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GUEST EDITORIAL

The Demand for Quality Care

The dental profession is very aware of the consequences of having excess dental personnel coupled with a dramatic reduction of caries and periodontal disease through prevention. Patients also are aware that they can seek quality dental care through satisfied patient referrals, even through the Internet. More patients than ever before are now seeking second opinions after discussing their dental treatment with friends.

The desire of most dentists to supply quality dental care and the economics involved in the competition for patients will predictably drive dentists to advance their professional knowledge and clinical skills. I feel the most satisfactory method for improving the technical ability of dentists while developing a common-sense approach to quality dentistry is to be actively involved in a clinical study club or to participate in hands-on continuing education courses. Most seminars and dental meetings that we attend are educational, but we need to actually *do it* to improve our clinical skills.

Fortunately many of us have been touched by someone in the dental profession who has inspired and taught us quality dentistry. Sadly, however, there are dentists who do not realize that their treatment planning and quality of care have slipped, because they are not involved in study club or peer review contact to evaluate their dental practice skills. Physicians have a form of peer review through hospital affiliations and/or clinic contacts. Dentists, however, can practice in their offices with no peer involvement.

Licensing bodies are mandated to protect the public interest as well as to encourage professional growth and development. Forty-three out of 50 states in the United States and nine out of 10 provinces in Canada have mandatory continuing education requirements to maintain licensure. I would highly recommend that a large number of these continuing education requirements need to be represented by hands-on courses or by active participation in one or more clinical study clubs. Our area in British Columbia has for many years had a great variety of clinical study clubs with a large participation percentage.

Ideally, study club activities should be made available to dentists in all areas of North America. One difficulty is developing mentors that can provide professional advice and constructive criticism of our dental treatment. Organizations such as the Associated Ferrier Gold Foil Group and the R V Tucker Academy have developed a tradition of mentor development. This has greatly assisted the formation of new study clubs and the continuation of existing clubs as mentors retire.

Recent graduates and new members of study clubs often feel intimidated by their lack of clinical skill compared to those of long-standing members. Most mentors are prepared to spend extra time with these dentists to help them develop their skills to a more comfortable level. Another attractive approach is to organize a group of dentists with similar interests and skills into a new study club. An existing, similar study club is often a good resource for mentors of these new groups. Where possible, the new clubs should approach a specialist or a qualified practitioner outside of their immediate location to mentor them. A major factor in developing a successful study club is respect for the mentor's ability to teach and a commitment by all club members to follow the mentor's directions. I encourage all of you to talk to members of an active clinical study club. You will see the enthusiasm, confidence and dedication to quality clinical treatment of patients by members as they strive for excellence in their profession.

Our patients not only deserve excellence but are in a position to demand it.

DR THOMAS E RAMAGE
President
American Academy of Gold Foil Operators

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ORIGINAL ARTICLES

Surface Roughness and Cutting Efficiency of Composite Finishing Instruments

M JUNG

Clinical Relevance
Finishing diamonds were best suited for gross removal and contouring of structured composite surfaces; for finishing, the tungsten carbide finishing burs achieved the best results.

SUMMARY

Trimming composite restorations includes gross removal of excess material, contouring, and finishing. Many surfaces such as the lingual surface of anterior teeth or the occlusal surfaces of posterior teeth require the use of rigid rotating instruments. The purpose of our study was to assess the suitability of eight finishing diamonds, five tungsten carbide finishing burs, and one ceramically coated finishing instrument for trimming a small-particle hybrid composite material. A total of 70 specimens of Herculite XRV were treated with the different finishing instruments under simulated practice conditions, and surface roughness was recorded quantitatively using an optical laser pick-up. The resulting surfaces were examined qualitatively with the help of scanning electron microscopy (SEM). Cutting efficiency of the diamonds and burs was evaluated at a constant pressure of 2.5 N using 42 additional specimens of Herculite XRV. Significant differences were calculated using one-way ANOVA and pairwise contrasts by Tukey's multiple range test. The results showed that finishing diamonds were characterized by high cutting efficiency and relatively rough corresponding composite surfaces, whereas tungsten carbide finishing burs led to smooth composite surfaces but had little cutting efficiency. For gross removal and contouring of composite restorations, a 15-40 μm finishing diamond is recommended followed by a tungsten carbide bur for finishing the restoration.

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INTRODUCTION

Trimming composite material is usually an inevitable procedure after the placement of direct composite restorations. This includes the gross removal of material and the contouring, finishing, and polishing steps (Lutz, Setcos & Phillips, 1983). Other than approximal surfaces that are treated using finishing and polishing strips, this is achieved with the help of finishing diamonds and burs. Flexible disks have turned out to be best suited for trimming and polishing composite surfaces (Chen, Chan & Chan, 1988; Eide & Tveit, 1988; Herrgott, Ziemiecki &

Table 1. Finishing Diamonds Used in This Study

Number	Order Number	Manufacturer	Particle Size	Color Code
1	806314249514012	Komet, Germany	24-40 μm	red
2	806314249504012	Komet	15-30 μm	yellow
3	862UF 314 012	Komet	6-12 μm	white
4	FG 249 C 012	Horico, Germany	40-60 μm	red
5	FG 249 F 012	Horico	35 μm	yellow
6	FG 249 U 012	Horico	10-20 μm	white
7	FG 4205 L 010	Intensiv, Switzerland	40 μm	yellow
8	FG 5205 L 010	Intensiv	15 μm	red

Dennison, 1989). Finishing diamonds and burs are necessary for trimming anatomically structured and concave surfaces such as the lingual surface of anterior teeth or occlusal surfaces of premolars and molars. Finishing diamonds and tungsten carbide finishing burs, ceramically coated finishing instruments, and rotating stones have been recommended for this purpose (Boghosian, Randolph & Jekkals, 1987; Goldstein & Waknine, 1989). These instruments have to meet two completely different requirements: on the one hand, their cutting efficiency must be high enough for the convenient removal of excess material and contouring; on the other hand, the resulting surfaces should not become too irregular or final polishing of the surfaces is difficult. Rotating stones are inappropriate for trimming composite restorations (Lutz & others, 1983) because of frequently occurring eccentricity, which exerts a destructive effect on composite surfaces.

The purpose of this study was to assess the influence of eight diamonds, five tungsten carbide finishing burs, and one ceramically coated finishing instrument on the surface of a small-particle hybrid composite material and to evaluate their corresponding cutting efficiencies.

METHODS AND MATERIALS

Surface Evaluation

Seventy specimens of the small-particle hybrid composite material Herculite XRV (shade A 3.5, Sybron/Kerr, Romulus, MI 48174) were fabricated using 7 x 7 x 4 mm glass molds. The forms were filled in one step and the specimens cured for 1 minute from both sides of the glass mold using a new polymerization unit VCL 401 (Demetron, Danbury, CT 06810). To remove the resin-rich surface zone and achieve a uniform standard, all specimens were surfaced using sandpaper disks (Leco Corporation, St Joseph, MI 49085) of 400- and 600-grit consecutively under water sprinkling for 2 minutes. Trimming the composite specimens in a phantom head was done by one experienced dentist, thus simulating the conditions of a dental practice. Eight finishing diamonds from three different manufacturers were selected for the study (Table 1). The diamonds were either available in three (Numbers 1-3 and 4-6) or in two different particle sizes (Numbers 7 and 8). The tungsten carbide finishing burs were chosen from two manufacturers and had a variety of either straight (Numbers 9-11) or twisted (Numbers 12 and 13) cutting blades (Table 2). The ceramically coated finishing bur (Order Number 35721.08; Kendall, Neustadt/Donau, Germany) was only available as a single type (Number 14). This instrument is a finishing bur for all types of restorative materials. It is available in four different shapes (pointed, flame-shaped, cylindrical, and oval); for our study the pointed shape was used. The manufacturer recommends its use up to 50,000 rpm.

For comparison we treated five additional specimens with flexible Al_2O_3-coated Sof-Lex disks (3M Dental Products, St Paul, MN 55144) of consecutively medium-, fine-, and superfine grit at 4000 rpm in a blue-ring 20L handpiece with a 68LD head (KaVo, Biberach, Germany). This group represented the generally accepted clinical standard.

All finishing instruments were mounted in a new friction-grip red-ring 24LS handpiece with a 2303LD head (KaVo) and were cooled by water spray. All instruments rotated at 50,000 rpm. Five composite

Table 2. Tungsten Carbide Finishing Burs Used in This Study

Number	Order Number	Manufacturer	Number of Blades	Direction of Blades	Color Code
9	500314166071014	Komet, Germany	8	straight	--
10	500314166041014	Komet	16	straight	yellow
11	500314166031014	Komet	30	straight	white
12	500314197072010	Sybron/Kerr, USA	12	twisted	--
13	500314218102010	Sybron/Kerr	30	twisted	--

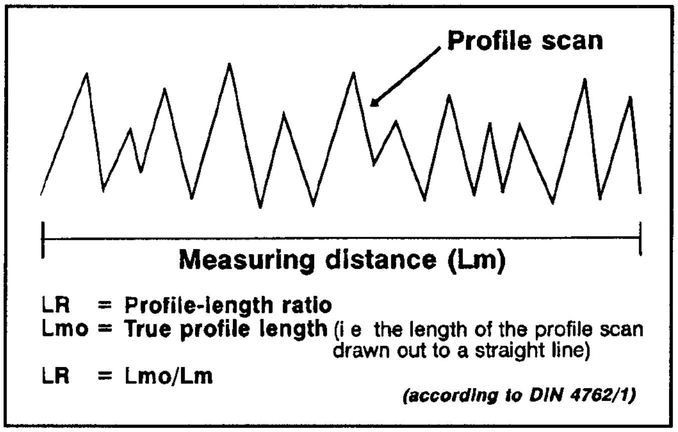

Figure 1. *Schematic description of the term "profile-length ratio (LR)"*

surfaces each were treated with one of the 14 instruments; for each surface a new diamond or bur was used.

Profilometric surface analysis was done quantitatively with the help of a Perthometer S8P (Feinprüf, Göttingen, Germany) using a laser pick-up (Rodenstock, Munich, Germany) with a diameter of 1 µm. Each surface was scanned automatically by nine parallel laser scans 0.22 mm apart at a transverse length of 1.75 mm. The complete transverse length was used for calculating roughness parameters; 1/7th of the transverse length at the beginning and at the end of the scan was excluded from calculation. Thus the measured surface was 1.25 x 1.76 mm; cut-off value was set at 0.25 mm (RC-filter).

Surface smoothness was characterized by the average roughness (Ra) and by the profile-length ratio (LR). According to DIN (German Institute of Standards), the profile-length ratio is defined as the ratio between the true profile length, i e, the length of the profile being drawn out into a straight line, and the measuring distance. Thus the profile-length ratio is a dimensionless parameter (Deutsches Institut für Normung, 1990). An ideal, smooth surface has an LR value of 1; the rougher the surface becomes, the greater the LR-value will be (Figure 1).

For all the results a one-way ANOVA was performed with pairwise contrasts by using Tukey's multiple range test, where the differences were regarded as significant with a probability of $P \leq 0.05$.

Qualitative evaluation of the resulting surfaces was done by SEM using the PSEM 500 (Philips, Eindhoven, The Netherlands) at 25 kV. Microphotographs were taken at an original magnification of X160.

Cutting Efficiency

Another 42 specimens of Herculite XRV (35 x 5 x 4 mm) were ground flat by sandpaper disks of 400- and 600-grit for 2 minutes under moist conditions. In order to mount the specimens to the cutting apparatus, each specimen was pasted to a dental glass plate. After storage in an exsiccator for 48 hours, the weight of the glass plates with the fixed specimens was measured twice by use of the precision balance H20T (Mettler, Giessen, Germany). Thus the weight of the specimens was obtained before sectioning.

Eight finishing diamonds, five tungsten carbide finishing burs, and one ceramically coated finishing instrument as described above (Tables 1 and 2) were tested for cutting efficiency at a rotating speed of 50,000 rpm in a red-ring 24LS handpiece (KaVo) cooled by water spray. Three composite specimens were treated with each of the 14 finishing methods. A new diamond or bur was used for each preparation.

The glass plates with the composite specimens were mounted to a device that permitted preparation under defined and reproducible conditions (Schneidprüfgerät Komet, Lemgo, Germany). Using a constant pressure of 2.5 N, the composite specimens were moved along the adversely rotating finishing instrument (Figure 2). Because of different cutting efficiency, the speed of the samples moving along the rotating instrument differed among the tested diamonds and burs. The time it took the specimens to move once along the rotating instruments was measured. After this procedure the specimens were again stored in an exsiccator for 48 hours so that all the remaining moisture from water cooling was removed. Then the final weight after cutting was measured twice.

The reduction of weight was related to the time it took to move the specimens along the rotating instrument; thus the cutting efficiency was calculated in mg composite/minute. Differences were examined statistically using one-way ANOVA with pairwise contrasts by using Tukey's multiple range test.

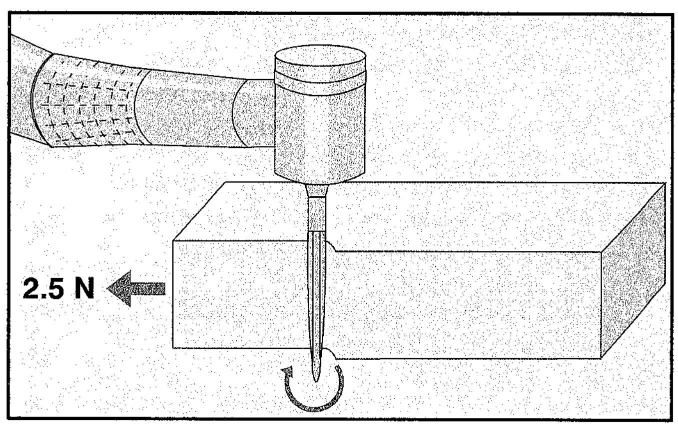

Figure 2. *Schematic drawing depicting trimming composite specimens under reproducible conditions. The arrow indicates the direction in which the specimen was moved.*

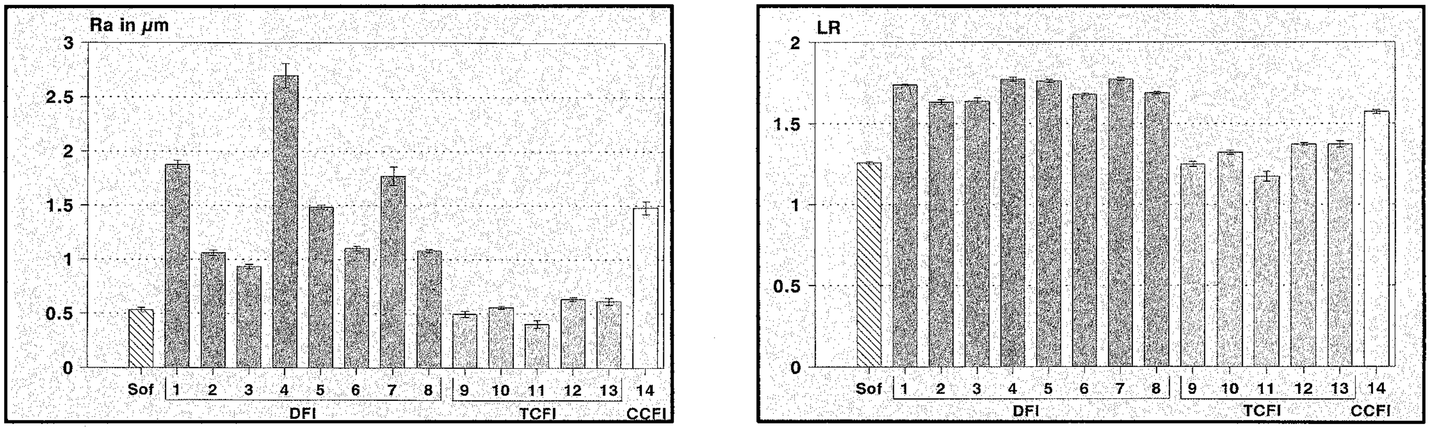

Figure 3. *Graphic presentation of roughness of composite surfaces after trimming with different composite finishing instruments (Sof = Sof-Lex disk; DFI = finishing diamonds; TCFI = tungsten carbide finishing burs; CCFI = ceramically coated finishing bur)* **A**. *Average roughness (Ra)* **B**. *Profile-length ratio (LR)*

RESULTS

Surface Evaluation

Surfaces treated by finishing diamonds were significantly rougher than those treated by tungsten carbide finishing burs (Figures 3A,B). Within the group of finishing diamonds a decreasing size of diamond particles led to significantly smoother composite surfaces. The roughest composite surface was found after the use of diamond Number 4 (Ra = 2.698 µm and LR = 1.773), which had the largest particle size (40 µm - 60 µm). The differences between the diamonds of a single manufacturer were significant except for the pairwise contrast of diamonds Numbers 2 and 3 for Ra. When evaluating LR the differences had the same tendency but were of smaller dimension with no significance being found between diamonds 2 and 3 as well as 4 and 5.

