Effects of Clinical Experience and Explorer Type on Judged Crown Margin Acceptability

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Abstract

Purpose: This study was undertaken to simultaneously compare instrumentation type and operator characteristics in judgments of clinical acceptability of crowns exhibiting a controlled range of marginal gaps. The research was conducted in a laboratory setting and generalizability analysis was used as a statistical technique to identify the sources contributing to variation in the judgment outcome.
Materials and Methods: A crown was seated on an ivorine tooth in a device that permitted continuous adjustment in intervals of 25 μm to produce known marginal gaps ranging from zero to 250 μm. Forty-nine students and six faculty members used five types of explorers each to determine, by tactile examination, the point on the controlled increasing marginal gap where they would no longer regard the gap as clinically acceptable.
Results: There were no differences across type of explorer. Operators with clinical experience had a threshold that rejected crowns at a smaller gap than did those operators without clinical experience ($p = 0.007$). Faculty members maintained a higher individual degree of consistency in their personal judgments than did students ($p = 0.02$); however, the inter-operator consistency was significantly lower for faculty members than for students ($p < 0.05$).
Conclusions: Differences among operators in a simulation of the decision regarding gaps in crowns accounted for 63% of the variance; type of explorer used in assisting this decision accounted for about half as much variance. Faculty members making such judgments exhibited high intra-operator consistency but significantly lower inter-operator consistency than did students. The study suggests that the internal standards dentists use for clinical decision making deserves further study as they may be as significant as the equipment used.

Dentists routinely evaluate crown margins intraorally with various explorers in an attempt to detect gaps at the interface between tooth structure and the restoration. Opinions as to the size of acceptable margin openings on cast restorations remain fairly constant among dentists beginning at around 40 μm.[1] Studies have been performed to assess marginal discrepancies and configurations.[2,3] Intuition could lead an observer to conclude that a more experienced clinician would evaluate a casting more critically than a novice student might; however, very few researchers have actually studied this phenomenon.

Baldissara et al[4] found that marginal gaps of 36 μm were detectable by 95% of their subjects using a sharp explorer. Christensen[5] showed that a group of dentists would reject a crown sooner at a smaller margin opening when evaluating accessible crown margins versus subgingival crown margins. Dedmon[6] observed that experienced dentists differed within and between operators in identifying acceptable openings of nonvisible margins with an explorer. More recently, Bronson et al[3] demonstrated that both prosthodontists and predoctoral students rated crown margins with greater marginal gaps as clinically unacceptable. The proportion of prosthodontists and

of predoctoral students rating a given surface as "clinically unacceptable" was highly correlated. A related study[7] found significant correlations ($p < 0.05$) between subjective evaluation and objective data on complete crowns. In terms of acceptability, the authors determined that overextension was more critical than was marginal gap. Marginal discrepancies on occlusal surfaces were evaluated concurrently with the effects of masticatory fatigue and fracture resistance in a recent article in the *Journal of Adhesive Dentistry*.[8] Hayashi et al[9] tested the influence of explorer tip diameter in identifying restoration margin discrepancies. They concluded that the diagnosis of restoration margin discrepancies and the rating of marginal adaptation in clinical trials may be best achieved using techniques other than the probing of restoration margins. Haak et al[10] used conventional and digital radiographs to detect marginal defects of composite restorations where secondary caries could develop on marginal openings or overhangs. They concluded that the validity of detecting marginal defects of composite resin restorations based on radiographs was only slightly affected by the radiographic system being used. The diagnosis of marginal gaps frequently resulted in false-positive and false-negative decisions. Mitchell et al[11] used profilometry as a nondestructive, accurate method of evaluating the absolute marginal fit of different types of crowns. Holmes et al[12] acknowledged that "fit" can be most easily defined in terms of "misfit." The authors categorized criteria of internal gap, marginal gap, vertical marginal discrepancy, horizontal marginal discrepancy, overextended margin, underextended margin, absolute marginal discrepancy, and seating discrepancy, and theorized that absolute marginal discrepancy would always be the largest measurement of error at the margin and would reflect the total misfit at that point. The effect of die spacer on retention and crown fit was studied by Olivera and Saito[13] who determined that increasing the area of the die surface covered with spacer improved the fit of the cast restoration. Marginal adaptation was one of the parameters measured by Federlin et al[14] in a project completed over 2 years in comparing cast gold and ceramic partial crowns. Newer CAD/CAM techniques used in the fabrication of titanium copings were assessed for marginal accuracy and refinement time. Manual adjustment was found to significantly improve results with this method.[15] Forces representative of food bolus in chewing were found to propagate lunar fracture patterns and subsequently margin failures in another investigation.[16]

The sharpness of the explorer has been studied,[2,17] as has the clinical experience of the operator[3,6,9] in studying the standards used in determining acceptability of crowns with various degrees of gap. To date there have been no studies that simultaneously investigated both operator and instrumentation characteristics and their potential interaction. By comparing explorer type and operator experience in the same study, it may be possible to identify the relatively most important sources of variance. This information would aid in improving clinical detection of gaps in crown margins and focus future research on factors having the largest variance.

