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Paul A. Hansen

Ariel Atwood

Mallory Shanahan

Mark Beatty

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RESEARCH AND EDUCATION

The accuracy of clinician evaluation of interproximal contacts using different methods

Paul A. Hansen, DDS,^a Ariel Atwood, DDS,^b Mallory Shanahan, DDS,^c and Mark Beatty, DDS, MSE, MS, MSD^d

Seating single or multiple crowns is one of the most basic skills for a dentist. If the interproximal contacts are excessively tight, complete seating of a single crown may not be possible. If the crown is slightly too large for the space it should occupy, the crown may not seat completely, and open margins may result. Open margins produced by improperly seated restorations on the maxillary right first molar and second premolar are shown in Figure 1. The clinician used floss to evaluate the interproximal contacts. Open margins are difficult to clean, can lead to inflammation of the gingival tissues, and may result in recurrent dental caries.¹ A contact that is too tight also may produce patient discomfort because of pressure exerted on the adjacent teeth. Therefore, it is important to ensure the complete seating of crowns.

ABSTRACT

Statement of problem. Complete seating of a single crown may not be possible if the interproximal contacts are excessively tight. Incomplete seating can lead to open margins, inflammation of the gingival tissue, and recurrent dental caries.

Purpose. The purpose of this in vitro study was to determine the accuracy of 3 different methods of evaluating interproximal contacts when seating a single crown.

Material and methods. Thirty-five restorative dentists practicing in the Lincoln, Nebraska, area were polled to determine the methods they used most commonly to evaluate the interproximal contacts of crowns. These dentists then evaluated the interproximal contacts of 9 anatomic contour zirconia crowns on a dentoform using 3 different methods: floss and explorer, occlusal articulating film (AccuFilm), and shim stock. Crown fit was evaluated using 1 method at a time. Each crown was recorded as either “accept” or “reject” according to the individual clinician. All data were analyzed with the McNemar test ($\alpha=.05$).

Results. Of the 35 restorative dentists polled, 34 identified floss and explorer, 9 identified occlusal articulating film, 3 identified shim stock, and 3 identified an occlusal spray as their method of evaluating interproximal contacts. These methods were used either alone or in conjunction with other methods. Evaluation of the in vitro data revealed that shim stock and occlusal articulating film were significantly more accurate than floss and explorer for assessing interproximal contacts in poorly fitting crowns ($P<.001$). For well-fitting crowns, shim stock and occlusal articulating film were significantly more accurate than floss and explorer ($P<.001$).

Conclusions. This study showed that the floss and explorer method was the least accurate means of evaluating the interproximal fit of crowns. Shim stock provided the most accurate method of evaluating interproximal contact, and occlusal articulating film provided both high accuracy and a visible mark to facilitate adjustment. (J Prosthet Dent 2019;■:■-■)

Difficulties arise when either a radiograph or an explorer are used to evaluate subgingival crown margins. Assif et al² recommended the use of impression materials when crown

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^aClinical Professor and Assistant Director, Advanced Education in General Dentistry Program, Department Restorative Dentistry, University of Missouri-Kansas City, Kansas City, Mo.

^bGeneral Dentistry Officer, United States Air Force, Ellsworth Air Force Base, Rapid City, SD.

^cPrivate practice, Walnut Grove, Tenn.

^dResearcher, Veterans Affairs Nebraska-Western Iowa Healthcare System, Omaha, Neb; Professor and Director of Biomaterials, Department of Adult Restorative Dentistry, College of Dentistry, University of Nebraska Medical Center, Omaha, Neb.

Clinical Implications

Accurate methods should be used to assess the interproximal contacts of crowns as complete seating onto teeth or implants is important to ensure margin closure. Incomplete seating can result in open margins, which can result in food impaction, dental caries, and gingival tissue inflammation.

margins are difficult to detect with an explorer. Christensen³ reported better results with explorer examination of visually accessible margins on a gold inlay than with radiographic examination of visually inaccessible margins. Liedke et al⁴ reported that variations occur in the evaluation of margins with radiographs and recommended evaluating original nonfiltered images for assessing teeth with metal restorations. Overall, a degree of uncertainty exists regarding these 2 widely used clinical methods.