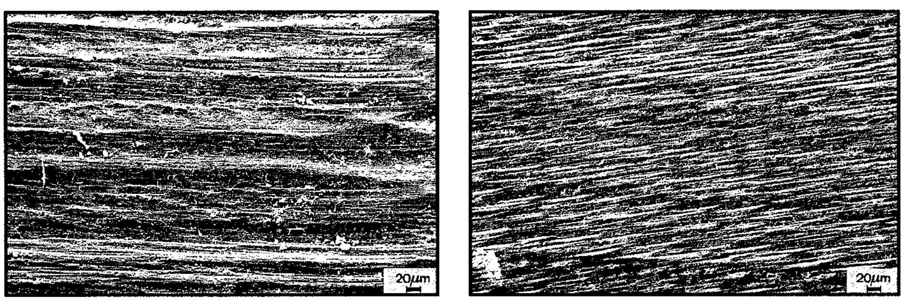

Figure 4. *Composite surfaces after trimming with finishing diamonds* **A**. *Number 4* **B**. *Number 6*

Differences in surface roughness within the group of tungsten carbide finishing burs were much smaller. No significant differences in Ra could be found between burs of a single manufacturer. Finishing bur Number 11 created the smoothest surface (Ra = 0.41 µm and LR = 1.174). The differences in LR compared to all other diamonds and burs were significant. It was interesting to note that the values for Ra and LR of the tungsten carbide finishing burs Numbers 9 and 11 were even lower than those for composite surfaces finished with super-fine flexible Sof-Lex disks, although the differences were not significant. Neither the number of cutting blades nor their direction showed any significance in surface roughness.

The ceramically coated finishing bur produced surfaces similar in roughness to the finishing diamonds.

SEM evaluation demonstrated that the surfaces treated by finishing diamonds showed numerous distinct grooves running parallel to the direction of rotation of the diamond (Figure 4A). With decreasing diamond particle size the number of the grooves increased and their depth decreased (Figure 4B). The surfaces finished with tungsten carbide

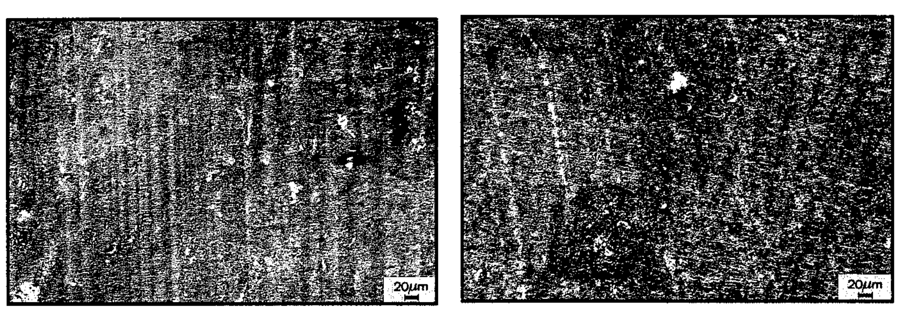

Figure 5. *Composite surfaces trimmed with tungsten carbide burs.* **A**. *With eight blades, Number 9* **B**. *With 30 blades, Number 11*

Figure 6. *Composite surfaces after trimming with a ceramically coated finishing bur (Number 14)*

finishing burs were very homogeneous; surface irregularities were not as distinct as those caused by the diamonds and ran parallel to the axis of rotation (Figure 5A). With a larger number of cutting blades, the surface characteristics did not change significantly (Figure 5B). The use of the ceramically coated finishing instrument resulted in surfaces similar to finishing diamonds (Figure 6).

Cutting Efficiency

Evaluation of the cutting efficiency of the 14 tested finishing methods (Figure 7) showed very clearly that the finishing diamonds achieved significantly

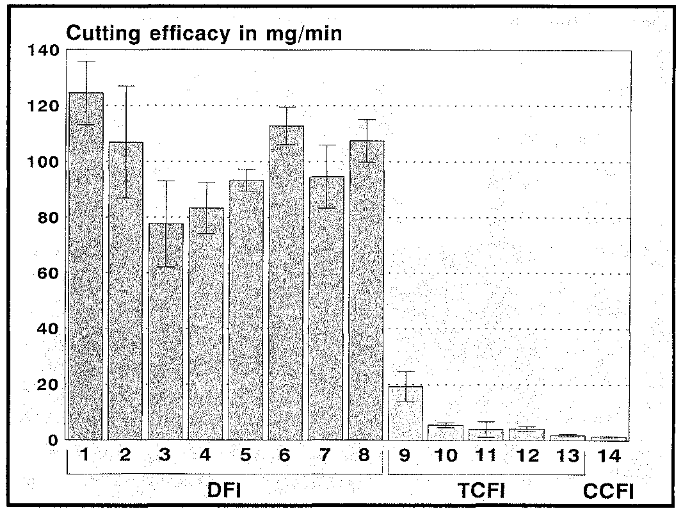

Figure 7. *Graphic presentation of the cutting efficiency of different composite finishing instruments*

higher values than all other methods ($P < 0.01$, Table 3). There was no difference in the cutting efficiency between tungsten carbide finishing burs and the ceramically coated bur ($P > 0.05$). There was a relationship between decreasing cutting efficiency and decreasing diamond particle size only for diamonds Numbers 1, 2, and 3. Although not significant, there

Table 3. Statistical Analysis of the Cutting Efficiency of 14 Finishing Instruments

Rotating Instrument (Number)	14	13	12	11	10	9	8	7	6	5	4	3	2
1	++	++	++	++	++	++	-	+	-	+	++	++	-
2	++	++	++	++	++	++	-	-	-	-	-	+	
3	++	++	++	++	++	++	+	-	++	-	-		
4	++	++	++	++	++	++	-	-	+	-			
5	++	++	++	++	++	++	-	-	-				
6	++	++	++	++	++	++	-	-					
7	++	++	++	++	++	++	-						
8	++	++	++	++	++	++							
9	-	-	-	-	-								
10	-	-	-	-									
11	-	-	-										
12	-	-											
13	-												

Tukey pairwise contrasts; ++ = $P < 0.01$; + = $P < 0.05$; - = $P > 0.05$.

was a tendency towards decreasing cutting efficiency with increasing the number of blades for finishing burs. The direction of the blades had no influence on the cutting efficiency. The highest cutting efficiency was achieved by diamond Number 1 (124 mg composite/min), while the lowest was found to be bur Number 14 (1.3 mg composite/min).

DISCUSSION

Evaluating the suitability of various finishing methods for contouring and finishing small-particle hybrid composite restorations required assessment of surface roughness of the composite surfaces as well as the cutting efficiency of the instruments.

In dentistry surface roughness measurements are usually carried out with the help of profilometry (Drummond & others, 1992; Eide & Tveit, 1988; Goldstein & Waknine, 1989; Jagger & Harrison, 1994; Scurria & Powers, 1994). The evaluation of finely finished surfaces with a great number of shallow grooves demands exact measuring equipment. Mechanical pick-up systems are mostly characterized by a stylus tip width of several microns (5-40 µm). In our opinion this technique is too crude to measure adequately finished and polished surfaces. This is supported by Eckolt (1983), who compared surface roughness measurement by mechanical profilometry to stereoscopic roughness measurement with the help of SEM and found differences ranging from 15-40%. The laser pick-up used in this study with a diameter of 1 µm permitted an exact evaluation of surface roughness.

Another problem in describing surface roughness arises from the fact that common roughness parameters such as average roughness (Ra) or maximum roughness (Rmax) describe roughness mainly or exclusively vertically. The horizontal dimension of roughness, i e, the number of irregularities, remains largely unconsidered. We tried to deal with this problem by characterizing surfaces by the profile-length ratio (LR), which takes into consideration the vertical and horizontal dimension of roughness at the same time. When looking at the roughness values for the finishing diamonds, the differences for Ra between the diamonds were greater than for LR with decreasing diamond particle size. We attributed this to the fact that the increasing number of grooves remained largely unconsidered when calculating the Ra value but did affect the LR value.

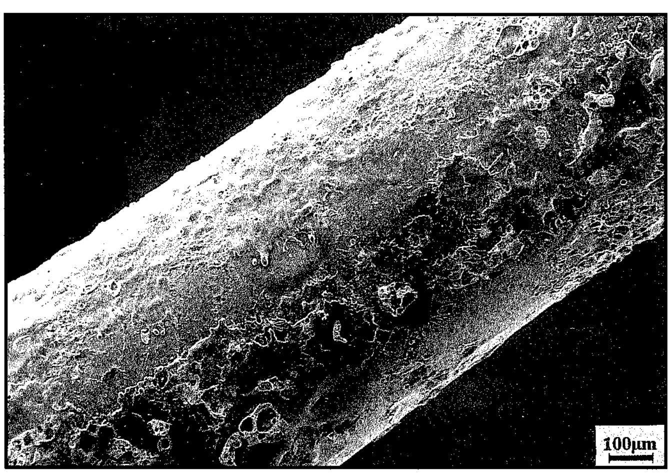

Figure 8. *The cutting part of the ceramic-coated finishing bur (Number 14)*

Finishing diamonds were associated with greater roughness values and a high cutting efficiency. This can be explained by the way these instruments work. They are characterized by a large number of diamond particles that were capable of penetrating the composite material easily at a given pressure. The pressure of 2.5 N chosen for the assessment of cutting efficiency was rather large due to the fact that the tungsten carbide finishing burs and the ceramically coated finishing bur produced no recognizable composite reduction below this level of pressure. Possibly, the relatively high pressure could be responsible for the fact that in this study increasing diamond particle size did not always correlate with a higher cutting efficiency.

When cutting, the tungsten carbide finishing burs contacted the composite surface with the whole length of the cutting blade and were, therefore, not able to remove as much composite at a given pressure as finishing diamonds. This resulted in a low cutting efficiency, but a relatively smooth surface.

Trimming composite restorations comprises steps where gross removal of excess material and contouring is of primary interest. From our results a finishing diamond coated with diamond particles of 15-40 µm seemed to be best suited for these purposes. This permitted a careful, pressureless, and controlled reduction of composite material.

For finishing composite surfaces the achievement of low roughness values is desired. Tungsten carbide finishing burs seemed to be best suited for this purpose. The ceramic-coated finishing bur tested combined a great surface roughness with the lowest cutting efficiency; therefore, this finishing instrument did not satisfy any of the requirements for contouring and finishing composite restorations. This could be due to the nature of the cutting part of the bur. This part of the bur consists of an irregularly shaped ceramic coating. Both a relatively smooth ceramic covering and a more granular coating can be observed (Figure 8). A sufficient cutting efficacy could not be achieved because of the large smooth areas on the bur that were not able to remove the composite material effectively.

CONCLUSIONS

1. Finishing diamonds were associated with a high cutting efficiency and rough corresponding composite surfaces.
2. Tungsten carbide finishing burs produced smooth composite surfaces but showed only poor cutting efficiency.
3. A combination of a finishing diamond with diamond particle sizes of 15-40 μm for the initial steps of gross removal and contouring followed by a tungsten carbide finishing bur for finishing the surface produced the best results.

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Computer-assisted Densitometric Image Analysis (CADIA) of Previously Sealed Carious Teeth: A Pilot Study

J B BRILEY • S B DOVE
E J MERTZ-FAIRHURST • C B HERMESCH

Clinical Relevance
Occlusal dental caries can be arrested by sealing the lesions without decay removal, and the teeth can be maintained up to 10 years.

SUMMARY

Previous studies have shown that occlusal dental caries can be arrested with sealants. Radiographic monitoring must be performed to ensure success. Standardized sequential bitewing radiographs over a 10-year interval of four patients who had sealed composite restorations placed without caries removal were digitized and analyzed using the CADIA algorithm. CADIA values for the 10-year period were analyzed using Analysis of Variance (ANOVA), and showed no significant change in radiographic density for this interval ($P>0.05$), which is suggestive of arrested dental caries.

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INTRODUCTION

Traditional treatment of carious teeth involves removal of the carious tooth structure, preparation of the teeth to receive restorative materials, and placement of the restorative materials. The surgical and restorative concept of treatment had been relatively unchallenged from the G V Black era until investigations of sealing carious teeth without decay removal were undertaken (Handelman, Buonocore & Schoute, 1973; Handelman, Washburn & Wopperer, 1976; Handelman, Leverett & Iker, 1985; Handelman & others, 1986; Leverett & others, 1983; Mertz-Fairhurst & others, 1979a,b, 1987, 1992; Mertz-Fairhurst & Ergle, 1995; Going & others, 1978). These studies suggested that occlusal dental caries can be arrested for up to 10 years by resin sealing. Concerns about this dramatic conceptual change in managing dental caries include assurance that the lesion has truly been arrested. The primary ways to ascertain that this has taken place include some combination of the following: radiographic change, patient symptoms, clinical examination to exclude a defective sealant or open cavitation of the lesion, and biopsy of the lesion with subsequent culture. If the clinical exam and patient symptoms are negative, the least invasive and most practical method to further assess caries activity is with radiographic analysis. Visual identification of density changes is dependent on proper viewing conditions and the ability to detect subtle changes in gray scale. Differences in film contrast and density complicate the visual analysis of sequential radiographs. Radiographic techniques that are able to detect small density changes, and therefore early or incipient caries progression, would lend significant credibility to this concept of dental caries management.

The clinical investigations involving sealing carious teeth have evaluated the radiographic caries progression of the sealed lesions using conventional visual techniques. These studies indicated that there was no radiographic progression of sealed carious teeth when the sealants remained intact (Mertz-Fairhurst & others, 1979b, 1992; Mertz-Fairhurst & Ergle, 1995; Handelman & others, 1973, 1976, 1985, 1986). Mertz-Fairhurst and others' radiographic analysis used standardized radiographs to visually assess change in lesion depth between pre- and postsealed teeth for up to 10 years.