The purpose of this study was to simultaneously compare instrumentation type and operator characteristics in judgments of clinical acceptability of crowns exhibiting a controlled range of marginal gaps.

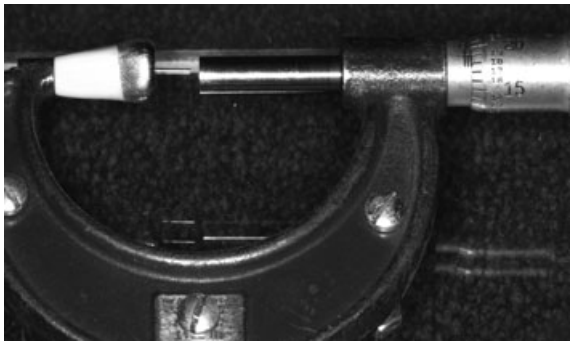

Figure 1 Experimental device permitting controlled introduction of marginal gap between prepared tooth and crown, in 25 μm increments.

Materials and methods

The cast crown was fabricated on an ivorine tooth and evaluated extensively at the Travis Air Force Base Dental Clinic in Fairfield, CA. It was studied under magnification, scanning electron microscope (SEM) evaluation, with enlarged photographs, and with a traveling microscope. The preparation had a thin shoulder, and the gold casting had a 90° butt joint fit at the margin.

A modified micrometer (Fig 1) was used to simulate, in a controlled fashion, a perfectly seated crown and, by adjustment of the device, progressively larger marginal gaps between the crown and the tooth. The micrometer was constructed in such a fashion that marginal discrepancy could be created reliably in intervals of 25 μm across the range of 0 to 250 μm. The micrometer was set to a gap of 0 μm, and the operator was instructed to use a particular explorer to determine whether the marginal gap was small enough so the crown could be seated as clinically acceptable. If the gap was thought to be "clinically acceptable," it was increased by 25 μm and a reevaluation was performed. This process was repeated until the size of the gap was judged to be clinically unacceptable. This process was repeated for each of the five explorers in random order. Figure 2 shows four photographs, under 20× magnification of

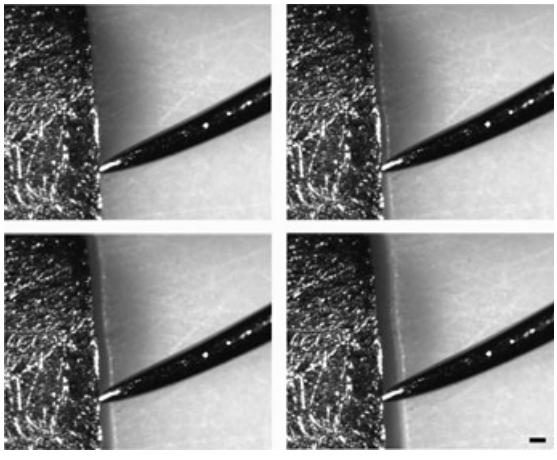

Figure 2 20× magnification of #2 explorer at (left to right from top left): 0, 25, 50, and 100 μm openings.

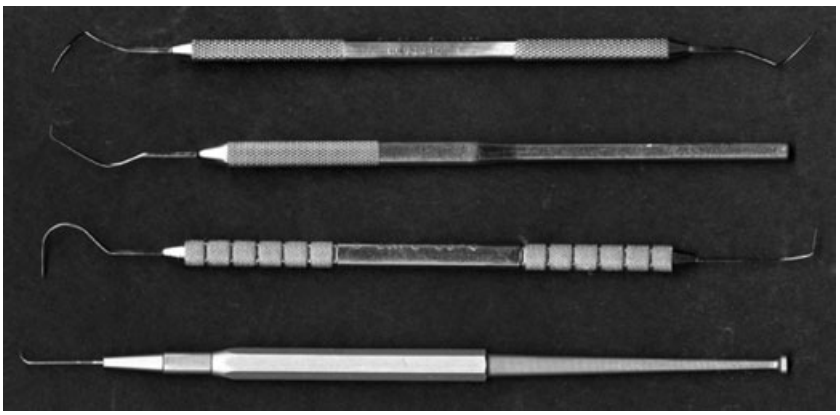

Figure 3 Explorers used in study of acceptability of crown margins by four types of examiners (from top: #2, #17, #23–6, G).

a #2 explorer placed on the crown margin with the device set at 0, 25, 50, and 100 μm.