Traditional techniques for clinically evaluating and adjusting interproximal contacts include dental floss, Mylar shim stock dental film, and Mylar articulation film.^{5,6} Adjacent tooth contacts must not be too tight or too open.⁷⁻⁹ A space of 13 μm between teeth has been found in 80% to 90% of interproximal contacts.¹⁰ The use of dental floss may not be the best method of contact evaluation because when floss snaps through, the contact can be visibly open when air-dried and inspected.^{11,12} Contact tightness frequently results in open crown margins. A tight or binding contact with shim stock represents a gap of less than 6 μm .^{11,12} Resistance, but no binding, while pulling the shim stock represents a gap of approximately 6 μm , and only light resistance while pulling the shim stock corresponds to a gap of 8 μm .¹¹ The shim stock or Mylar articulating film should pass between teeth with slight resistance. If it binds, adjustments should be made, followed by reassessment to verify proper interproximal contact.¹²

Previous assessments of interproximal contact have focused primarily on unrestored teeth or teeth containing direct restorative materials.^{2-5,8,10-23} The authors are unaware of evidence-based reports that have evaluated the best methods for assessing the tightness of interproximal contacts of crowns. This study was conducted to provide information by comparing 3 different evaluation methods in which the interproximal distance was controlled by varying the crown width.

The purpose of the present study was to poll restorative dentists regarding their preferred methods of evaluating interproximal contacts when seating single crowns and to compare the accuracy of 3 methods of evaluating interproximal contacts in a series of crowns seated on a dentoform when performed by these dentists. The null hypothesis was that no significant differences would be

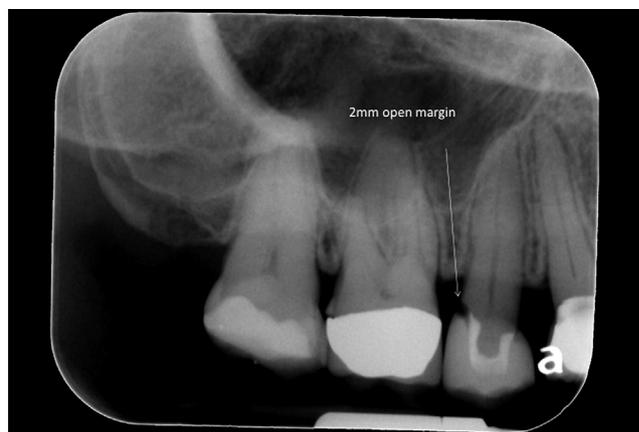


Figure 1. Incompletely seated crowns on maxillary right first molar and second premolar, resulting in open margins with potential for caries, gingival inflammation, and patient discomfort.

Table 1. Characteristics of dentists participating in study and methods to determine interproximal contact

Characteristic or Method	Number of Dentists
Years in practice	
1-9	6
10-19	4
20-29	7
30-39	13
≥40	4
Percentage of practice dedicated to fixed prosthodontics	
≤15	4
16-25	10
26-50	12
>50	9
Methods used to determine interproximal contact*	
Floss and explorer, visual examination	34
Occlusal spray, marker	3
Articulating film or articulating tape	9
Shim stock	3

*Multiple answers permitted.

found between the use of floss and explorer, articulating film, or shim stock with respect to the restorative dentists' ability to determine the proper fit of a single crown.

MATERIAL AND METHODS

Thirty-five restorative dentists in the Lincoln, Nebraska, area or at Offutt Air Force Base in Omaha, Nebraska, agreed to participate in this institutional review board-approved study (#443-1-EX) and signed written informed consent documents. Participant demographics relating to years in practice, methods used to assess interproximal contact, and percentage of practice time dedicated to fixed prosthodontics are presented in Table 1. The dentists were asked to assess interproximal contacts with floss and explorer, articulating film, and shim stock. The floss (Floss Singles) was 100 μm thick when held tightly.