Use of computer technology combined with digital radiographic analysis has led to quantitative techniques for measurement of radiographic density changes. Quantitative techniques have the advantage of eliminating the subjective visual element when evaluating sequential radiographs for minute changes in density; they also generate parametric data, which allows for more robust statistical analysis. One such technique is CADIA, as described by Braegger and others (1987, 1988, 1989); it is based on subtraction of gray values as measured on two radiographs in a 2x2 pixel area. The subtracted values that are greater than the system threshold are recorded and the mean of the subtracted numbers in a selected Area Of Interest (AOI) is the mean gray level change. Change in mineral content of tissue is proportional to gray level change on radiographs. Zubery, Dove, and Ebersole (1993) used a computer-assisted radiographic evaluation (CARE) system, which utilized the CADIA algorithm to detect small density changes in vitro. The system could detect density changes of 0.048 optical density corresponding to 0.27 mm of aluminum thickness or compact bone equivalent. The use of CADIA has not been used to enhance occlusal caries diagnosis, therefore the purpose of this pilot study was to evaluate the radiographic progression of sealed carious teeth over 10 years using this method.

Patient Data--Part I

Patient/ Tooth #	Carious Area	Marginal Integrity--Year 10	Patient Age at Baseline (Years)
1/3	central & distal pits	More than 50% of margins are sealed, no open margin.	11
2/15	central & distal pits	Less than 50% of margins are sealed, open margin is present.	12
3/15	central & distal pits	More than 50% of margins are sealed, no open margin.	21
4/5	distal pit	More than 50% of margins are sealed, no open margin.	26

METHODS AND MATERIALS

Part I

Standardized bitewing radiographs (Mertz-Fairhurst & others, 1979b) of four carious teeth, one in each of four patients, that previously had sealed composite restorations placed without decay removal were used for analysis. A standardized technique was used to reproduce alignment of study tooth, film, and x-ray tube head on successive radiographs by using a film holder alignment apparatus combined with custom fabricated bite blocks. Settings for all radiographs were: 65 KvP, 10 ma, and 1.5 seconds. The radiographs were taken at baseline (preoperative), 6 months, 2, 4, 6, 9, and 10 years. The four teeth and sequential radiographs are a subset of a larger investigation that compared the sealed composite restorations placed over caries with 1) ultraconservative, localized, sealed amalgam restorations with no extension for prevention and 2) traditional unsealed amalgam restorations with the usual extension for prevention outline form. The 10-year results of the larger investigation have been reported (Mertz-Fairhurst & Ergle, 1995). Pertinent details for the four patients are presented in the table. These four patients and teeth had no signs or symptoms clinically or radiographically throughout the 10-year follow-up suggestive of active dental caries progression, i e, provoked pain with cold, hot, or sweets, pulpalgia and/or visual increase in extent

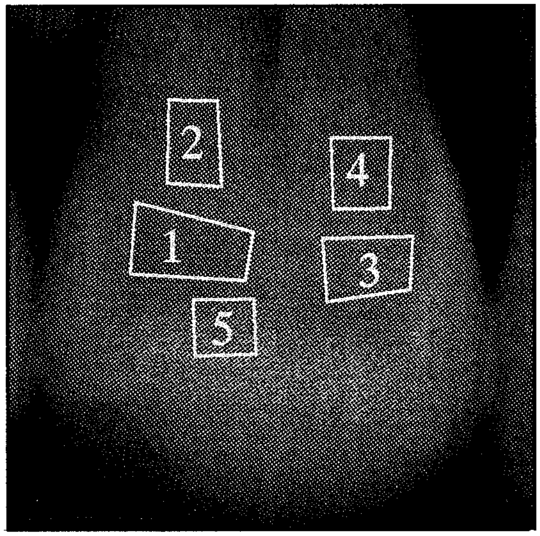

Figure 1. *Part I. AOIs for CADIA analysis on standardized digitized radiographs of 26-year-old woman with caries in distal pit of maxillary right first premolar, same patient as Figures 2A-2D, 3A-3C, and 7D. AOI1: Corresponds to the area of caries immediately apical to the sealed composite restoration that is most visually obvious. AOI2: Negative control apical to AOI1. AOI3: Corresponds to the next most probable carious area. AOI4: Negative control apical to AOI3. AOI5: Positive control corresponding to an area on the sealed composite restoration.*

of lesion radiographically when radiographs were viewed in a normally lighted room with a view box and dark film mounts. From these findings, the previously active caries appeared to have been arrested.

A computer-assisted radiographic evaluation (CARE) system was used to analyze the baseline (preoperative), 6-month, 2-, 4-, 6- and 10-year radiographs. The CARE system is composed of an x,y translation stage, light source, optical lens system, video camera and stand, frame grabber, video monitor, and computer. Radiographs are converted to digital images using a 640 x 480 x 8-bit pixel format with pixel gray levels ranging from 0 (black) to 255 (white). The digital format allows mathematical manipulation of individual pixel values. Corrections for film contrast differences, i e, "gamma" correction, due to errors such as differences in film development, light source variation, photon flux variations, etc, are made using the contrast matching procedure (Ruttiman, Webber & Schmidt, 1986). Sequential radiographs were aligned with the reference image by using a real-time subtraction technique; the radiographs were then digitized and stored in computer memory. CADIA analysis was then performed on areas of interest (AOIs) for each radiographic image (five different AOIs were analyzed per radiograph). The baseline radiograph served as the reference radiograph from which all subsequent radiographs were compared. AOI1 corresponded to the area of caries immediately apical to the sealed composite restoration that was the most visually apparent; AOI2 was a negative control apical to AOI1, which, after visual analysis of the 10-year digitized radiographs, showed no apparent radiographic change; AOI3 corresponded to the next most probable carious area, either mesial or distal to AOI1 and at approximately the same occluso-apical position; AOI4 was a negative control apical to AOI3 which, after visual analysis of the 10-year digitized radiographs, showed no apparent radiographic change; AOI5 was a positive control and corresponded to an area on the sealed composite (radiopaque) restoration that was expected to be more radiopaque compared to the preoperative baseline radiograph (Figure 1). The five AOIs formed a custom template that was superimposed over the sequential radiographs for each tooth. CADIA values (mean gray level change x affected area of change) were then calculated for all AOIs on each sequential radiograph. ANOVA was used to determine if any statistically significant change occurred in CADIA values over time for each AOI. Samples of sequential intraoral photographs for a patient are presented in Figures 2A-2D, and samples of sequential digitized radiographs for the same patient are presented in Figures 3A-3C. The four patients and teeth offered an opportunity to evaluate whether analysis of CADIA values over time would detect similar results as conventional clinical and radiographic findings.

Part II

If a restoration failed during the 10-year study, it was replaced or repaired. All but one patient (age 15 years at baseline) complied with recommended intervention. This uncooperative patient with a failed sealed composite restoration, which had been placed over caries in the central and distal third areas of the occlusal surface, refused to allow repair or replacement to be done from year 4 through year 10. The restoration was considered a clinical failure at year 5. The patient continued to allow clinical evaluations and radiographs of the area to be done (Figures 4A-4F). The radiographs were taken in a standardized manner as described above.

The radiographs of this noncomplying patient offered the opportunity to evaluate whether analysis of CADIA values over the 10-year interval would detect radiographic change when caries progression was occurring. After digitizing the radiographs as described above (Figures 5A-5F), AOIs were selected similar to those described in Part I (four AOIs were selected) and CADIA analysis was done on each AOI. AOI1 corresponded to a positive control that included the radiopaque sealed

Figures 2A to 2D. *Part I. Intraoral photographs, same patient as in Figures 1, 3A-3C, and 7D.*

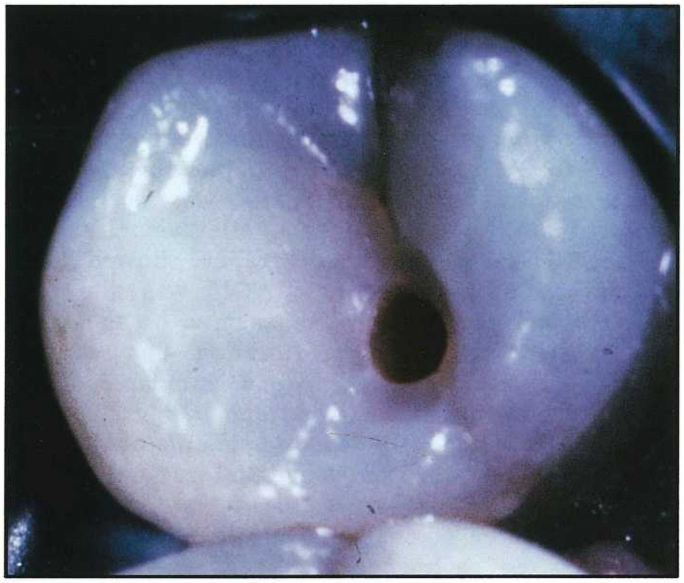

Figure 2A. *Preparation at baseline. A bevel has been placed in enamel. Soft caries is left inside below the enamel bevel.*

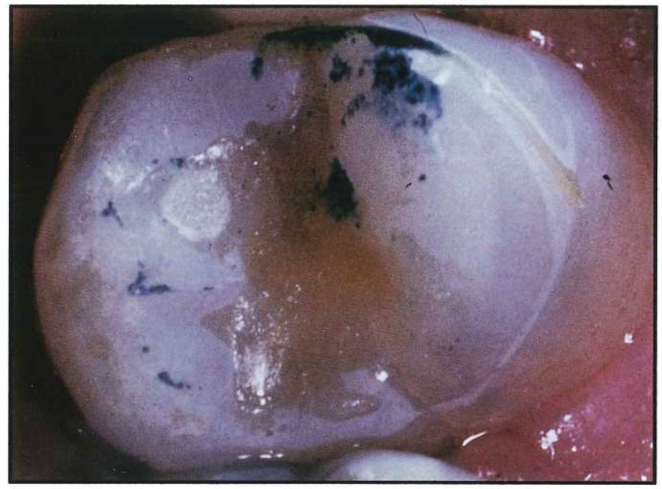

Figure 2B. *Sealed composite restoration at baseline. A flash of composite resin extended into the sound mesial pit area prior to sealant placement; it was deemed unnecessary to remove this flash. Restoration is completely sealed.*

Figure 2C. *Restoration at 4 years. All margins are sealed, but there is a bare area in the middle.*

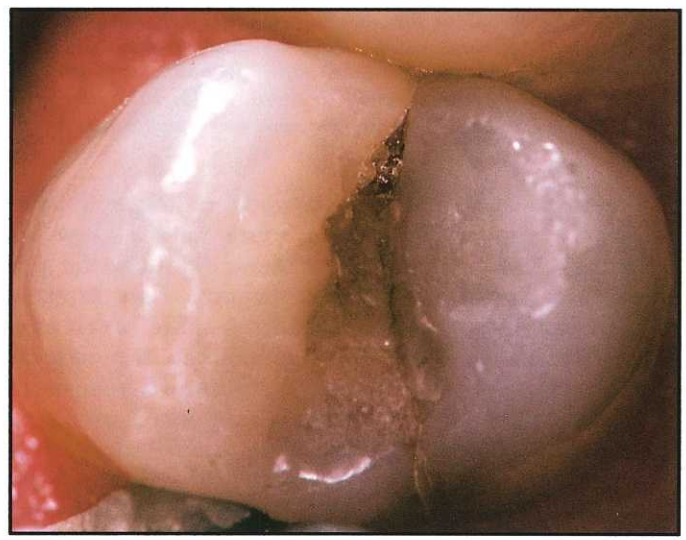

Figure 2D. *Restoration at 10 years. More than 50% of margins are sealed, no open margin. Breakdown of composite flash area is noted; should remove flash and reseal this area.*

composite restoration and was expected to be more radiopaque compared to the preoperative baseline radiograph. AOI2 was a negative control in the dentin mesially which, after visual analysis of the 10-year sequential radiographs, showed no apparent radiographic change. AOIs 3 and 4 corresponded to the dentin under the central and distal occlusal pits respectively that had extensive carious involvement at the 10-year follow-up (Figure 6). The CADIA analysis was compared to visual analysis of the radiographs to determine if radiographic change could be detected earlier with CADIA.

RESULTS

Part I

Results are presented in Figures 7A-7D and indicate that there was no significant change in CADIA values over the 10-year period for AOIs 1, 2, 3, 4, 5 for each patient ($P > 0.05$). The positive control, AOI5, showed no change in CADIA value over time ($P > 0.05$) and also showed relatively large positive CADIA values consistent with its role as a positive control except for patient 1. The baseline radiograph of patient 1 was underexposed (radiopaque)

Figures 3A-3C. *Part I. Standardized digitized radiographs, same patient as in Figures 1, 2A-2D, and 7D.*

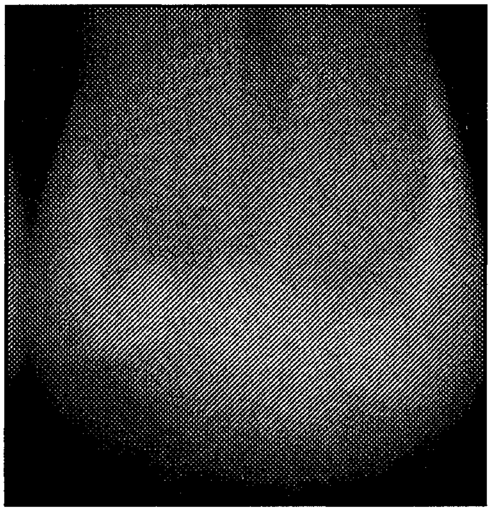

Figure 3A. *Preoperatively at baseline, a radiographically observable radiolucency is apparent in the distal pit of the maxillary first premolar, which corresponds to the clinical area of caries. The smaller radiolucency apparent in the mesial pit area has been previously described as representing the Mach band effect (Mertz-Fairhurst & others, 1992).*

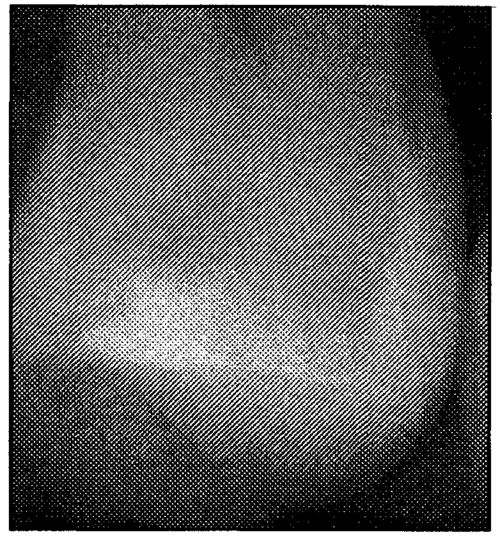

Figure 3B. *Year 4. Lesion appears slightly lighter than baseline; however, the entire radiograph is lighter also. The sealed composite restoration is apparent.*

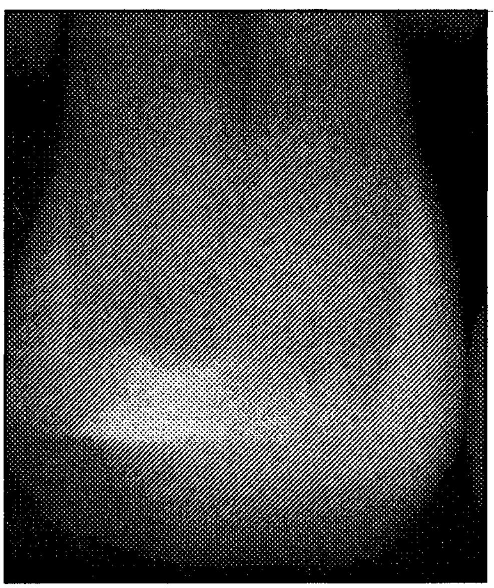

Figure 3C. *Year 10. No apparent visual change in lesion compared to baseline.*

especially in the area that the composite restoration was subsequently placed; this had the effect of masking out the relative appearance of the composite in this area on subsequent radiographs and, when combined with the small relative area of the AOI, contributed to the low positive CADIA values in AOI 5 (Figures 7A-7D).