Five explorers were studied: #2, #17, #23–6, G, and S (Figs 3 and 4). The first two explorers are the most commonly used in the laboratory and clinic at the dental school where the research was conducted. Participants chose which end of double-ended explorers they preferred to use. The explorer labeled G is a microsurgery instrument. The sensor of a stethoscope was replaced with a #17 explorer and identified as explorer S. The explorers were new, made to manufacturer's specifications, and never used prior to the study. Diameter of the explorers (in order mentioned at the beginning of this paragraph), measured 1 mm from their tips, were 0.40, 0.25, 0.22, 0.35, and 0.25 mm, respectively.

Fifty-six operators participated in the study. This sample included 4 first-year students (during the first quarter of their preclinical instruction in the Fixed Prosthodontics course), 26 second-year students, 19 third-year students, and 6 faculty members who were preclinical instructors in the Department of Restorative Dentistry. Subjects indicated whether they had had clinical experience seating a crown. None of the first-year students and all of the faculty members had seated crowns on patients. At the point during the year when the research was conducted, 19% of the second-year students and 89% of the third-year students had seated crowns on patients.

Figure 4 Experimental explorer use in study of acceptability of crown margins by four types of evaluators; explorer labeled S consisted of a #17 explorer inserted into a stethoscope.

Each operator in the study completed five simulated evaluations of crown marginal discrepancy: one with each type of explorer. The subjects were asked to judge the casting as "acceptable for cementation or not acceptable?" The students had been taught in their restorative dentistry course that 50 μm is the tolerance for acceptability, but they were not told anything further prior to participation in the study. Crown margins were visible to the participants, but the participants were encouraged to evaluate the casting based on tactile sensitivity. The use of direct vision was discouraged. All participants, including faculty members, were calibrated to the same standard, as taught in the preclinical course at the school.

In this study, operators were fully crossed with explorers, and supplemental information was available to characterize each operator in terms of education experience (including faculty status) and experience seating a crown clinically. In addition to descriptive statistics, analysis of variance (ANOVA), interclass correlation, and generalizability analysis[18] were conducted.

Results

Average and median marginal gaps detected as clinically significant for each type of explorer are shown in Table 1 and Figure 5. Although the G-explorer appears to be less sensitive (shows higher average and median values as clinically acceptable), these differences are not statistically significant when tested using a two-factor ANOVA test on the mean values. (Micrometer settings have been combined in 50 μm units in Figures 5 and 6 for better visual clarity; statistical tests were performed on 25 μm units.)

Average and median marginal gaps detected as clinically significant for each class of operator are shown in Table 1 and Figure 6. Although first-year students appear to be somewhat less sensitive to marginal gaps, the differences among classes of operators are not statistically significant. An independent *t*-test was performed contrasting operators who reported having seated a crown on a patient with those who had not. Those operators with clinical experience created an average threshold for acceptance at 113.7 μm; those without experience had a

Table 1 Threshold for gap detection (μm) in a simulated study of acceptability of crown fit by four groups of operators using five types of explorers

	N	Median	Ave	SD	α
Explorer					
#17	56	95	120.5	55.8	
#2	56	89	109.8	48.8	
#23–6	56	104	118.6	55.9	
#G	56	119	139.3	54.3	
#S	56	105	124.1	54.2	
Operator level					
First-year students	4	113	130.0	41.3	0.906
Second-year students	26	100	126.5	58.4	0.924
Third-year students	19	97	111.6	46.2	0.852
Faculty members	6	95	132.5	64.7	0.950
Source	SS	df	MS	F	p
ANOVA					
Explorer	29.277	4	7.319	1.570	0.183
Operator status	26.924	3	8.975	1.926	0.126
E x O	39.349	12	3.279	0.704	0.748
e	112.463	257	4.661		

significantly less sensitive threshold average of 131.6 μm ($p = 0.007$).