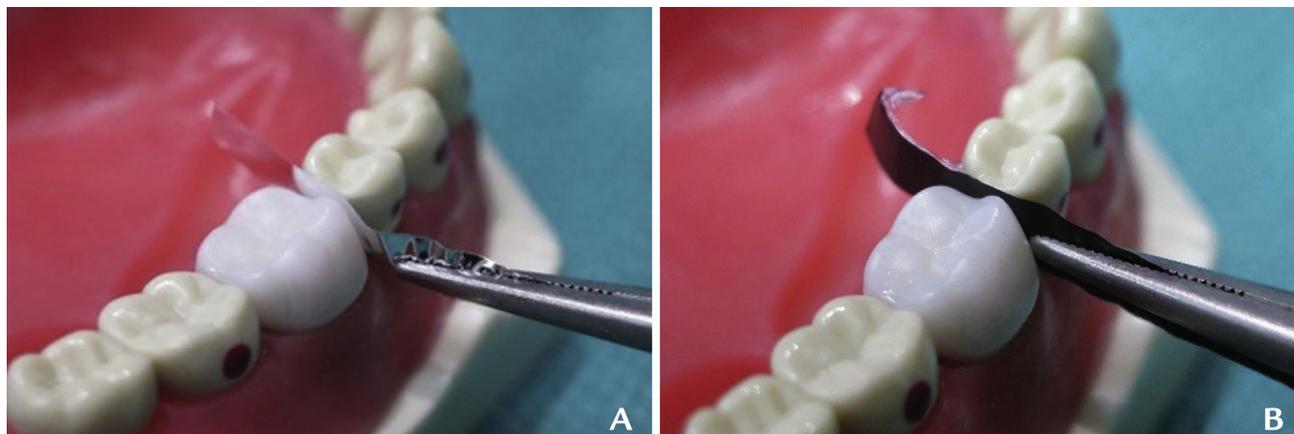


Figure 2. Feeling contact between mandibular right second premolar and first molar facilitated by use of hemostat. A and B: AccuFilm.

The dentists were given the option of using either a Hu-Friedy single end #2E pig tail or #23SE hook type of explorer and were permitted to use the explorer as they preferred. An articulating film (AccuFilm II; Parkell, Inc) was used by pulling on the film after inserting it interproximally, as depicted in Figure 2A. The AccuFilm II has a thickness of 25 μm , according to the manufacturer. The shim stock (Almore Intl) method evaluated the contact by pulling the shim stock after it was placed between the crown and the adjacent tooth using standards for normal interproximal contact set by Boice et al,¹⁰ as shown in Figure 2B. Shim stock has a thickness of 8 μm , according to the manufacturer.

A dentoform with plastic as soft as simulated gingival tissue was chosen (Columbia dentoform model PUR-8612 ON MQDT). A mandibular right first molar was prepared for a single crown, and the dentoform was sent to the Eurodent dental laboratory in Overland Park, Kansas, for scanning to ensure that the margins were smooth and that adequate tooth removal had been accomplished (3Shape D700 scanner with 2014 version software). After the scan, a digital image of the prepared tooth was constructed, and 9 crowns were milled from high-translucency zirconia (HT Zirconia; Talladium, Inc) to match the prepared tooth. The crowns varied in width, with the mesial interproximal contact milled exactly and the distal contact varying in its contact with the mandibular right second molar. One crown (the ideal) matched the interproximal contact exactly, 4 had deficient contact, and 4 had excessive contact. A single crown with exact contact is shown in Figure 3A. Table 2 shows the code for each crown and the difference in contact spacing from the ideal one. Each crown was crystallized in a Vita sintering oven (Zyrcomat YC; Vita Corp) at 1530°C for 7.5 hours and then polished but not glazed to avoid alterations that may occur with a traditional glaze. Using a stereomicroscope (Mobiloskop KL200; Renfort) at $\times 15$ magnification, the margins were examined for

gaps or inconsistencies. If any existed, the crown was rejected.

The prepared tooth possessed margins located below the free gingival margin to simulate a crown margin that is difficult to evaluate in the mouth. This was intended to encourage the examiner to rely more on the use of the indicator method. A crown with a distal contact that was too tight, resulting in incomplete seating of the unit, is shown in Figure 3B. With the shroud removed, the open margin is obvious, whereas with the shroud in place, the operator cannot see the open margin.

The mesial-distal width of each crown was measured to determine the relative gap size between the crown and adjacent teeth. A micrometer (Digitrex; Fowler High Precision) with a precision of $\pm 2.5 \mu\text{m}$ was used to generate 3 independent measurements of each crown. The measurements were averaged and are presented in Table 2.

To allow evaluators to identify a specific crown for assessment, a number or symbol was randomly stained onto the cameo surface of each crown using feldspathic porcelain before sintering. The crowns were placed in a small bowl and randomly tried one at a time, allowing a random placement and try in of each crown. The markings were not revealed until all evaluations had been completed.

