Clinical Acceptability of Crown Margins Versus Marginal Gaps as Determined by Pre-Doctoral Students and Prosthodontists

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Purpose: **Marginal integrity is a very important element in evaluating a restoration; however, there is no agreement in definition of a clinically acceptable margin. The purpose of this investigation was to examine margin acceptability using an explorer versus the actual marginal gap widths at four locations on uncemented crowns on three extracted teeth using both predoctoral students and prosthodontists as evaluators.**

Materials and Methods: **The crown margin evaluation used 16 surfaces of four crowns fitting to three extracted caries-free teeth fitted into a dentiform. The teeth (nos. 14, 20, and 29) were prepared for a full cast (gold) crown using a chamfer finish line configuration, with some margins supragingival and others subgingival. After final impressions and working casts were made, die spacer was applied to the marginal area of the die before waxing to vary the marginal opening. The dentiform was placed in a mannequin in a supine position. Predoctoral students (N = 10) and prosthodontists (N = 9) evaluated each axial surface of each crown in the zone along the margin with an explorer and rated each surface as either "clinically acceptable" or "unacceptable." After casting, the axial marginal openings were measured with Image Pro Software using a digital microscopic image of the surface. Each participant repeated the margin evaluations 6 months later.**

Results: **Upon casting, marginal gaps ranged from 40 μm to 615 μm. The proportions of prosthodontists and of predoctoral students rating a given surface as "clinically unacceptable" were highly correlated (Spearman rank correlation = 0.81, $p = 0.0001$). The prosthodontists did not provide more or fewer ratings of clinical acceptability than the students, although kappa results indicated that the prosthodontists might be more consistent among themselves than the student raters. Upon re-evaluation, both groups rated between one and six of the surfaces differently than they had previously: the median number of inconsistencies was 1 for prosthodontists and 3 for predoctoral students. The prosthodontists tended to have fewer inconsistencies than the predoctoral students ($0.05 < p < 0.10$ Wilcoxon rank sum test), but this was not statistically significant.**

Conclusion: **The data provided evidence that those surfaces associated with greater margin gaps tended to have a greater proportion of ratings of "clinically unacceptable." The proportion of prosthodontists and predoctoral students rating a margin "clinically unacceptable" were highly correlated. Prosthodontists tended to have fewer inconsistencies than predoctoral students, but that difference was not statistically significant.**

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INDEX WORDS: crowns, marginal evaluation, marginal integrity, margins

MARGINAL INTEGRITY is a very important element in evaluating a restoration. The fit of a crown margin is important to the long-term success of a cast restoration. This has been shown to be clinically significant to the periodontal health[1] and development of recurrent marginal caries;[2] however, there is no agreement in definition of a clinically acceptable margin.[3]

In an early study concerning marginal fit, experienced practitioners accepted up to a 119 μm margin opening in the gingival region while rejecting openings as little as 26 μm in occlusal areas.[4]

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The findings also showed more inconsistency between clinicians in clinical acceptability of gingival margins. Another study looked at expert opinion on acceptable margin openings and reported a range of acceptable margin openings from 32 μm to 230 μm, and showed disagreement not only between subjects but also within subjects.[5] When marginal opening acceptability with limited physical access was evaluated, the disagreement among dentists increased, as the physical access to margins was limited.[6]

In trying to find a more reliable method of margin evaluation, one study looked at comparing three techniques. The explorer, radiograph, and impression techniques were evaluated and, except for isolated areas, the impression technique was found to be the most reliable method for evaluating marginal adaptation.[7] This, however, may be a more expensive and labor-intensive process to use.

There is not yet any correspondence between the laboratory measurement of good margins and clinical judgments of good margins when using tactile feedback from an explorer. There are also a variety of definitions to describe marginal fit, whether it is clinically acceptable or clinically unacceptable.[8] The contour and/or the extension of the crown can affect the outcome of the evaluation. With no correlation and a varied degree of marginal fit, the ramifications for both clinical evaluation in practice and also the teaching of what good margins actually are in education can be very challenging.

Evaluating the margins is a learned skill that develops and improves as students/practitioners gain experience. This skill is empirically learned during preclinical laboratory exercises or in clinical situations. Supragingival margins are easily evaluated by direct visual examination and by using an explorer.[4] Much of the learning experience in the preclinical courses is by direct visual examination. Although this may be an adequate starting point, it is difficult to apply clinically. Margins are ideally placed supra-gingival, but this is not always clinically feasible. Even with instructor supervision, it can be difficult to learn the skills of margin evaluation in a clinical environment.