Part II

Results are presented in Figure 8 and indicate that AOI1 (positive control) and AOIs 3 and 4 (corresponding to areas of extensive carious destruction) had large negative increases in CADIA values at the 10-year point, which is consistent with ongoing tooth demineralization. AOI4 had a large negative increase in CADIA value at 4 years (10, -6, and -12 at 6 months, 2 years, and 3 years respectively, then -49 at 4 years), which suggests advancing carious activity at this time. AOI1 had similar large positive CADIA values for the first 4 years (range 54 to 62) consistent with its role as a positive control; the extensiveness of the carious process caused loss of tooth structure and the restoration then caused more negative CADIA values throughout the remainder of the evaluation (-2 at 5 years, 7 at 9 years, -239 at 10 years). The negative control, AOI2, showed similar CADIA values (range 2 to 13) until year 10 when it had a large increase to CADIA value of 63.

DISCUSSION

CADIA values (mean gray level change x affected area of change within an AOI) are relative numbers that have meaning only when compared within the same AOI on the same patient. In order to make valid comparison between different AOIs or patients, a reference standard must be present in the image. The reference standard provides a

Figures 4A-4F. *Part II. Intraoral photographs of patient with advancing caries; same patient as in Figures 5A-5F and 6. Note: Ideal photographs were not possible due to patient being uncooperative.*

Figure 4A. *Tooth #19 preoperatively at baseline. Confluent caries is evident involving the occlusal central and distal pit areas. No baseline postoperative photos available.*

Figure 4B. *Restoration at 1 year. More than 50% of margins remain sealed; open margin is present in distal area. Area resealed at this time.*

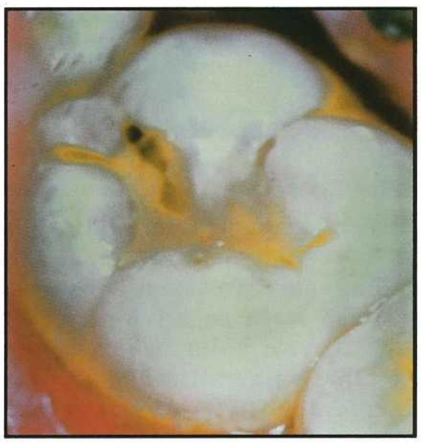

Figure 4C. *Restoration at 4 years. More than 50% of margins remain sealed; open margin is present in distal area. Patient refused to allow repair or replacement to be done from year 4 throughout the remainder of the study.*

Figure 4D. *Restoration at 6 years. Considered a clinical failure at year 5: loss of some composite material. Study restoration was scheduled for replacement with extirpation of caries, but patient broke numerous appointments and stated she would accept treatment for this tooth "only when it hurts."*

Figure 4E. *Restoration at 9 years. Large open lesion present involving occlusal central and distal areas, lingual and distal surfaces.*

Figure 4F. *Restoration at 10 years. Very large open lesion present with extensive involvement of occlusal, lingual, and distal surfaces.*

Figures 5A-5F. *Part II. Standardized digitized radiographs, same patient as in Figures 4A-4F and 6. Note: Radiographs were not available to chronologically match clinical photographs in Figures 4A-4F.*

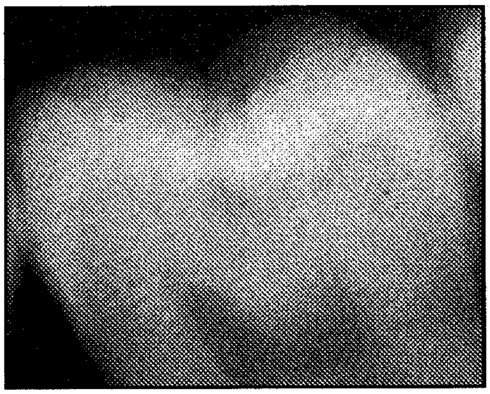

Figure 5A. *Preoperatively at baseline. A radiographically observable radiolucency is apparent corresponding to caries in the occlusal central and distal pit areas.*

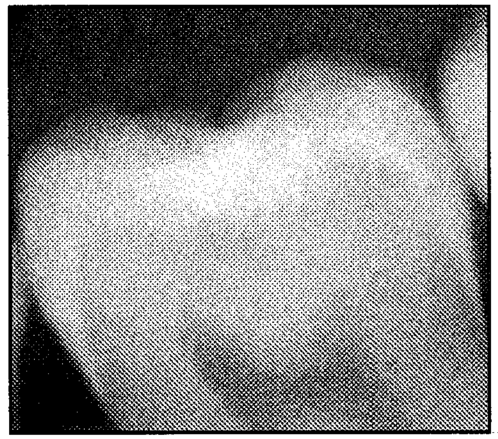

Figure 5B. *Year 2. No apparent visual change in lesion compared to baseline.*

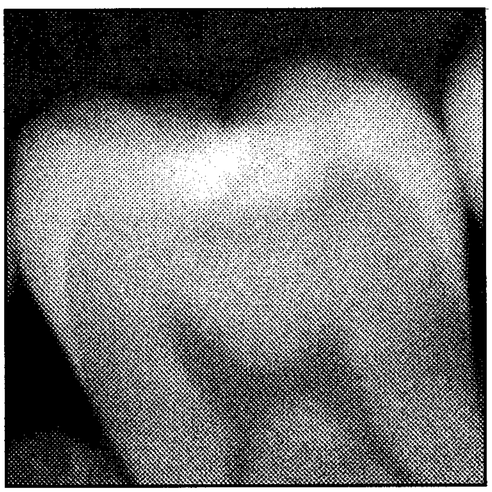

Figure 5C. *Year 4. Slightly darker and larger than baseline*

Figure 5D. *Year 5. Slightly darker and larger than baseline*

Figure 5E. *Year 9. Obviously darker and larger than baseline*

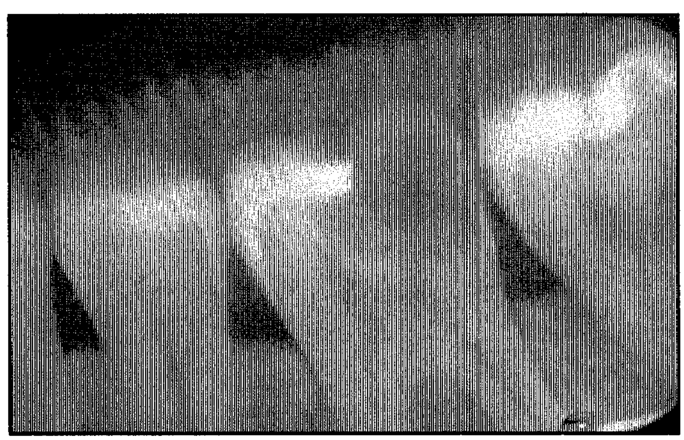

Figure 5F. *Year 10. Obviously darker and larger compared to year 9 radiograph*

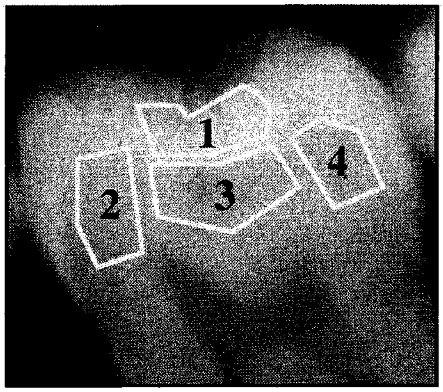

Figure 6. *Part II. AOIs for CADIA analysis on standardized digitized radiographs of 15-year-old woman with carious lesion in the occlusal central and distal pit areas of the mandibular left first molar. Same patient as in Figures 4A-4F and 5A-5F. AOI1: Positive control corresponding to an area on the sealed composite restoration. AOI2: Negative control in mesial area. AOI3: Corresponds to area of caries in the occlusal central pit area. AOI4: Corresponds to area of caries in the occlusal distal pit area.*

method to convert gray level to aluminum thickness or compact bone equivalent (Webber, Ruttimann & Heaven, 1990). Once the gray levels are converted to standard values, they can be directly compared by statistical methods. For the purpose of this investigation, however, standardization was not possible because of the retrospective nature of the image data. CADIA was used as a relative measure of radiographic stability over the 10-year period.

The relative activity of the carious lesion can be accessed radiographically using CADIA. No change in CADIA values over time indicates that caries activity has been arrested, an increase in CADIA values indicates remineralization, and a decrease indicates caries progression.

All four of the sealed carious teeth in Part I had clinical and radiographic signs and symptoms consistent with arrested dental caries. CADIA values did not change significantly ($P>0.05$) over the 10-year interval for any of these teeth in any AOI, which implies radiographic stability and arrested caries.

CADIA analysis was able to detect caries

Figures 7A-7D. *Part I, CADIA analysis results: No significant change ($P > 0.05$) in CADIA values over 10-year interval for AOIs 1, 2, 3, 4, 5 for each patient.*

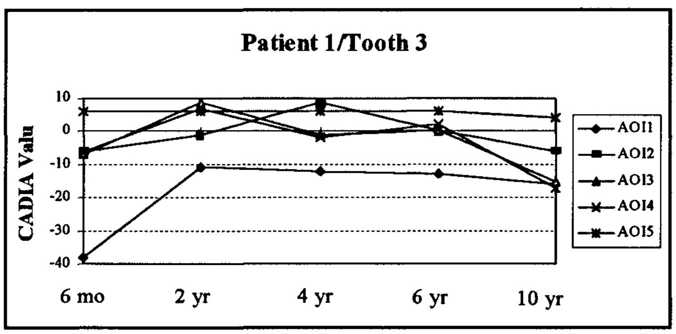

Figure 7A. *Patient 1/Tooth #3*

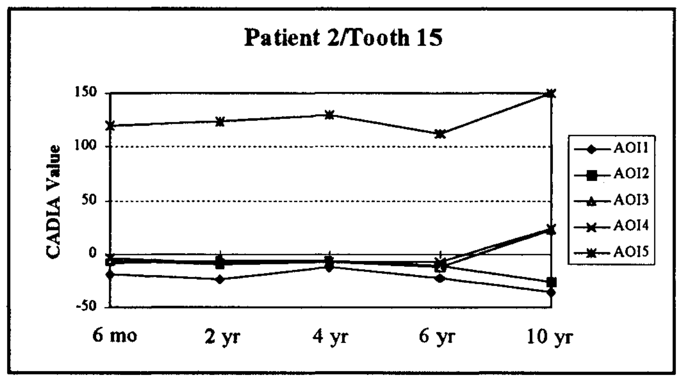

Figure 7B. *Patient 2/Tooth #15*

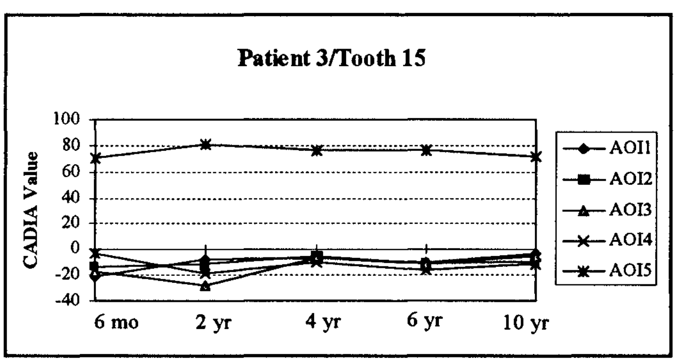

Figure 7C. *Patient 3/Tooth #15*

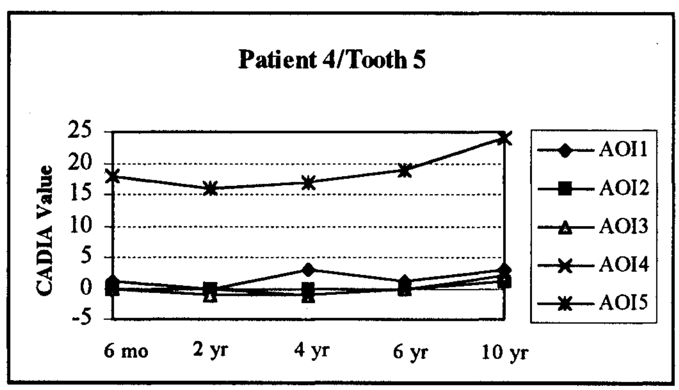

Figure 7D. *Patient 4/Tooth # 5 (same patient as in Figures 1, 2A-2D, and 3A-3C)*

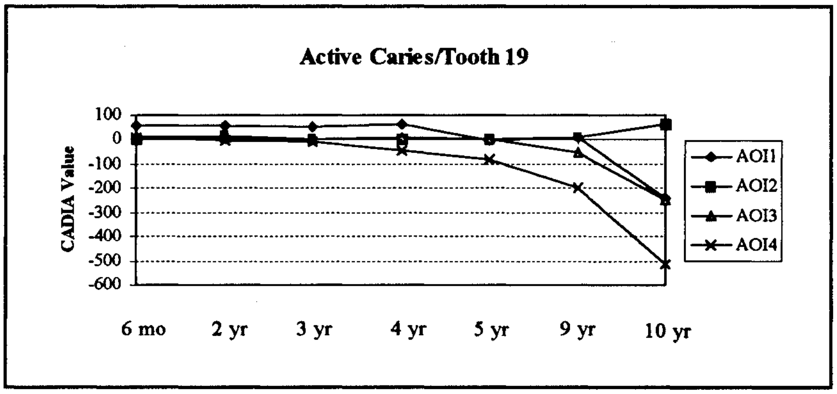

Figure 8. Part II. CADIA analysis results.

progression when active caries was present as indicated in Part II of this investigation. Three observers using a viewbox and film masking were unable to detect significant radiographic change until year 9; however, analysis of CADIA values suggested significant change as early as year 4. It should be noted that no radiographs were taken of this subject at year 6 (pregnancy) or at year 7 and 8 (due to lack of funding). Radiographic detection by visual inspection may have been possible at these earlier intervals.

It is interesting to note that in Part II of this study the negative control (AOI2) had a large increase in the CADIA value at year 10. This increase could represent an artifact in measurement or remineralization of the dentin in an attempt to wall off the advancing dental caries.

Conventional restorative dentistry has many negative consequences such as need for local anesthesia, time-consuming appointments, obtrusive noise and vibration, irreversible tissue removal, potential of creating dental phobias, pulpal reactions, susceptibility of marginal breakdown, recurrent caries, periodontal complications, fractured restoration/tooth, and tooth loss. Protocols for more conservative therapies for dental caries management have recently been presented by Anderson, Bales, and Omnell (1993) and Anusavice (1995). Anderson and others espouse a concept of caries management which favors a "medical model" rather than the traditional "surgical model." Anusavice emphasizes monitoring the progress of carious lesions to determine the activity status in conjunction with controlling the infectious process. Remineralization or "tooth healing" are concepts both Anderson and others and Anusavice espouse in their protocols, which emphasize topical antimicrobials and fluorides. These concepts have risks also; patients not complying with frequent recall and recommended home care could become "lost" with the potential for continued and/or recurrent caries activity. Patient selection is therefore critical when choosing this approach.