The 9 zirconia crowns were randomized in the small bowl, and the restorative dentists were asked to evaluate the interproximal contacts with each of the 3 methods, recording whether a crown should be accepted or rejected for fit. Although the dentists did not perform a series of calibration exercises, they were instructed regarding the use of an articulating film and shim stock. If binding occurred when the articulating film or shim stock was pulled through the contact, the contact was considered too tight and therefore unacceptable. If the articulating film or shim stock was able to slide through the contact without contacting the adjacent teeth, the crown was considered unacceptable because of lack of contact. If the articulating film or shim stock was pulled with contact

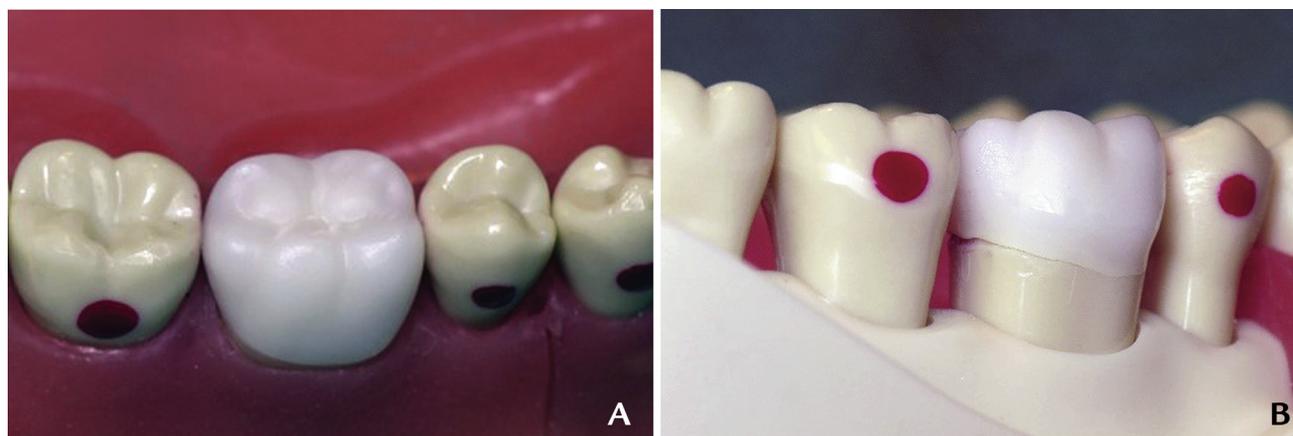


Figure 3. Zirconia crown completely seated on dentoform. A, With shroud in place. All margins below shroud. B, With shroud removed, distal margin easily observed. Distal margin open, crown not acceptable for cementation.

being felt, but no binding, the contact was considered acceptable. To simulate evaluations in a clinical setting, the clinicians were required to perform all dentoform contact evaluations without removing the dentoform from the table to look at the contacts from the facial view. Each crown was evaluated twice at each interproximal location, and an “accept” or “reject” decision for crown seatability was recorded for each evaluation method. Accept was recorded as “0” and reject was recorded as “1.”

For statistical analysis, 945 scores were recorded (35 dentists evaluating 9 crowns using 3 evaluation methods). The dependent variable was the accept or reject score (0 or 1), and the independent variable was the evaluation method (floss, articulating film, or shim stock). Contingency tables (2×2) were constructed for the overall data set, which included all evaluations. The data set was also divided into subsets, and 2×2 tables were constructed to evaluate the results for contacts that were very tight (+193 μm and +201 μm mesial-distal crown width discrepancies), slightly tight (+25 μm and +33 μm discrepancies), even or “proper” (0 μm discrepancy), slightly open (−38 μm and −41 μm discrepancies), and very open (−160 μm and −167 μm discrepancies) (Table 2). Data from each 2×2 table were analyzed using the McNemar test¹⁴ to determine whether there was a significant difference ($\alpha=.05$) between the 2 methods being compared.

RESULTS

The results of the McNemar tests are summarized in Table 3. Pairwise comparisons showed that for all measurements combined, the shim stock, articulating film, and floss and explorer methods produced significantly different accept or reject responses from one another (0.022 < P < .001). When the data set was assessed according to the crown fit, the responses for shim stock and

Table 2. Mesial-distal dimensions of crowns prepared and resulting interproximal contact