The objective of this study was to evaluate the marginal adaptation of cast restorations using an explorer versus the actual marginal gap widths at four locations on uncemented crowns in a simulated clinical situation.

Materials and Methods

Three extracted teeth were fitted into a dentiform and prepared for full cast crowns. After the working cast was fabricated, die spacer was placed over the marginal area of the die before waxing to vary the marginal opening. Simulating a clinical situation, predoctoral students and prosthodontists assessed the marginal fit of four uncemented crowns.

Three extracted caries-free teeth (two bicuspids and one molar) were fitted into a dentiform. The hard acrylic "gingiva" was removed and replaced with simulated soft tissue (Softissue Moulage, Kerr Corp., Romulus, MI) to give a more realistic feel for the subgingival areas.

The teeth were prepared for the full cast (gold) crowns using a chamfer finish line configuration. The margin zones to be evaluated were placed in both supragingival and subgingival sites. Impressions (Extrude, Kerr Corp.) made of the prepared teeth allowed fabrication of removable die working casts (Silky-Rock, Whip Mix Corp., Louisville, KY) for fabricating crowns using conventional methods. Prior to fabricating the crown, die spacer (Tru-Fit, Geo. Taub Prod. and Fusion Co. Inc., Jersey City, NJ) was applied to each margin zone before waxing in order to create marginal openings. Die spacer was not applied at the line angles in order to provide a positive seat. The different thicknesses of die spacer layers were used to vary the marginal openings and to have a range of distribution. Once the castings (Par 7, W. E. Mowrey Co., St. Paul, MN) were completed, the crowns were fitted to the prepared teeth using traditional methods. Teeth were stored in distilled water at room temperature during the fabrication of the crowns and between evaluations.

Ten predoctoral students and nine prosthodontists evaluated each margin and repeated the evaluation after a 6-month interval. Predoctoral students were third-year dental students at the University of Iowa who were arbitrarily chosen from a list of students who volunteered to participate. The prosthodontists were all full-time faculty members of the Departments of Prosthodontics or Family Dentistry at the University of Iowa College of Dentistry and had an average of 21 years of practice.

Each participant was assigned an identification number. They were asked to evaluate the clinical "acceptability" or "unacceptability" of each axial

surface margin (mesial, buccal, distal, and lingual) of each crown. The criteria for evaluating the crowns were based on the criteria developed for the preclinical fixed course. The criteria included marginal extension, contour, integrity of fit, and finish. The crowns were presented to each participant for evaluation in the same sequence: tooth 14 first, 20 second, and 29 third. The participants were instructed to make the assessment at the margin toward the middle of each axial surface, avoiding the margin at the line angles. The crown was held in position with finger pressure, and could be held in place by the participant, or the participant could request the assistant to hold the crown. The mannequin was placed in the supine position. The same explorer (DE #5, Brasseler USA, Savanna, GA) was used by all participants. Each participant used the latex glove size he/she commonly wore while treating patients. Participants were free to practice their own systematic technique for the evaluation. An "A" was recorded if the margin was determined to be clinically "acceptable" and a "U" if it was clinically "unacceptable." The same assistant recorded all assessments by each of the participants (Table 1).

After the crown margins were evaluated, a digital microscopic image was obtained of each axial surface, and marginal gaps were measured using Image Pro software (Media Cybernetics, Silver Spring, MD). The chamfer margins were marked in red for better visualization. The crown was placed on the prepared tooth and held in place with finger pressure while the photo was obtained. The Image Pro software was calibrated with an image taken of a millimeter ruler. Lines were drawn on the chamfer cavosurface finish line and cast crown margins to the extent of the positive seats or line angles. The maximum, minimum, and average lengths for the distance between the two drawn lines were calculated by the computer program. It was felt that the average value best represented the marginal gap located at the middle of each axial surface. This average value was used as the marginal gap value for the corresponding surface (Fig 1).