Conservative therapies that arrest and/or heal carious lesions will require ongoing monitoring and evaluation of the carious area to ensure continued arrestment. Certainly radiographic analysis will be an important part of this process and practical and objective techniques with high caries-predicting capabilities are the ideal. Recent advances in imaging technology may provide improved detection and diagnosis for the clinician. The ramifications of this conceptual change for dental caries management dictate that further analysis of this study population and others be done to move these emerging techniques and technologies from the research to the clinical arena.

CONCLUSIONS

1. The CARE system using CADIA can be readily adapted for longitudinal caries analysis.
2. Analysis of CADIA values over time on bitewing radiographs of four teeth, one on each of four patients, revealed no caries progression and corroborated findings of a clinical study that evaluated sealed composite restorations for 10 years without removal of caries.
3. Analysis of CADIA values over a 10-year period detected caries progression on a tooth with advancing dental caries and detected it earlier than conventional viewing of bitewing radiographs.

The views expressed in this article are those of the authors and do not reflect the official policy of the Department of Defense or other departments of the U S Government.

At the time of this study (June 1992 - June 1994), Dr Briley was a second-year resident in Advanced Education in General Dentistry Residency, Wilford Hall Medical Center, Lackland AFB, TX 78236-5551.

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The Anticariogenic Effect of Fluoride in Primer, Bonding Agent, and Composite Resin in the Cavosurface Enamel Area

S-H PARK • K-Y KIM

Clinical Relevance
The use of glass-ionomer cement may prevent the initial caries on the cavosurface enamel margin, whereas composite resins that include fluoride in the primer, bonding agent, or composite resin may not prevent it.

SUMMARY

The role of fluoride in the prevention of initial caries is well known in dentistry. This study was designed to evaluate the anticariogenic effect of fluoride in primers, bonding agents, composite resins, and glass-ionomer cements in enamel. Twenty-five extracted teeth that had no cracks, white spots, or enamel defects were selected. A 2 x 3 x 1.5 mm cavity was prepared on either the buccal or the lingual surface of each tooth. After pumicing, tooth enamel was etched with 37% phosphoric acid gel for 30 seconds, and the samples were divided into five groups. The samples were primed, bonded, and filled using ART Bond and Brilliant Enamel in group A, OptiBond and Herculite XRV in group B, Syntac and Tetric in group C, Scotchbond Multi-Purpose and Z100 in group D, and a resin-modified glass ionomer (Fuji II LC) in group E. All surfaces except a 2 mm zone adjacent to the cavosurface margin of each sample was protected with nail varnish, and samples were then placed into a buffered solution for 3 days to develop the initial caries. The samples were then sectioned through the restoration faciolingually into wafers that were approximately 300 µm in thickness then thinned to 150 µm. These thin samples were then examined with a polarizing microscope under water imbibition. The fluoride in primer, bonding agent, and composite filling material did not prevent the initial caries in the enamel area adjacent to the restoration, whereas the fluoride in the glass ionomer did prevent the initial-stage caries.

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INTRODUCTION

Since it is well known that fluoride is effective in preventing initial caries, it has been used as a preventative measure in water fluoridation, topical fluoride solutions and gels, and via iontophoresis. In addition, fluoride has been incorporated into restorative materials such as silicate (Forsten & Paunio, 1972), glass ionomer (Wilson, Groffmann & Kuhn, 1985), amalgam (Forsten, 1976), and composite resin

(Rawls & Zimmerman, 1983) in an effort to prevent secondary caries.

Polymerization contraction and weak bonding to dentin and cementum are undesirable characteristics of composite resin materials. Fluoride has been incorporated into these materials in an effort to prevent secondary caries. Research is ongoing to determine the viability of using fluoride in this manner. The first trial involved a fluoride-exchanging resin system (Rawls & Zimmerman, 1983). This system was adequate for fluoride release but has not been widely used due to the general properties of the composite. The second trial involved applying a fluoride solution to the tooth surface before composite bonding (Shen, 1985). However, this approach was impractical (Arends & Ruben, 1988) and the bond strength to the tooth was poor (Nystrom, Holtan & Douglas, 1990). A third method involved incorporating fluoride into a composite resin filler. In this type of composite resin, it was suggested that fluoride be deposited adjacent to the enamel in a gap-simulating situation (Arends & van der Zee, 1990) and that demineralization of the tooth would thus be prevented (Dijkman & Arends, 1992). In experimental sealants, fluoride ions that are released slowly by hydrolysis are reported to be incorporated into the adjacent enamel (Tanaka & others, 1987). There has been a recent market penetration involving products in which the sodium fluoride is incorporated in the primer and in which boron fluoride is included as the bonding agent filler.

Many reports conclude that these composite resins have anticariogenic effects on the adjacent enamel. The following claims have been made: that fluoride is released (Arends & Ruben, 1988; Temin & Csuros, 1988), that fluoride is deposited in the enamel and dentin (Arends & van der Zee, 1990; Capilouto, DePaola & Gron, 1990), and that smaller amounts of hard tissue loss result from usage (Dijkman & Arends, 1992; Tanaka & others, 1987). However, composite resins release much less fluoride than glass-ionomer cement (Forsten, 1990), and most of this may be washed out from the oral cavity. Thus, it has more clinical relevance to observe microscopically whether fluoride that is released from the composite will prevent the initial caries on adjacent tooth structure.

This in vitro study was designed to evaluate the effect of fluoride in primers, bonding agents, and composite filling materials in situ on prevention of initial caries in cavosurface enamel compared to using glass ionomer for prevention.

Table 1. Description of the Materials

Experimental Group	Priming/Bonding Material	Restorative Material	Characteristics	Manufacturer
A	ART Bond	Brilliant Enamel	F in primer	Coltène AG, Altstätten, Switzerland
B	OptiBond	Herculite XRV	F in bonding agent	Kerr, Romulus, MI 48174
C	Syntac	Tetric	F in composite resin filler	Vivadent, Schaan, Liechtenstein
D	Scotchbond Multi-Purpose	Z100	No F	3M Dental Products, St Paul, MN 55144
E		Fuji II LC	F in matrix	GC Int'l Corp, Tokyo, Japan

METHODS AND MATERIALS

Twenty-five extracted teeth, which were within 7 days of extraction and had no cracks, white spots, or enamel defects were selected. After removal of calculus and stain with a hand instrument, each tooth was cleaned with pumice without fluoride in its component and stored in a 0.5% chloroform solution. Cavity preparations with dimensions of 2 x 3 x 1.5 mm were prepared on either the buccal or the lingual surface of

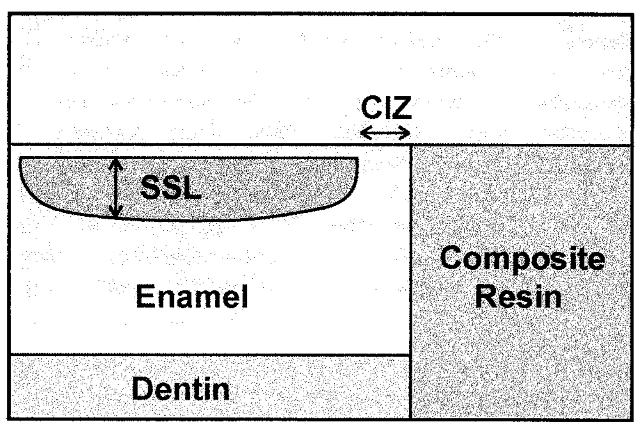

Figure 1. *Diagrammatic representation of caries inhibition zone and subsurface lesion. SSL = subsurface lesion; CIZ = caries inhibition zone.*

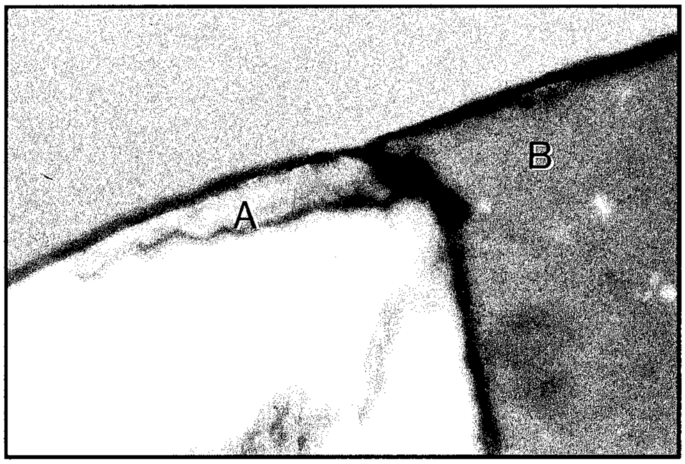

Figure 2. *Samples in groups A, B, C, and D show subsurface lesions that extend to the restoration. A = subsurface lesion; B = composite resin.*

each tooth with carbide burs. The teeth were cleaned with pumice again and the cavosurface margins of the preparations were contoured to provide butt-joint margins, which were then finished with hand instruments. The samples were divided into five groups (Table 1). In groups A, B, C, and D, the enamel of the cavity walls was etched with 37% phosphoric acid gel (Etchant Gel, Coltène) for 30 seconds. The preparations were then primed, bonded, and filled using the ART Bond system and Brilliant Enamel composite resin in group A, OptiBond and Herculite XRV in group B, Syntac and Tetric in group C, and Scotchbond Multi-Purpose and Z100 in group D (Figure 1). In group E, the preparations were filled with resin-modified glass-ionomer cement (Fuji II LC). In all groups, the restoration materials were light cured for 60 seconds. After the composite resin or glass ionomer was cured, the cavosurface margins were trimmed with a #15 blade to make sure that there was no flash extending over the margin. All samples were stored in water for 24 hours. In group E, the surface of the glass-ionomer cement had been protected with petroleum jelly before water storage. The surface of each specimen was then cleaned by irrigation and light pumicing, and all surfaces except the 2 mm beyond the cavosurface margin of the sample were protected with water-resistant nail varnish. The samples were then immersed in a caries-activating solution for 3 days at 25 °C. The composition of this solution was based on a previous study (Park, Lee & Lee, 1993): pH 4.3, lactic acid 100 mM, calcium chloride 16 mM, potassium phosphate 8mM, sodium azide 3mM, and degree of saturation 0.15. The samples were then sectioned with a microtome (Maruto, Tokyo, Japan) faciolingually through the restoration into wafers that were about 300 µm thick. Sections were thinned with SiC paper to 100-150 µm. The samples were then observed using a polarizing microscope under water-imbibed conditions.

Table 2. Number of Samples That Showed Caries Inhibition Zone around Cavosurface Margin

Group	Caries Inhibition Zone around Cavosurface Margin			n
	Present	Not Present	Sample Failed	
A	0	4	1	5
B	0	5	0	5
C	0	5	0	5
D	0	4	1	5
E	4	0	1	5

RESULTS

All samples in groups A, B, and C, and control group D demonstrated subsurface carious lesions that extended to the restoration (Table 2, Figure 2). In some samples, it was clearly noted that the initial caries began at the cavosurface margin (Figure 3); however, the subsurface lesion extended short of the restoration in group E (Figure 4). The depth of the subsurface lesions in all samples was about 70 µm (Table 3).

DISCUSSION

There are two main arguments regarding the anticariogenic effect of fluoride in composite resin.

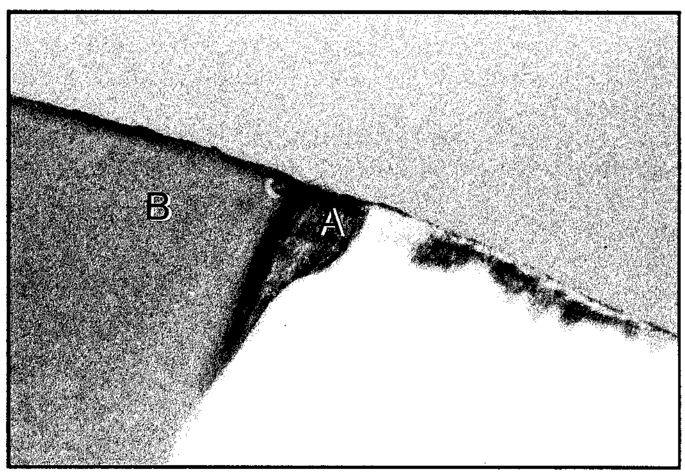

Figure 3. *In some samples in groups A, B, C, and D, the initial caries extended more deeply into the cavosurface. A = subsurface lesion; B = composite resin.*

Table 3. Average Depth (µm) of Subsurface Lesion

Group	Depth of Subsurface Lesion $\overline{X}$	sd
A	70	15
B	70	10
C	65	15
D	70	10
E	70	10

Groups joined by vertical lines were not significantly different at the $P = 0.05$ level.

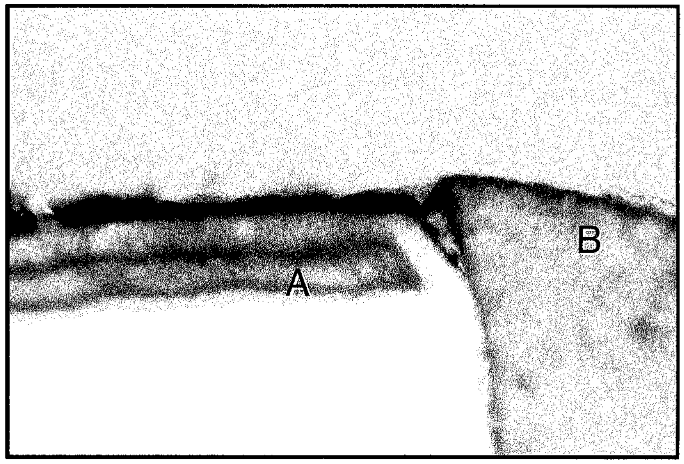

Figure 4. *Samples in group E show the subsurface lesion, which extends short of the restoration. A = subsurface lesion; B = glass ionomer.*

The first one is that sodium fluoride can inhibit the growth of *Streptococcus mutans* and reduce the adhesion of bacteria to the resin (Bapna, Murphy & Mukherjee, 1988). Another study reports, however, that while the fluoride-containing resin liner does not inhibit *Streptococcus mutans* growth, glass-ionomer cement does inhibit it (DeSchepper, White & von der Lehr, 1989).

The second major argument supports the view that fluoride is transferred from the surface of the composite resin, deposits to the tooth surface, and thus prevents tooth demineralization. It is shown in in vitro studies that the fluoride deposits onto the adjacent enamel when the 200 µm artificial gap is formed between the fluoride-containing composite filling material and the tooth chip (Arends & van der Zee, 1990). However, if microleakage occurs around the restoration under clinical circumstances, the opportunity for the fluoride to deposit onto the adjacent enamel will be greatly reduced, because the intraoral condition is not as static as that of this experiment.

In this study, the Tetric compound did not create an anticariogenic effect on the adjacent enamel. We believe that the reason for this was that the bonding agent blocked the transfer of fluoride into teeth, and that the amount of released fluoride from Tetric was not sufficient to prevent the initial caries. The release of fluoride from the composite was much less than that released from the glass-ionomer cement (Forsten, 1990).

In OptiBond, boronfluoride fillers are incorporated in the bonding agent. They did not prevent the initial caries at the cavosurface margin in our study. This result is inconsistent with results reported by Capilouto and others (1990). They report that fluoride is released slowly from the resin matrix and deposited on deeper enamel than the contralateral tooth. However, the contralateral tooth may not be a proper control, because the amount of fluoride differs from tooth to tooth and fluoride concentrations differ from area to area on the same tooth.

