a color-matched cement to achieve ideal color of the final restoration [37]. Additionally, leucite and lithium disilicate crowns achieve optimum strength when they are bonded to tooth structure with a ceramic primer and resin cement [14]. The busiest dentists also preferred full metal and PFM posterior crowns, which may also be related to perceived ease of use. Tooth preparation is simplified because minimal tooth reduction is required if metal is used for the occlusal surface. Adjustment and polishing of metal restorations is also faster and more forgiving than adjusting or polishing zirconia.

Two practice characteristics that can be related to the type of practice are the percentage of patients who have insurance coverage and the practice location. However, conclusions about these characteristics can be difficult to interpret. For instance, a practice with a low percentage of insurance coverage may treat patients in a low socioeconomic status (SES) that cannot afford dental insurance or may treat patients in a high SES and operate a fee-for-service practice. Similarly, a practice in the inner city could treat high SES patients in a major metropolitan area or low SES patients in a distressed inner-city neighborhood. Dentists with over 80% of their patients with insurance coverage were more likely to select full metal and PFM posterior restorations, which could be related to insurance reimbursement and difficulties justifying to an insurance company the use of a ceramic crown on a posterior tooth. Another interesting observation was that rural dentists were the most frequent prescribers of posterior all-zirconia restorations. This observation highlights the prevalent role of large national laboratories that can ship cases throughout the country, as well as the increasing tendency for a local laboratory to scan and design a crown, and then send to a milling center for production.

The results of this study suggest that factors other than clinical evidence influence the dentist's selection of materials. Part of the difficulty in utilizing evidence for crown material selection is that many of these materials have relatively short clinical histories with few reported long-term clinical trials. A 2015 systematic review of survival rates of single crowns revealed that PFM, lithium disilicate, leucite reinforced, and zirconia restorations had statistically similar 5-year survival rates. The authors noted that layered zirconia and PFM restorations showed a greater incidence of chipping, whereas leucite and lithium disilicate materials showed a higher incidence of framework fracture [38]. The good 5-year clinical success rate of all of these restorative materials implies that dentists need to use their judgment to match the esthetic and mechanical properties of their restorative materials with the clinical presentation of their patient.

Few other studies have examined practice and practitioner characteristics related to material selection or performance. Burke et al. performed a 10-year study on porcelain veneers and found that tooth position was not associated with longevity of the restoration, but did find that veneers placed in female patients had a longer survival, although it was not significant. However, there was a significant difference by patient age, showing poor survival in patients over 60 and under 30 years of age [21]. Dentist factors, such as years since graduation, gender, and place of graduation, were not significantly associated with the survival of the veneer [21].

Haj-Ali et al. developed a survey of material selection for posterior restorations [39], with a focus on amalgam versus

composite materials only. The only practice characteristic noted was whether or not the practice was amalgam-free. Another study looking at dentist factors and a 10-year outcome of porcelain laminate veneers [21] found no difference in survival as a function of the dentist factors, which were gender, years since graduation, and country of qualification. This same study also investigated the outcomes of direct restorations and dentist factors and found that age, country of qualification, and employment status were associated with survival of direct restorations [22].

This study does have certain limitations, and conclusions should consider these issues. This study relied on questionnaire information rather than direct observation of procedures; therefore, the inferences made are based on responses from this questionnaire. Questions related to continuing education courses or other sources for information by which these dentists make their decisions was not included in the questionnaire. Additionally, the response rate was very good, but it is possible that non-respondents would have reported different behavior. Although network dentists have much in common with dentists at large [40], it is possible that their material selection is not representative of a wider representation of dentists. Network members are not recruited randomly, so factors associated with network participation (e.g., an interest in clinical research) may make network dentists unrepresentative of dentists at large. While 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. This assertion is warranted because: (1) substantial percentages of network general dentists are represented in the various response categories of the characteristics in the Enrollment Questionnaire; (2) findings from several network studies document that network general dentists report patterns of diagnosis and treatment that are similar to patterns determined from non-network general dentists [41–44] and (3) the similarity of network dentists to non-network dentists using the best available national source, the 2010 ADA Survey of Dental Practice [45].

## 5. Conclusion

To our knowledge, this is the first study to report the association between single-unit crown material and dentist/practice characteristics. These results indicate that there are many factors that are significantly associated with material selection for single-unit crowns in the anterior and posterior region. Network dentists use a broad range of materials for single-unit crowns for anterior and posterior teeth, adopting newer materials into their practices as they become widely available. Clinical studies are currently underway in the network to document material selection as part of a larger study about crown preparations and clinical success, so additional work will be done to further explore these associations.

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