Crown Code	Crown Width (mm)	Type of Contact	Deviation from Proper Fit (μm)
1	11.783	Closed, very tight	+201
2	11.544	Open, slightly open	−38
7	11.615	Closed, slightly tight	+33
8	11.542	Open, slightly open	−41
1-1	11.422	Open, very open	−160
11	11.415	Open, very open	−167
VI	11.775	Closed, very tight	+193
20	11.608	Closed, slightly tight	+25
23	11.582	Even contact	0

articulating film did not differ significantly from each other, regardless of whether the interproximal contact was tight, open, or proper (0.083 < P < .763). Both shim stock and articulating film produced significantly more correct responses for each type of interproximal contact than did floss and explorer (P < .001), except for very tight contacts for which the responses did not differ significantly between the articulating film and floss and explorer ($P=.178$). For the properly fitting crown, 32 of 35 floss/explorer evaluations rejected the crown for cementation, whereas similar numbers of accept and reject evaluations were recorded for articulating film and shim stock (not shown). Interestingly, 50% of floss and explorer evaluations rejected crowns with slightly open contacts, but only 27% of evaluations rejected crowns with very open contacts.

DISCUSSION

To the authors’ knowledge, this was the first study comparing different methods of assessing interproximal contacts for seating single crowns. Although the results presented here are based on evaluations obtained from a limited number of participants, the study’s main intent

Table 3. Comparison of three methods of determining interproximal contact

Amount of Contact	Shim Stock Versus Articulating Film	Shim Stock Versus Floss/ Explorer	Articulating Film Versus Floss/ Explorer
All measurements	.022*	<.001*	<.001*
Slightly tight	.197	<.001*	<.001*
Very tight	.083	.005*	.178
Proper fit	.564	<.001*	<.001*
Slightly open	.763	<.001*	<.001*
Very open	.109	<.001*	<.001*

*Denotes statistical significance (McNemar test).

was to provide baseline information for further study. The null hypothesis—no significant differences would be found among the floss and explorer, articulating film, or shim stock methods with regard to a restorative dentist's ability to determine the proper fit of a single crown—was rejected. In nearly every situation, shim stock and articulating film were similar in their ability to assess crown fit correctly, and both were significantly more accurate than the assessment using floss and explorer.

A wide range of results was obtained during the floss and explorer evaluations. For example, a high number of rejections were recorded for a properly fitting crown, and results were similar for the floss and explorer and articulating film for crowns with very tight contacts. Another discrepancy occurred with crowns with open contacts; equal numbers of accept and reject scores were observed for crowns with slightly open contacts, but nearly three-fourth of crowns with very open contacts were accepted. These inconsistencies may be attributed to variations in dimensions that occur when handling floss. When held tightly, floss thickness is approximately 100 μm , but floss thickness varies according to changes in the amount of applied tensile force. Consequently, when compared with shim stock or articulating film, the thickness of which is well controlled, floss cannot reliably discriminate between a contact that is too tight and one that is too open. Also, if the gap between teeth is smaller than 100 μm , as was the situation for crowns with very tight, slightly tight, proper, and slightly open contacts, the floss may still snap through the contact, making the crown fit appear acceptable. This explains why detecting an open margin with tight-fitting crowns at the recall appointment is not uncommon; the crown may have been cemented without the clinician realizing that the crown was incompletely seated.

Findings from this study cannot be directly compared with those reported previously as similar studies are lacking. Research involving shim stock has focused primarily on measuring the interproximal contact force,¹⁵⁻¹⁸ and the use of different shim stock thicknesses, different measuring devices, and different clinical questions has led to results that cannot be compared with those

reported in this study. Similarly, floss¹⁹⁻²¹ and articulating film^{22,23} have been used to evaluate different restorative procedures and materials, but direct comparisons with the results of the present study are not possible.

In surveying the dentists who participated in this study, only 1 of the 35 did not use floss as a method of evaluating the interproximal fit of a crown or fixed partial denture. Nine clinicians indicated the use of marking film for contact evaluation, but this method was used primarily to identify the contact for adjustment rather than to evaluate the fit. Comments offered during the evaluation indicated that some dentists were unaware of the different methods used to evaluate interproximal contact, with floss and explorer being the only known method. Although various methods of interproximal contact evaluation are taught in North American dental schools, the authors are unaware of reports documenting the methods taught at specific institutions. Based on the results presented in this study, all 3 evaluation methods should be incorporated into dental school curricula.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusion was drawn:

1. Shim stock and articulating film were significantly more accurate in evaluating interproximal contacts during the seating of single crowns than floss and explorer.

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Corresponding author:

Dr Paul A. Hansen
Department of Restorative Dentistry
School of Dentistry
University of Missouri-Kansas City
650 E 25th St
Kansas City, MO 64108
Email: Hansenp@umkc.edu; Hans398@aol.com

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