After the initial evaluation, an additional crown was fabricated for tooth 20 to broaden the range of marginal gaps being evaluated. The evaluation of the new crown and the reevaluation of two of the original crowns were performed 6 months later. The participants were not informed of which two of the three crowns were being reevaluated. The crowns were presented to each subject for evaluation in the same sequence as during the initial evaluation. The same explanation was given, and the same procedural methodology was followed. The original explorer was used by each subject for the reevaluation. The same predoctoral students (N = 10) and same prosthodontists (N = 9) participated in the reevaluation. One prosthodontist, who was unable to participate at the time reevaluations were being performed, was not included in the data analysis.

The initial evaluation consisted of 12 surfaces: the axial surfaces of the three crowns. Seven of the surfaces had supragingival margins and five were subgingival. At the reevaluation, a new crown was introduced and two original crowns were used. Only eight surfaces of the two crowns used initially and at reevaluation were used in the reevaluation statistical analysis. The additional crown provided a broader range of marginal gaps being evaluated. Sixteen surfaces were evaluated, with nine having supragingival margins and seven having subgingival margins.

One explorer was used throughout the study by all participants. A digital image was made of the explorer tip used. Using the Image Pro software, two lines were drawn outlining the most distal 1 mm diameter of the explorer tip. Maximum, minimum, and average values were used to calculate the diameter. The minimum value of the explorer used for the study had a tip measurement of 53 μm.

Cohen's kappa was used as a measure of participant agreement. The nonparametric Wilcoxon signed rank test for paired data was used to assess whether there were differences between clinically "unacceptable" ratings by the prosthodontists versus the students for the set of 16 surfaces. The nine supragingival surfaces versus the seven subgingival surfaces with clinically "unacceptable" scores were compared using the Wilcoxon rank sum procedure. The Wilcoxon rank sum test was also used to analyze the number of inconsistent ratings.

Results

Upon casting and fitting, the marginal gaps ranged from 40 μm to 615 μm. The data provided evidence that those surfaces associated with greater marginal gaps tended to have a greater

Table 1. Marginal Gap Measurements and Ratings by Prosthodontists and Third Year Dental Students

			Prosthodontists N = 9, First evaluation		*Prosthodontists N = 9, Reevaluation*		*Third Year Students N = 10, First Evaluation*		*Third Year Students N = 10, Reevaluation*	
Tooth/ Surface	*Margin Gap (μm)*	*Margin Location*	*Clinically Acceptable*	*Clinically Unacceptable*	*Clinically Acceptable*	*Clinically Unacceptable*	*Clinically Acceptable*	*Clinically Unacceptable*	*Clinically Acceptable*	*Clinically Unacceptable*
14 M	40	Supra	9	0	9	0	10	0	10	0
B	149	Supra	0	9	1	8	2	8	1	9
D	268	Sub	3	6	6	3	8	2	5	5
L	201	Supra	6	3	9	0	6	4	6	4
20(A*)M	382	Sub	1	8			4	6		
B	130	Supra	9	0			9	1		
D	615	Sub	0	9			0	10		
L	163	Supra	8	1			7	3		
20(B*) M	77	Sub			9	0			10	0
B	62	Supra			9	0			10	0
D	66	Sub			9	0			7	3
L	117	Supra			8	1			9	1
29M	455	Sub	3	6	2	7	4	6	2	8
B	182	Supra	3	6	4	5	2	8	4	6
D	235	Supra	4	5	3	6	6	4	1	9
L	171	Sub	6	3	7	2	6	4	7	3

A* Designates the first crown that was evaluated.
B* Designates the second crown that was evaluated at the 6-month reevaluation.

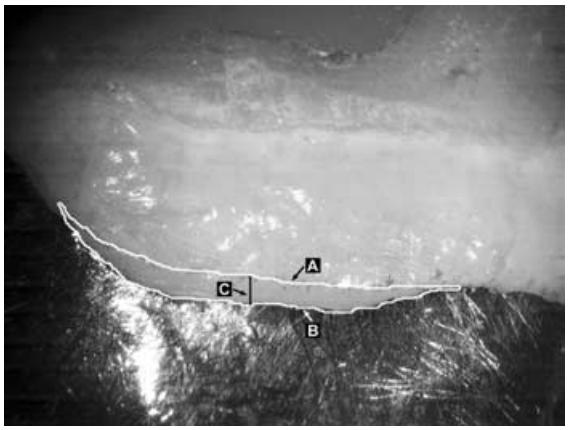

Figure 1. The measured digital image of the distal axial surface of the crown prepared for tooth no. 14 with a margin gap of 268 μm, indicated by C. A indicates the finish line on the tooth and B indicates the margin of the crown.

proportion of ratings of "clinically unacceptable." (Spearman rank correlation = 0.80, $p = 0.0002$). The marginal gap of 615 μm was determined as "unacceptable" by all examiners. There was also complete agreement that the marginal gaps of 40, 62, and 77 μm were clinically "acceptable;" however, there was a wide range of distribution of the gaps accepted by both the prosthodontists and the predoctoral students (Fig 2).