In ART Bond, sodium fluoride is mixed with maleic acid in the primer, and the manufacturer insists that sodium fluoride infiltrates the tooth structure when the maleic acid primes the tooth. The fluoride may infiltrate deeply into the dentin while the maleic acid dissolves the smear layer, but no anticariogenic effect was observed in the enamel.

In this study, only caries prevention in enamel was examined, so the results do not elucidate the effect of fluoride in the form of YbF, boronfluoride, or NaF on dentin or cementum. It has been reported that fluoride infiltrates more effectively into dentin than enamel, because dentin has dentinal tubules and a lower mineral component (Skartveit & others, 1990; Tveit & Totdal, 1981). Thus, the fluoride component in primers, bonding agents, and/or composites may still have a preventive effect on dentin or cementum (Jensen & others, 1991; Shibatani & others, 1989).

Many clinical papers have reported a lower rate of caries around glass-ionomer restorations compared to composite resin. Mejàre and Mjör (1990) reported that when the glass ionomer was used as a fissure sealant, no recurrent caries occurred, even though 84% of the glass ionomers were lost; on the other hand, more caries occurred around the resin-based sealant even though the retention rate was higher. At 5 years in a study of class 5 restorations, only 1% showed recurrent caries when glass-ionomer cement was used, whereas 6% became carious when composite resin was used (Tyas, 1993). The reason for the cariostatic activity of glass ionomers is thought to be the slow release of fluoride over a prolonged period (Swift, 1989) and the reduction of acidogenecity of plaque, leading to the inhibition of *Streptococcus mutans* (Svanberg, Mjör & Ørstavik, 1990). However, one study has indicated that the amount of fluoride in plaque adjacent to the glass ionomer is not high enough to inhibit the *Streptococcus mutans* (van Dijken, Persson & Sjöström, 1991). In our study, when the preparations were filled with glass-ionomer cement, only the cavosurface margin area showed anticariogenic potential, even though a broader area was exposed to acid. This could indicate that the amount of fluoride that is deposited at the cavosurface area is more important in preventing caries than the amount of fluoride that is released from the surface of the glass-ionomer cement.

The method of producing artificial caries that was used in this study was based on previous studies by Margolis and Moreno (1985) and Margolis, Murphy, and Moreno (1985). This method was so effective that it took only 3 days to develop artificial initial caries. However, this might have affected the results, because artificial caries was developed more rapidly than in in vivo conditions.

CONCLUSIONS

Using an acid solution to produce artificial caries, the fluoride that was incorporated in the primer, bonding agent, and composite resin did not prevent formation of initial caries on the cavosurface enamel margin of class 5 restorations. However, initial caries was prevented when glass-ionomer cement was used.

Acknowledgment

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Fit of Veneers Made by CAD-CAM and Platinum Foil Methods

P S SUH • R JOHNSON • S N WHITE

Clinical Relevance
The fit of CEREC CAD-CAM glass-ceramic veneers was very slightly inferior to platinum foil porcelain veneers.

SUMMARY

Veneers were fabricated by CEREC CAD-CAM and the platinum foil techniques for standardized preparations on 10 artificial teeth. Mesial preparation contacts were broken, but distal contacts remained intact. The veneers were cemented in a standardized manner to their teeth. The veneers and their attached cement were embedded in epoxy resin and sectioned twice gingivally-incisally and mesially-distally to produce eight sections. Three-way ANOVA disclosed that the main effects of fabrication method, section location, and measurement point location as well as all interaction terms significantly affected fit ($P < 0.05$). However, the difference in mean overall fit between the fabrication methods was too small to be of clinical importance. Restoration of the broken approximal contact did not compromise fit. Incisal margins had the greatest marginal openings. Surface measurement point locations were less well adapted than internal locations. Fit maps for CEREC and platinum foil veneers were strikingly similar.

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INTRODUCTION

Porcelain veneers, first introduced by Dr Charles Pincus in the 1930s, are now a widely used, predictable, conservative, and esthetic treatment modality for anterior teeth (Calamia, 1989; Karlsson & others, 1992; Dunne & Millar, 1993). Porcelain veneers can be made in several different ways, including conventional porcelain build-up, casting, and computer-aided design/computer-aided manufacturing (CAD-CAM) techniques. Porcelain can be applied directly to refractory models or to platinum foils carefully adapted to stone casts and fired conventionally. Porcelain build-up techniques allow internal characterization, but this demands much time and technical skill. Alternatively, CAD-CAM methods can quickly form veneers from monolithic blocks of reinforced porcelain or glass ceramic (Siervo & others, 1992; Liu, Isenberg & Leinfelder, 1993), and therefore can be made and delivered at a single appointment. However, they lack internal characterization, so their surfaces may have to be extrinsically stained, and their shade carefully modified by resin cements. Furthermore, the marginal adaptation of CAD-CAM restorations has often been disappointing. Currently, the CEREC CAD-CAM system (Siemens, Bensheim, Germany) is widely used. It is usually used to form inlays, but their fit is often less than desirable, especially internally (Sturdevant & others, 1991; Inokoshi & others, 1992; Krejci, Lutz & Reimer, 1993). The CEREC CAD-CAM is also capable of producing veneers, but these have rarely been comprehensively examined with respect to fit or marginal adaptation (Essig & others, 1991; Liu & others, 1993). The purpose of this study is to compare the fit of veneers produced by the CEREC CAD-CAM with veneers produced by a conventional laboratory technique.

METHODS AND MATERIALS

Ten artificial upper left central incisors (Ivorine, Columbia Dentoform Corp, Long Island City, NY 11101) were prepared for porcelain veneer in a typodont (Columbia Dentoform). Artificial teeth were used so that the preparations could be standardized and the cement later removed. A depth cutting bur (DC4, Lasco Diamond Products, Chatsworth, CA 91311) was used to form 0.5 mm reduction grooves. Then the facial surface was uniformly reduced using diamond burs (LVS #3 & 4, Brassler, Savannah, GA 31419). Well-defined chamfers were placed on all margins. The gingival margin was placed 0.5 mm above the simulated cementoenamel junction. The distal margin was placed approximately to a depth of one-third the faciolingual distance, so the distal approximal contact remained intact. In contrast, the mesial approximal contact was broken, simulating a clinical case where diastema closure was needed. The teeth remained in the typodont for conventional and optical impression procedures.

Impressions were made of the 10 tooth preparations using a polyvinylsiloxane impression material (Extrude, Sybron/Kerr, Romulus, MI 41874). These were cast in an improved die stone (Milestone, Modern Materials, Southbend, IN 46975). A commercial laboratory (Haupt Dental Laboratory, Anaheim, CA 92821) fabricated a conventional porcelain veneer for each of the 10 preparations using the platinum foil (1 µm, Ney, Bloomfield, CT 06002) technique and a feldspathic dental porcelain (Ceramco, Burlington, NJ 08016). The conventional porcelain veneers were etched on their internal surfaces with 10% hydrofluoric acid. No fit adjustments were made to these veneers.

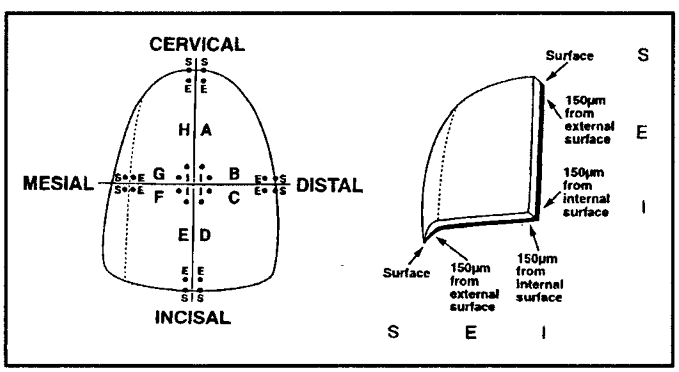

Figure 1. *Section and measurement point locations. The veneers wrapped around the broken contact on the mesial surfaces.*

A wetting agent and a thin layer of light-reflecting powder were applied to the prepared tooth surfaces (Hembree, 1995). Optical impressions were made using a three-dimensional intraoral scanner. Images were then displayed on the computer monitor. The veneers were designed using a cursor and tracking ball and CEREC inlay/onlay software (Version 2.1, 1992, Siemens). The previously open mesial contact points were closed. A CEREC electric drive machine milled the veneers from appropriately sized glass-ceramic blocks (Dicor MGC, light shade, Dentsply, York, PA 17405). CAD-CAM veneers were fabricated for each of the 10 tooth preparations. No fit adjustments were made to these veneers.

The veneer fitting surfaces were all cleaned with acetone, treated with a silane coupling agent (Monobond-S, Vivadent, Schaan, Liechtenstein) and a multipurpose bonding agent (Heliobond, Vivadent). The artificial tooth surfaces were lightly coated with a silicone mold release agent (Hastings Plastics, Santa Monica, CA 90404) to enable later removal of the veneers with their attached cement. The veneers were then cemented with a dual-cure resin composite cement (Variolink, Vivadent) to their respective teeth. To simulate finger pressure, a load of 8.8 N was applied for 10 minutes to the center of the facial surface of the veneers using a customized loading jig. Excess cement was removed using a brush wetted in unfilled BIS-GMA enamel bonding resin. The composite resin cement was then light cured (Optilux 150, Demetron Research Lab, Danbury, CT 06810) for 45 seconds from facial, distal, mesial, and incisal aspects. One hour after cementation the veneers were carefully removed from their teeth with their attached polymerized cement.

The veneers with their attached cement layers were embedded in slow-setting epoxy resin (Hastings Plastics). After 1 week, the specimens were sectioned into four pieces using a slow-speed diamond saw (Buehler Ltd, Lake Bluff, IL 60044). The cut width was 1.2 mm. A vertical gingivo-incisal cut divided each specimen in mesial and distal halves. Each half was then divided by mesiodistal cuts, cutting each specimen into four quarters (Figure 1). This provided eight separate exposed section measurements on each specimen (A-H, Figure 1).

Cement thickness was measured at three separate points on each of the eight exposed sections (Figure

1). These points were at the external surface of the margin (S), 150 µm inwards from the external surface margin (E) and 150 µm from the internal end of each surface near the intersection of the vertical and horizontal cuts (I). Measurements were made using a toolmaker's microscope at X500 magnification (Unitron, Newton Highlands, MA 02161) with digital positioners (Boeckeler Instruments, Tucson, AZ 85706-5024) of 0.1 µm accuracy. All measurements were displayed digitally and recorded. One measurement was made for each point, three points per section, with eight exposed sections per tooth, and 10 teeth for each of two experimental groups, for a total of 480 measurements.

A three-way analysis of variance (ANOVA) was computed to evaluate the main effects of fabrication method (CEREC or platinum foil), section location (A-H), measurement point location (I, E, or S), and their interaction terms ($P < 0.05$). Group means and their standard deviations were calculated for both materials (n = 240), for each of eight section locations (n = 60), for each of the three point locations (n = 160), and for each method/section/point subgroup (n = 10).

RESULTS

Three-way ANOVA showed that the main effects of fabrication method, measurement point location, section location, and all interaction terms were significant ($P < 0.05$) (Table 1). The significance of the interaction terms precluded further analysis of the main effects. Measurement point mean cement thicknesses are displayed in Figures 2 and 3. These ranged from 53.1 (standard error 4.3) µm for platinum foil porcelain veneer/A/internal up to 209.7 (standard error 19.7) µm for platinum foil porcelain veneer/B/surface. Mean cement layer thicknesses for the fabrication methods, for the eight different sections, and for the three different measurement points are listed in Table 2. The mesial sections' cement layer thicknesses were substantially smaller

Table 1. Three-Way ANOVA for Fabrication Method, Section Location, and Point Location

Source of Variation	Sum of Squares	Degrees of Freedom	F-ratio	P Value
Main Effects				
M: Method	6893	1	4.1	0.0432
S: Section Location	643651	2	192.0	<0.0001
P: Point Location	147240	7	13.6	<0.0001
Interactions				
M*S	17391	2	5.2	0.0059
M*P	45095	7	3.8	0.0005
S*P	104129	14	4.4	<0.0001
M*S*P	42460	14	1.8	0.035
Residual	724057	432		
Corrected Total	1735313	479		

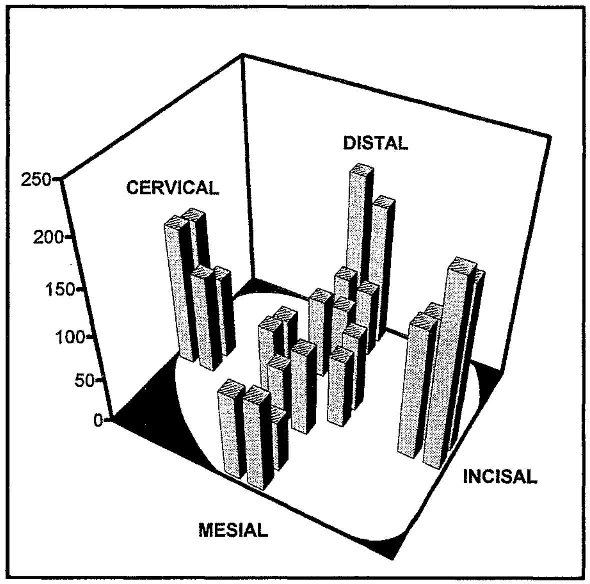

Figure 2. *Fit map for platinum foil veneers, mean fit (µm) at all 24 measurement locations (n = 10). Internal points were much better adapted than the external points, and the mesial broken contact areas were better adapted than the distal unbroken contact areas. Incisal areas had the worst fit.*

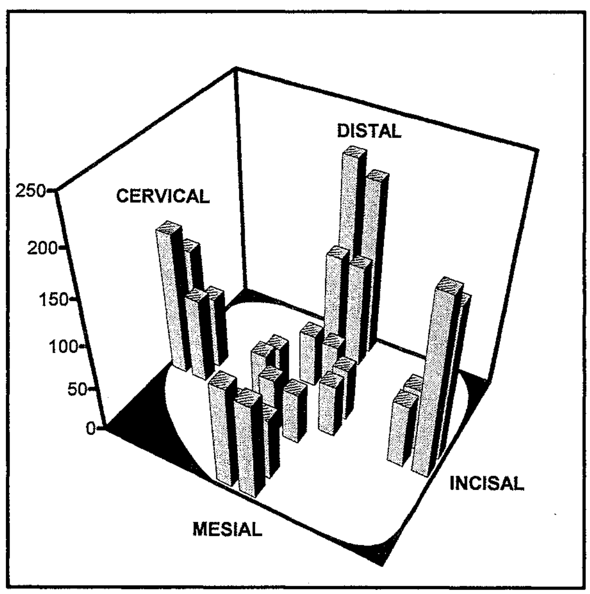

Figure 3. *Fit map for CEREC veneers (n = 10). This map is strikingly similar to the platinum foil map.*

than cervical, distal, or incisal locations. Surface adaptation was considerably worse than that 150 µm inside to the surface, or than the internal locations. Minimal cement flash was found in this study. Likewise, no pull-out of cement at the margins was seen.

DISCUSSION

Although the effect of fabrication method, CEREC or platinum foil, was just statistically significant ($P = 0.042$), the small difference between means (7.5 µm) is unlikely to be of clinical importance (Tables 1 and 2). Statistical significance is based on the relationship between the group means relative to the variability of the data, so with low variance, a small difference caused by differing fabrication methods became significant. Other less-sophisticated analyses might not have discerned a significant difference.