The two-factor ANOVA also permits a test for interaction between operator and explorer: one type of explorer might be more sensitive in the hands of first-year students while another is more sensitive for third-year students. No such interaction effect was detected.

Although average thresholds varied little across class or student and faculty operator status or explorer type, the stability of these judgments (as represented by variation within the groups) were subject to differences. Figure 6 shows that the judgments by faculty members were rather uniformly distributed across the range of potential results: there were more faculty judgments of very low thresholds and more of very high thresholds than for any group of students. The ratio of variances for faculty members compared to the variances for students (combined) was $F = 1.710$, $p < 0.05$. This means that some faculty members have a "high standard" for clinical acceptability and some have a "low standard."

An alternative way to look at variability is to examine interclass correlation coefficients. The estimates of degree to which individual operators apply their personal standards consistently across various types of explorers are shown in Table 1. The Cronbach alpha values are high, with consistency across the entire group being $\alpha = 0.906$. It should be noted that the consistency rating for faculty members is $\alpha = 0.950$, significantly higher than the alpha for students ($p = 0.02$). This means that individual faculty members have a highly defined and consistently applied personal threshold for clinically acceptable marginal gaps on crowns. There was no difference in internal consistency among operators who had seated a crown previously ($\alpha = 0.917$) and those who had not ($\alpha = 0.895$).

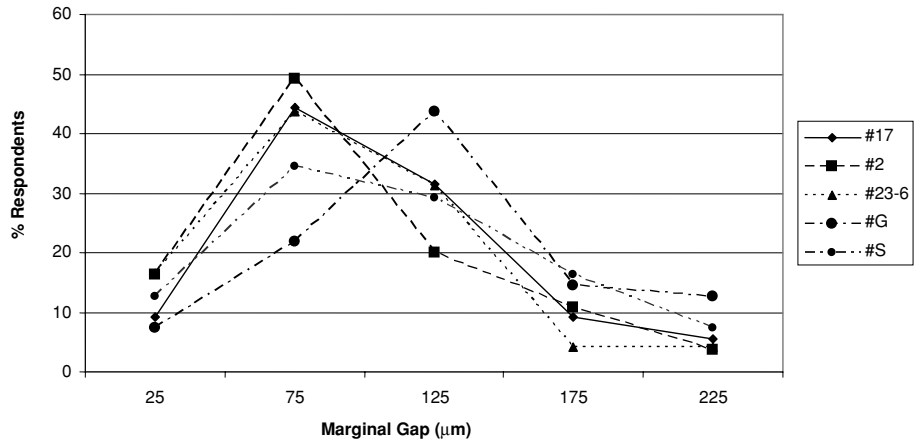

Figure 5 Frequency distribution of threshold gap detection of acceptable crown margins for five types of explorers.

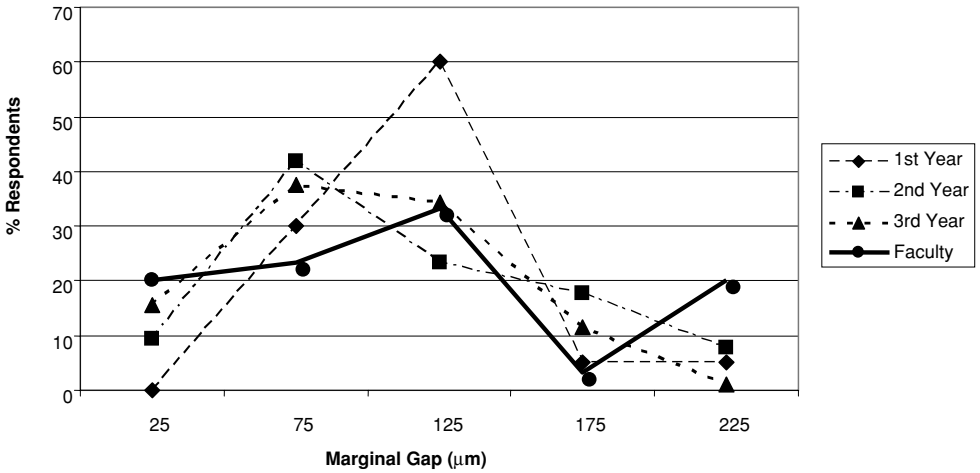

Figure 6 Frequency distribution of threshold gap detection of acceptable crown margins for four groups of operators.