Kappa coefficients were obtained to measure agreement among all 19 raters, among the prosthodontists (N = 9), and among the predoctoral students (N = 10), based on ratings of clinical acceptability of 16 surfaces. The kappa coefficient ($p < 0.0001$ in all three instances), indicated that the level of agreement was moderate (Table 2).

Additionally, in looking at the proportion of participants who classified a given surface as "clinically unacceptable" over the set of 16 rated surfaces, the proportion of prosthodontists giving a rating of "clinically unacceptable" was positively correlated with the proportion of students giving a similar rating (Spearman rank correlation = 0.81, $p = 0.0001$).

Table 2. Kappa Coefficients

	Kappa Coefficients	Approximately 95% Confidence
Predoctoral students	0.30	0.23 to 0.37
Prosthodontists	0.51	0.43 to 0.52
Mean	0.39	0.35 to 0.42

Kappa = 0.4 to 0.8 indicate moderate agreement.
$p < 0.0001$ in all three instances.

Clinically unacceptable ratings by the two groups of participants were compared for the first set of 16 surfaces using the nonparametric Wilcoxon signed rank test for paired samples. Although the kappa statistics suggested that the prosthodontists might be more consistent among themselves than were the student raters, there was no suggestion that the prosthodontists provided either more or fewer ratings of clinical acceptability than the students ($p > 0.9$) for this sample of surfaces.

Comparison was made of nine supragingival surfaces versus the seven subgingival surfaces with clinically unacceptable scores. The data provided no evidence that ratings differed for these two groups ($p > 0.35$, Wilcoxon rank sum test). This was true whether all raters were considered together, or the prosthodontists and students were considered separately. Although the supragingival surfaces tended to have somewhat lower marginal gaps, this trend was not significantly different ($p = 0.16$) in the expanded sample of 16 surfaces.

None of the 19 raters participating in the reevaluation study rated all eight surfaces the same way at both evaluation times. Among the prosthodontists, the number of surfaces rated differently at the two evaluations ranged from one to six, with a median of 1; five of the nine prosthodontists rated only a single surface of the eight surfaces differently at the two evaluations. Of the remaining four prosthodontists, one rated two surfaces inconsistently, two rated three surfaces differently, and one assigned different ratings to six of the eight surfaces at reevaluation.

Among the students, the number of surfaces rated differently at the two evaluations also ranged from one to six, but with a median of 3; seven of the ten students rated three or more surfaces inconsistently at the two evaluations. One rated a single surface inconsistently, one rated two surfaces inconsistently, five rated three surfaces inconsistently, two rated five surfaces differently and one assigned different ratings to six of the eight surfaces at reevaluation.

Comparing the number of inconsistently rated surfaces for the two groups suggested that the prosthodontists tended to have fewer inconsistencies ($0.05 < p < 0.10$ by the Wilcoxon rank sum test