Table 2. Least Square Means for Cement Layer Thickness

	n	Mean	Internal Standard Error	Pooled Standard Error
Grand Mean	480	106.6	1.9	1.9
Methods				
Conventional	240	102.9	4.1	2.6
CEREC	240	110.4	3.6	2.6
Section Locations				
F: Mesial	60	81.7	4.6	5.3
G: Mesial	60	79.0	5.2	5.3
H: Cervical	60	110.8	7.8	5.3
A: Cervical	60	100.6	6.4	5.3
B: Distal	60	123.6	8.2	5.3
C: Distal	60	114.9	8.2	5.3
D: Incisal	60	118.8	8.5	5.3
E: Incisal	60	127.4	9.6	5.3
Point Locations				
Surface	160	154.3	5.1	3.2
150 µm from external	160	86.2	3.5	3.2
150 µm from internal	160	68.3	2.1	3.2

The fit of the CEREC veneers did not greatly differ from that of conventional platinum foil porcelain veneers (Tables 1 and 2). This is in contrast to CEREC inlays, which are typically poorly adapted, especially internally (Sturdevant & others, 1991; Inokoshi & others, 1992). Possibly the simple planar geometry of veneer preparations facilitates CAD-CAM imaging and machining. The choice of platinum foil or CEREC technique should be based on factors other than fit. Dicor MGC is several times stronger than conventional feldspathic porcelain (Grossman, 1991). However, Dicor MGC cannot be colored internally, is available in few shades, and must be customized by less-stable external stains. Intrinsic internal layering of conventional feldspathic porcelain veneers is an important part of their clinical success. CAD-CAM systems may decrease the number of office visits and lab costs. However, unless some CAD-CAM procedures, veneer polishing, and staining are delegated, additional chairside time may be needed, and the capital cost of CAD-CAM equipment must be amortized (Meijering & others, 1995). Both conventional and CAD-CAM veneer techniques challenge dentists and technicians with many possibilities for failure.

Potential disadvantages of the platinum foil technique include the possibilities of less than perfect impression accuracy, die reproduction, and adaptation of the platinum foil; shrinkage, curling, and rounding during porcelain firing; as well as marginal damage during glazing or polishing. CAD-CAM veneers also have many theoretical disadvantages. These include poor optical impressions, the limits of preparation digitization, and the limits of CAD software. The CAM phase also has many limitations, including the number, size, and precision of the tools used and the inability of current machines to include all six degrees of motion. Conventional laboratory techniques have not been evolving quickly. However, CAD-CAM techniques, while still in their infancy, continue to evolve rapidly. New CEREC hardware and software have recently been introduced, but were not available when this study was performed.

Despite additional tooth reduction and more complex geometry, the mesial sections without approximal contacts, simulating diastemata, were better adapted than the distal sections (Table 2, Figures 2 and 3). Possibly, the absence of approximal contacts facilitated optical imaging of these contacts for the CAD-CAM veneers as well as conventional impressions and lab procedures for the platinum foil porcelain veneers. Alternatively, the large-scale geometry of the veneers could have facilitated adaptation in these more curved mesial areas. The results of this study suggest that deliberate breaking of contacts or restoration of diastemata will not have a deleterious effect on fit.

The external marginal cement thicknesses were substantially greater than internal cement thicknesses for both platinum foil and CEREC veneers (Table 2, Figures 2 and 3). This finding is in contrast to typical results for CEREC inlays (Sturdevant & others, 1991; Inokoshi & others, 1992; Krejci & others, 1993). Marginal cement exposure necessitates careful finishing after placement (Tay, Lynch & Auger, 1987). At the high magnification used in this study, the exposed resinous cement appeared slightly rough. As approximately 150 µm of resinous cement was exposed, supragingival margin placement is biologically preferable. It should be noted that different measurement points produced significantly different measures of fit on the same restoration ($P < 0.05$). Thus extreme caution should be exercised when different studies are compared. In this study measurement point and section locations produced a greater effect than the fabrication method (Table 1).

Fit maps for the platinum foil and CEREC veneers are illustrated in Figures 2 and 3. The similarity between the fit maps is striking. This suggests that the patterns of fit were largely independent of the fabrication method, and that preparation geometry could be much more influential. CEREC veneers had superior internal adaptation, whereas the platinum foil veneers had superior external adaptation. This subtle difference may account for the significance of the interaction terms.

As differing measurement protocols and sites can influence fit, a clearly defined measurement protocol and multiple measurements sites were included. Prior studies on crowns have often used several sites to evaluate marginal adaptation as well as internal adaptation (Abbate, Tjan & Fox, 1989; Byrne, 1992; Valderrama & others, 1995). Although clinicians and technicians endeavor to produce sharply defined margins, most restoration and tooth preparation margins have rounded and blunted appearances when viewed under high magnification, as in this study. Thus, margins cannot be fully described by a single point. Therefore, two separate measurements were made in the marginal area, one at the surface and another 150 µm inwards from the surface. Similar distances have been used in prior studies, because they are still in the marginal area, but are located just far enough internally to be less affected by rounding, or by finishing procedures (Abbate & others, 1989; Byrne, 1992; Valderrama & others, 1995).

Data from adjacent surfaces, e g, B and C, were included. This was thought to be reasonable because the adjacent surfaces were separated by the thickness of the saw blade, 1.2 mm. Thus, adjacent surfaces were separated by a distance of approximately 10 times the size of the cement layers being measured. Adjacent surfaces may not have been entirely independent from each other in this study, but analyses in similar studies have shown such adjacent surface points to be independent (White & others, 1995).

In this investigation, the veneers were cemented to their respective artificial teeth and the resulting cement layers measured in cross section (Harasani, Isidor & Kaaber, 1991; Sorensen & others, 1992; Wall, Reisbick & Espeleta, 1992). The fit of the veneers could have been partly limited by the luting cement. However, differences between fabrication methods, tooth surfaces, and between internal and external adaptation were evident (Tables 1 & 2, Figures 2 and 3). Natural teeth might have been more desirable, but the artificial teeth were chosen so that preparations could be standardized and the cement easily removed intact for measurement. Measurement of the adaptation of cemented veneers is probably more clinically relevant than measurement of the adaptation of uncemented veneers. Cross-sectional visualization of the cement layer may be superior to direct viewing of the external margin, because the interfaces can be more clearly identified in cross section. Cross-sectional measurements will not be confounded by excess cement, or cement pull-out. Furthermore, cross-sectional viewing can better enable standardization of specimen alignment. The cross-sectional technique also allowed measurements to be made at internal locations.

Several investigators have studied the fit of cemented veneers. Harasani and others (1991) examined the marginal fit of porcelain veneers on the buccal surfaces of extracted third molars. They reported much more cement flash in marginal areas than discerned in this study. Like the current study, greater cement thickness was found on the occlusal (incisal) margins. However, the overall cement thickness was slightly lower than in this study. Sorensen and others (1992) compared in vitro vertical marginal discrepancies of porcelain veneers made by platinum foil and refractory die techniques. They reported that their platinum foil veneers had significantly better marginal fidelity. However, despite fit adjustment, the overall fit of their platinum foil veneers was much worse than in this study. Wall and others (1992) measured cement thickness beneath platinum foil porcelain veneers cemented to artificial teeth. Like this study, they reported that the internal adaptation was better than marginal adaptation and that the incisal margins were the least well adapted. They attributed the inferior marginal adaptation to folds in the platinum foil, but the striking similarity of fit maps for platinum foil and CEREC veneers in our study suggests a different cause (Figures 2 and 3).

Other researchers have evaluated the fit of uncemented veneers. Essig and others (1991) used a template technique to produce CEREC glass-ceramic veneers with a mean marginal gap of 248 µm, but after fit adjustment the mean fit improved to 128 µm. Incisal margins exhibited the greatest discrepancies. Sim and Ibbetson (1993) examined seating of uncemented veneers on stone casts and concluded that the platinum foil technique was superior to refractory die and casting techniques. However, prior to measurement 40% of their platinum foil veneers were rejected and remade because of unacceptable fit. Even without cementation, marginal discrepancies and differences between measurement point locations were greater than in the current study. Liu and others (1993) attempted to compare the fit of refractory die veneers to CEREC CAD-CAM veneers. They adjusted the fit of the veneers before measuring their adaptation to epoxy replicas of their tooth preparations without cement. They noted that CEREC veneer groups required much more adjustment than others before measuring, but this was not quantified or controlled in the analysis. They reported that electric drive CEREC veneers were apparently equivalent to refractory die veneers, and ranked incisal margins worst.

These prior in vitro studies reported a wide range of fit values for veneers. Differing equipment, methods, materials, measuring protocols, and technical experience may account for these differences. Findings in common with the present study included: ranking the fit of platinum foil veneers best; ranking internal adaptation superior to marginal adaptation; and the ranking of incisal margins worst.

Calamia (1989) reported excellent 2- and 3-year results of conventional porcelain veneer marginal adaptation according to United States Public Health Service criteria. He noted that at baseline all veneers received the highest rating, but that marginal quality decreased with time. Most marginal deficiencies occurred on the incisal margins, and this was attributed to attrition of the cement line caused by occlusal force. An alternative possibility is that the veneers were initially less well adapted in this area, but the poorer adaptation did not become visible until some cement wear occurred. In this in vitro study and in other prior studies, incisal margin locations exhibited the worst fit (Table 2) (Harasani & others, 1991; Essig & others, 1991; Wall & others, 1992; Liu & others, 1993). Karlsson and others (1992) used similar California Dental Association quality evaluation guidelines to evaluate conventional porcelain and cast glass-ceramic porcelain veneers that had been in function for a mean period of 18 months. They reported a 99% satisfactory rating for marginal integrity, but only 31% received excellent ratings. These clinical studies suggest that although veneer margins are adequate, room for improvement still exists.

CONCLUSIONS

CEREC CAD-CAM veneers' fit is slightly inferior overall compared to platinum foil porcelain veneers in vitro. Simulated diastema closure or restoration of broken contacts did not compromise fit. Fit was influenced by the cross section location within the tooth, and adaptation of incisal margins was worst. Fit was also influenced by the location of measurement points within cross sections, and adaptation of surface measurement point locations was worst. Fit maps for CEREC and platinum foil veneers were strikingly similar.

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Fracture Resistance of Complex Amalgam Restorations

J O BURGESS • A ÁLVAREZ • J B SUMMITT

Clinical Relevance
Amalgambond Plus combined with pins provided significantly greater resistance to fracture than pins or Amalgambond Plus alone.

SUMMARY

This study evaluated fracture resistance provided to complex amalgam restorations by adhesive and mechanical resistance features. The occlusal surfaces of 30 extracted molar teeth of similar size were ground flat to approximately 2 mm coronal to the CEJ. The teeth were divided into three groups. Roots were notched and embedded in acrylic resin. In two groups, four TMS Minim stainless steel pins were placed into dentin at the line angles. A copper band matrix was applied to each specimen and reinforced with compound. After applying either Copalite or Amalgambond Plus, Tytin amalgam was condensed into the matrix. The bands and excess amalgam were removed 10 minutes later, and each amalgam occlusal surface was ground flat to give the amalgam restoration a 4 mm occlusal height. Specimens were thermocycled for 2500 cycles at 6 - 60 °C with a 30-second dwell time. They were then stored in deionized water for 1 month at room temperature. A 1 mm 45° bevel was placed on the facio-occlusal angle of the amalgam. Each specimen was loaded to failure in compression at 45° in an Instron Testing Machine at a crosshead speed of 5 mm/min. The groups were: Group 1, four Minim pins and Copalite; Group 2, four Minim pins and Amalgambond Plus; and Group 3, Amalgambond Plus only. The data were analyzed using a one-factor ANOVA and a Tukey B post hoc test. There was no significant difference between Groups 1 and 3. The Amalgambond Plus combined with pins provided significantly greater resistance to fracture than pins or Amalgambond Plus alone ($P < 0.05$).

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INTRODUCTION

A complex amalgam restoration is a restoration in which cusps are replaced with amalgam when inadequate tooth structure is available to provide for the retention and resistance of the restoration (Plasmans, Welle & Vrijhoef, 1986). Several studies have shown that complex amalgam restorations can provide dependable service for a significant period of time (Smales, 1991; Bentley & Drake, 1986; Robbins & Summitt, 1988; Martin & Bader, 1995).

Resistance form has been defined as the ability of a restoration to resist being dislodged by oblique forces. Retention form has been defined as the ability of a restoration to resist tensile forces directed parallel to the long axis of the preparation (Plasmans & others, 1986; Robbins, Burgess & Summitt, 1989). In the 1950s, Markley advanced the use of stainless steel pins to provide resistance and retention for extensive amalgam restorations (Markley, 1958). Buikema and others (1985) demonstrated that increased resistance was provided to complex amalgam restorations by an increased number or size of self-threading stainless steel pins.

Several manufacturers have introduced resin materials that are designed to bond amalgam to enamel and dentin. Support for the effectiveness of some of these agents is growing. Several laboratory studies have tested the bond strength of these materials used to bond amalgam.

This study was undertaken to determine the resistance form provided for complex amalgam restorations by Amalgambond Plus, self-threading pins, and a combination of the two.

METHODS AND MATERIALS

Thirty extracted human maxillary molar teeth were selected, and the occlusal surface of each molar was ground flat using a model trimmer (Torit Corp, St Paul, MN) to 2 mm occlusal to the cementoenamel junction (CEJ). The ground surface was then finished using 600-grit silicon carbide paper with water spray on a polisher-grinder (Polimet Polisher, Buehler, Ltd, Evanston, IL 60204). Teeth were stored in deionized water at room temperature at all times except when being prepared, restored, or tested. The roots were notched, the teeth were aligned so that the flattened occlusal surfaces were horizontal, and the roots were embedded in clear acrylic resin (Orthodontic Resin, L D Caulk/Dentsply, Milford, DE 19963) to 2 mm apical to the CEJ. The maximum faciolingual and mesiodistal dimensions of each ground surface were measured, and the two dimensions were multiplied together to give a surface area factor for each specimen. Specimens were then sorted using these factors into three groups of 10 teeth each, with tooth sizes equally distributed among groups. Groups were prepared for restoration with amalgam using either TMS Minim pins (Coltène/Whaledent, Inc, Mahwah, NJ 07430), Minim pins and Amalgambond Plus (Parkell, Famingdale, NY 11735), or Amalgambond Plus alone to provide resistance (table).

In Groups 1 and 2, four TMS Minim pins, one at each line angle, were placed in each tooth, at least 0.5 mm inside the dentinoenamel junction (DEJ). Pin channels were prepared using a 2 mm self-limiting pin channel drill, 0.021" (0.53 mm) in diameter (Coltène/Whaledent) in a low-speed handpiece (KaVo Intraflex LUX 2 shank handpiece with 62LDN latch head, KaVo America Corp, Hoffman Estates, IL 60195). Pin channel drills were oriented parallel to the adjacent external surface of the tooth. TMS Minim pins were inserted using a hand wrench (Coltène/Whaledent). After insertion, pins were cut to a length of 2 mm with the tip of a #169L bur (Midwest Dental Products Corp, Des Plaines, IL 60018) in a high-speed handpiece (KaVo Bella-Torque LUX 2 Turbine 642 B, KaVo America Corp), with the bur oriented perpendicular to the pin.

In Group 1, two coats of Copalite varnish (Cooley & Cooley Ltd, Houston, TX 77041) were applied to the ground surface before pins were inserted. In Groups 2 and 3, the Amalgambond Plus was applied, in accordance with the manufacturer's instructions, just before the amalgam was condensed.