A generalizability analysis was performed to estimate the proportion of variance in the judgments of threshold for clinically acceptability attributable to operator, explorer type, or the interaction between these factors. Nearly twice as much variance was the result of operator differences (63%) as explorer type (33%), with almost no variance contributed by the preference of individual operators for various types of explorers (4%).

Discussion

This study is consistent with other research that reports operator differences contributing substantial variation to clinical outcomes.[19] In this case, where the outcome of interest is threshold for clinically acceptable marginal gaps between crown and tooth, almost twice the amount of variance was attributable to operator (students from three dental school classes and faculty members) as to differences among five types of explorer. The possibility that acoustical feedback provided by linking an explorer with a stethoscope to provide enhanced clinical sensitivity was not confirmed by the data. There were no detectable individual differences among classes of operator and different explorers in contrast to the findings of Hayashi et al, who found a significant effect of explorer tip diameter on the detection of horizontal gaps.[9] The difference in threshold among operators appears to be largely explained by presence or absence of clinical experience seating crowns on patients (or with any other factors that might be associated with this variable) as anticipated by previous studies on operator differences in such clinical judgments;[5,9] however, reports of general operator differences in judgment may mask effects when they are presented as *averages* across major categories such as operator and explorer.[16] The effects emerge more clearly when considering sources of variation. For example, faculty members exhibited significantly more variation *across* or from individual to individual than did students. At the same time, the variation *within* individual faculty members was smaller than the variation within individual students. (This distinction is commonly referred to as inter-individual and intra-individual variation.) One faculty member rejected a crown with a gap of 0 μm. At the other extreme, faculty members were four times as likely as were students to accept crowns with marginal gaps as large as 225 μm. When considering only faculty members, the proportion of variance attributable to differences among faculty members was 77%, with the variance coming from explorer type being less than 1%. This effect must certainly cause concern among dental students who find that any particular faculty member is very consistent in what he or she is willing to accept clinically, while different faculty members vary widely in where they place their personal standards.

The detection of marginal gap is important in clinical dentistry involving crowns because operators use this information as part of their decision regarding acceptability of care. This research is suggestive of a hypothesis that clinical standards, such as acceptable marginal gaps on crowns, become internalized with experience, and that these standards are personal and tend to override sensitivity that could potentially be provided through various measurements of instrumentation. Further research is necessary to explore this possibility.

The limitations of this study must be acknowledged. This was an in vitro simulation that excluded such factors of patient anatomy and function and interferences of the clinical situation. The effects of such factors are unknown. Extreme care was taken in the construction and calibration of the micrometer; however, the possibility remains that some forms of variation remained. The stimuli were presented in order of increasing size rather than randomly, but this approach was uniform throughout the study. Subjects in the study were instructed to attend to tactile evidence only, but no physical barrier was used to preclude the intrusion of visual information. Clinical cementation of indirect dental restorations involves displacement of the restoration by operator technique and luting agent film thickness; however, this variable was not part of the present study. Although these and possibly other sources of variance may have been present, there is no reason to believe that they would have systematic differential effects on instruments or operators.

Further, variance analysis techniques[18] were used to partition the total variance, including error due to instrument, operator, and remaining (random) effects. Only 4% of the overall variation could be attributed to experimental variation.

The use of a micrometer to control and standardize the objective stimulus (marginal gap of a crown on a tooth) represents an attractive model for such investigations. The relatively small sample size (especially for first-year students and faculty members) poses a minor limitation on the generalizability of the findings in this study. Because previous clinical experience seating crowns on patients was the variable that demonstrated significance in outcomes (rather than year in class), the small number of first-year students may not have presented a major threat to validity. The fact that significant patterns of results emerged concerning faculty members, despite small numbers, suggests a robust underlying phenomenon.

Conclusion

This is the first investigation to combine an aid in evaluation (five types of explorers) and operators with a range of clinical experience in a single study. It was found that, among those studied in this simulation, the type of explorer used contributed a small amount to decisions regarding acceptability of crowns for seating with varying degrees of marginal gap. Differences among operators accounted for twice as much variance in the judgment regarding clinical acceptability. Operators without clinical experience were willing to accept a wider gap. Among operators who had faculty appointments, there was good consistency of judgment within each operator and lack of consistency from one operator to another. This suggests that personal standards used by practitioners is an important determinant of decision making and deserves further study.

This research also demonstrated the value of a simulation model that standardizes the stimulus situation and permits controlled gradation of increments in marginal gap. The use of generalizability analysis for revealing the distribution of variance across its sources was also demonstrated.

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