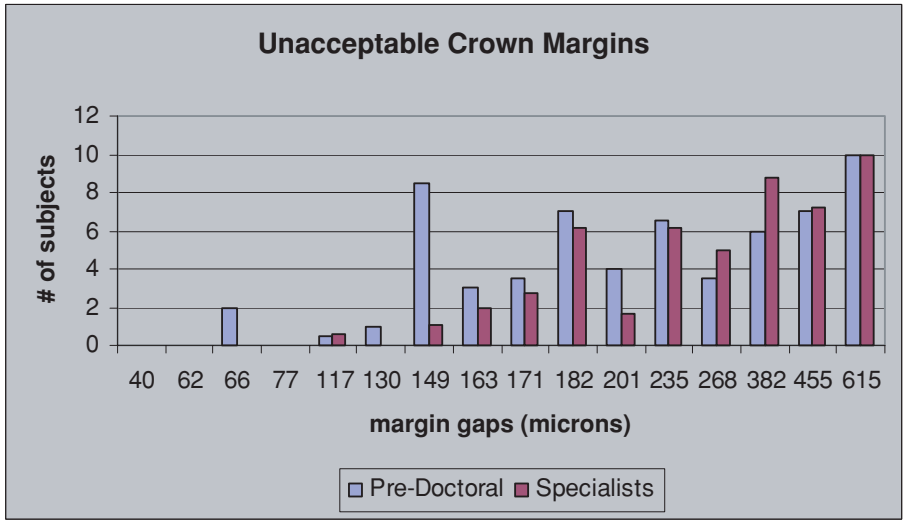

Figure 2. Crown margins judged to be unacceptable both during the initial evaluation as well as the 6 month reevaluation.

using exact tables); however, this was not clinically significant.

Discussion

As with previous studies,[4-6] there was not always agreement among the participants on what was considered to be clinically acceptable or unacceptable for a crown margin. The prosthodontists accepted marginal gaps as great as 455 μm while rejecting marginal gaps as small as 117 μm. As a group, they showed significant but moderate levels of agreement in rating the surfaces. Upon 6 months reevaluation, they tended to have fewer inconsistencies.

The predoctoral students also accepted gaps as great as 455 μm, but rejected gaps as small as 66 μm. Compared with the prosthodontists, they showed significant but even more modest agreement in their ratings and had a greater range of variability upon reevaluation. The marginal gap of 149 μm was rejected by a majority of predoctoral students; this was thought to have been a result of a margin gap with a horizontal discrepancy.

Those surfaces associated with greater margin gaps tended to receive greater numbers of unfavorable ratings. A marginal gap of 615 μm had agreement among all participants as being clinically unacceptable. Marginal gaps of 455 μm and 382 μm had most participants rating them as clinically unacceptable. In the range of 182 μm to 268 μm margin gaps, the participant rating was more variable. There were no physical gap measurements that were correlated to clinical acceptability or unacceptability. Significance was not achieved when comparing the evaluation of supragingival and subgingival gaps. There was not agreement among participants as to marginal gap rating when the marginal gaps were similar in supragingival versus subgingival locations, which differed from a previous study by Dedmon.[6]

Exercises of marginal evaluation of cast restorations that simulate a clinical situation in the preclinical courses for dental students could be beneficial for teaching and development of tactile skill. This in turn may help students develop confidence with those skills before coming to the clinic. The marginal evaluation exercises could also help to standardize the instructors for grading procedures and make the grading more consistent. It is hoped that developing better clinical skills associated with evaluating marginal accuracy will ultimately aid in the long-term success of cast restorations for patients.

What was not done with this investigation was reevaluation of the crowns after cementation. This additional step may have influenced the evaluation of the crown margins by the participants. This is certainly another criterion to consider in the evaluation of marginal adaptation.

Conclusions

The data provided evidence that those surfaces associated with greater marginal gaps tended to have a greater proportion of ratings of "clinically unacceptable" (Spearman rank correlation = 0.80, $p = 0.0002$). The proportion of prosthodontists' and predoctoral students' rating of a "clinically unacceptable" margin were highly correlated. Prosthodontists tended to have fewer inconsistencies than predoctoral students, but this was not statistically significant.

References

1. Felton DA, Kanoy BE, Bayne SC, et al: Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent 1991;65:357-364
2. Walton JN, Gardner FM, Agar JR: A survey of crown and fixed partial denture failures: Length of service and reasons for replacement. J Prosthet Dent 1986;56:416-421
3. Hunter AJ, Hunter AR: Gingival margins for crowns: A review and discussion. Part II: Discrepancies and configurations. J Prosthet Dent 1990;64:636-642
4. Christensen GJ: Marginal fit of gold inlay castings. J Prosthet Dent 1966;16:297-305
5. Dedmon HW: Disparity in expert opinions on size of acceptable margin openings. Oper Dent 1982;7:97-101
6. Dedmon HW: Ability to evaluate nonvisible margins with an explorer. Oper Dent 1985;10:6-11
7. Assif D, Antopolski B, Helft M, et al: Comparison of methods of clinical evaluation of the marginal fit of complete cast gold crowns. J Prosthet Dent 1985;54:20-24
8. Holmes JR, Bayne SC, Holland GA, et al: Considerations in measurement of marginal fit. J Prosthet Dent 1989;62:405-408