A copper band matrix (Union Broach, Long Island City, NY 11101) was applied to each specimen and reinforced with green stick impression compound (Sybron/Kerr, Romulus, MI 48174).

For the specimens receiving Amalgambond Plus (Groups 2 and 3), Amalgambond Activator was brushed onto the enamel of the ground surface and allowed to remain for 20 seconds, then brushed onto dentin and allowed to remain on the ground surfaces for an additional 10 seconds; the Activator was then rinsed away with an air-water spray and the surface dried. The Amalgambond Adhesive Agent was then brushed on the ground surface, blown gently to a thin layer, and left undisturbed for 30 or more seconds. Three drops of Amalgambond Base, one drop of Catalyst, and one scoop of HPA (high-performance additive) powder were mixed and applied to the ground surface, and amalgam condensation was begun immediately, with all Amalgambond Plus being covered with amalgam within 30 seconds.

Amalgam (Tytin, Sybron/Kerr) was prepared according to the manufacturer's instructions and condensed into each preparation by one operator using

Mean Failure Loads [Newtons(N)] of Each Resistance Form Configuation

Group	Resistance Form Configuration	Mean Failure Load (N)	SD
1	Four Minim TMS pins, Copalite	1028*	306
2	Four Minim pins, Amalgambond Plus	2360	575
3	Amalgambond Plus	1361*	703

Groups identified with an asterisk (*) were not significantly different from each other.

Figure 1. *Specimen positioning device that is holding specimen at 45° for loading in Instron Testing Machine*

hand condensation. The matrix bands were removed 10 minutes after completion of condensation and any marginal flash or overextension of amalgam was trimmed using sharp carvers. The flat amalgam occlusal surface of each specimen was adjusted on a polisher-grinder (Polimet Polisher, Buehler) to provide a 4 mm height of amalgam above the flat surface of the prepared tooth.

Specimens were thermocycled 2500 cycles at 6 - 60 °C with a 30-second dwell time. After storing the specimens in deionized water for 1 month at room temperature, each specimen was placed in a device that positioned the occlusal surface at 45° from horizontal. A separating disk mounted in a straight handpiece (Bell International, Burlingame, CA 94010), held vertical by a Ney surveyor (J M Ney Co, Bloomfield, CT 06002) so that the disk was horizontal, was used to place a 1 mm 45° bevel on the facio-occlusal line angle of the amalgam. Using the same 45° positioning device (Figure 1), each specimen was loaded on the bevel with a flat ended rod in an Instron Testing Machine (Instron Corp, Canton, MA 02021) at a crosshead speed of 5 millimeters per minute until failure.

RESULTS

The failure load in newtons was recorded for each specimen. The mean failure loads are summarized in the table and graphically illustrated in Figure 2. The data were analyzed using a one-factor analysis of variance (ANOVA) and a Tukey B post hoc analysis to determine the presence and location of intergroup differences. Significant differences were set at the 0.05 level. The group with four pins and Amalgambond Plus (Group 2) required a significantly greater load ($P < 0.05$) to cause failure than the other two groups. The mean fracture loads for the group using only four pins (Group 1) and for the group using only Amalgambond Plus (Group 3) were not significantly different ($P > 0.05$).

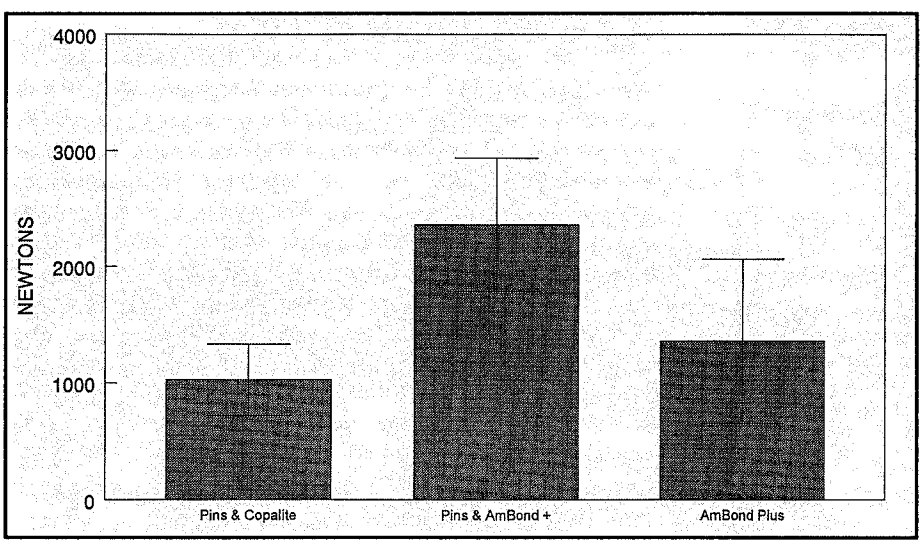

Figure 2. *Failure loads for the three groups are illustrated by the bars; lines show standard deviations.*

DISCUSSION

Support for the use of amalgam bonding materials instead of, or in conjunction with, mechanical resistance features is growing. Several studies have compared the resistance or retention provided by various amalgam bonding materials to that provided by mechanical resistance features such as pins or amalgapins. Hadavi and others (1994) reported that, in a shear bond test, All-Bond 2 (Bisco, Itasca, IL 60143) provided more adhesion of amalgam to dentin than one TMS Minim pin or Amalgambond Plus, and that Amalgambond Plus provided resistance to shear similar to one Minim pin. Specimens were not thermocycled. They concluded by saying that both Amalgambond Plus and All-Bond 2 bonding systems appear to be satisfactory alternatives to the use of retentive pins. Vargas, Denehy, and Ratananakin (1994), using thermocycled specimens, tested five different bonding agents with amalgam, using a shear load, and found Amalgambond

Plus provided significantly more resistance to shear than the other four agents.

Dossett and others (1994) compared the load to cause cusp fracture in thermocycled premolar teeth when the cusp was attached to the amalgam restoration with either two horizontal TMS Minim pins, All-Bond 2, or Amalgambond Plus. Each cusp was loaded at 45 degrees to the long axis of the tooth. The horizontal pins provided significantly more fracture resistance for the cusps than the Amalgambond Plus; there was no significant difference between the Amalgambond Plus and the All-Bond 2 in resistance provided. Another study of cusp reinforcement with amalgam bonding (Roth & Boyer, 1994), using thermocycled specimens, showed that All-Bond 2, Scotchbond Multipurpose (3M Dental Products, St Paul, MN 55144), and Amalgambond Plus provided significant attachment of amalgam to the cusps of natural teeth. Teigen and Boyer (1994) reported that amalgam bonded with All-Bond 2 allowed less deformation of adjacent cusps than unrestored control teeth and provided cusp reinforcement similar to that achieved with bonded resin composite restorations.

Imbery, Hilton, and Reagan (1995), also testing thermocycled specimens mounted at 45 degrees and loaded in compression, reported that Amalgambond alone and Amalgambond in conjunction with four amalgapins provided more resistance to fracture than four Regular TMS pins.

This study investigated the efficacy of Amalgambond Plus in conjunction with pins and demonstrated an additive effect. The Amalgambond Plus alone gave resistance similar to four Minim pins, but, when the two methods were combined, the resistance provided approximated the sum of the two methods used independently. This finding should give comfort to those clinicians who are reluctant to rely totally on bonding for retention of large amalgam restorations, because the combined use does not have a detrimental effect on mechanical retention.

Although this study, as well as other studies, used thermocycling in an attempt to more closely simulate a clinical situation, laboratory studies provide only preliminary evidence. Long-term clinical studies will be needed to confirm the efficacy of amalgam bonding before proven mechanical resistance features should be abandoned. Several clinical studies have demonstrated reliability of amalgam bonding for 1 or 2 years. In one study involving complex amalgam restorations in molars (Burgess & others, 1996), Amalgambond Plus was used with very little or no mechanical retention in the preparations; this study has demonstrated 100% retention after 1 year. Another clinical study (Ruzickova & others, 1996), using All-Bond C&B (Bisco) as the bonding material, has also reported 100% retention at 1 year in nonretentive preparations. A third clinical study (Stewart & Belcher, 1996) demonstrated 100% retention of complex amalgam restorations at 2 years when either Amalgambond or Amalgambond Plus was the principal mode of retention.

Although longer periods of testing are needed to confirm the efficacy of bonding amalgam, evidence of their dependability is accumulating, and the use of amalgam bonding is increasing (Christensen, 1994, 1995).

CONCLUSIONS

1. Amalgam bonding, using Amalgambond Plus, provided resistance for complex amalgam restorations on flattened molars that was similar to that provided by four Minim pins.
2. The effect of amalgam bonding, used in combination with four Minim pins, was additive.

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CLINICAL ARTICLE

A Comparison of Two Teaching Simulations in Preclinical Operative Dentistry

N K LONG • T G ZULLO • K W HINKELMAN

Clinical Relevance
Ceramic-coated teeth are an acceptable alternative to human teeth in teaching preclinical operative dentistry.

SUMMARY

The purpose of this study was to determine whether a ceramic tooth would be as effective as a natural tooth in teaching preclinical operative skills. Subjects consisted of all second-year students enrolled in a preclinical inlay course. Students were classified into high- and low-dexterity groups, randomly assigned to oane of the tooth simulators, taught the same four procedures, and asked to keep a log of the amount of time spent on each. All students participated in a practical examination that consisted of preparing a cavity for a gold casting using a resin tooth. There were no statistically significant differences between students who prepared natural teeth and those who prepared ceramic teeth for either the qualitative practical examination score or the amount of preparation time required. High-dexterity students achieved significantly higher scores on the practical than did low-dexterity students, whether practicing on natural or ceramic teeth. The MOD onlay required significantly more time to complete than did any of the other preparations on both natural and ceramic tooth simulators. Written evaluations of the ceramic simulators revealed that students perceived ceramic teeth to be as good or better than natural teeth because of their anatomic uniformity.

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INTRODUCTION

Preclinical operative dentistry is that portion of the dental school curriculum which introduces the student to the technical skills necessary to restore carious and/or defective teeth. These fundamental skills are taught through lectures, seminars, and simulated exercises in a laboratory using either artificial or extracted natural teeth, prior to the student delivering care to an actual patient.

Extracted human teeth have a long history as simulators for preclinical teaching. Natural teeth have the advantage of allowing for realistic tactile experience in cavity preparation. Their use, however, is limited because of decreasing availability.

As a result of the increased emphasis on preventive dentistry, dental health education, fluoridation, and infection control, dental schools are experiencing difficulties in obtaining sufficient numbers of extracted natural teeth for use in teaching preclinical restorative dentistry. A recent survey by Schulein (1994) on the use of extracted teeth confirms this problem.

Because of this decrease in the number of extracted natural teeth available, it has become more difficult to obtain a representative sample of each type of tooth (incisors, canines, premolars, molars), and thus difficult to standardize a preclinical operative procedure using extracted natural teeth.

Resin teeth have been used as a second type of simulator in teaching preclinical operative dentistry. They have the advantage of realistic contours, anatomy, proper dental arch alignment, and ease of replacement. However, physical properties of resin teeth, such as elasticity, hardness, and color differentiation have limited similarity when compared to the enamel or dentin of natural teeth. These limitations were alluded to in a study by Rosenstiel and others (1989) that measured wear rate and cutting efficiency of diamond cutting instruments used in preparing resin teeth for a preclinical course.

Ambrose, Halhoul, and Gourley (1981) described a technique by which artificial teeth could be altered to create carious lesions of varying depths and degrees of involvement. Although the technique produced carious lesions that were very realistic, the authors felt the task of preparing the artificial teeth was monotonous.

A more recent study by Taira and others (1990) compared the cutting characteristics of several glass-ceramic, composite resin materials, and extracted bovine teeth. From the results of the study, the authors concluded that there is a need to produce new typodont teeth from glass-ceramic materials that have similar physical properties to natural tooth enamel.

An artificial tooth (Kilgore International, Inc, Coldwater, MI 49036) has been developed in an attempt to more realistically simulate the clinical situation. This tooth has an outer shell made from a ceramic composite material that is claimed by the manufacturer, C Kilgore (personal communication, 1986), to closely resemble enamel in its physical properties, and in its anatomical contours with relation to the underlying dentin. The outer shell is bonded to a dentin-colored inner core made from epoxy resin.

Reader and others (1994) utilized this same artificial tooth for teaching a preclinical endodontic exercise. Comparisons with natural teeth revealed student preference for the ceramic tooth for creating access cavity preparations, as an aid in the visualization of the concepts of endodontic treatment, and as a teaching model.

Long and Zullo completed a pilot study with 24 students, 12 of whom completed a preclinical exercise using the above-noted ceramic teeth, and 12 of whom completed the exercise using extracted natural teeth. No statistically significant differences were found in qualitative performance between the two groups on a preclinical exercise.

The purpose of the present study was to replicate and expand the findings of the pilot study using a larger sample size. Additionally, this study was undertaken to determine if there was a significant difference in the amount of time required to complete a procedure by students using a ceramic tooth simulator when compared with those students using a natural tooth simulator.

METHODS AND MATERIALS

Second-year students from the University of Pittsburgh's School of Dental Medicine comprised the subjects for this study.

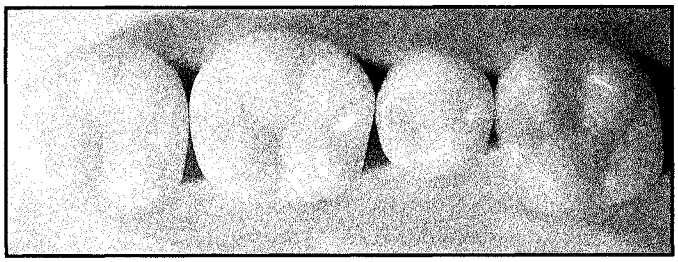
All second-year students (n = 87) participated in a preclinical inlay course in which the principles of cavity design for and the fabrication of gold castings were taught. Approval for the use of human subjects had been obtained from the Dental Institutional Review Board. All subjects had completed their first year of dental school, which included 1 year of training in preclinical operative dentistry.

Prior to beginning preclinical operative in the first year, the Crawford Small Parts Dexterity Test was administered to all students. The administration and scoring of the Crawford test is a modification of the original method, and has been described by Zullo (1969).

Previous studies by Kress and Jacobs (1973) and Hinkelman (1976) have shown small-parts dexterity skills to be related to performance on dentally oriented tasks. Specifically, Hinkelman (1976) found that subjects with higher scores on the Crawford test performed significantly better than subjects with lower scores. Therefore, scores from the Crawford test were employed as a blocking variable in this study to control the effects of initial psychomotor abilities.

Using a median break, one-half of the class was identified as the High-Dexterity group, and the other half as the Low-Dexterity group. One-half of the subjects in each dexterity group were randomly assigned to one of the two simulation conditions—ceramic or natural teeth.

Those students who used extracted natural teeth were given a laboratory outline of the teeth needed and instructed to obtain the best possible specimens of posterior teeth they could find in order to



Quadrant of mounted ceramic-composite teeth

complete the laboratory procedures. The students were given instructions on how the teeth were to be arranged, and the teeth were mounted in a quadrant fashion in a small block of dental stone. The teeth were checked by an instructor to make sure that they were in contact with one another, and in proper faciolingual and occlusogingival relationship.

Students who used the ceramic-composite teeth (Kilgore International, Product Number A20A-500B) were also given a laboratory outline and instructions to arrange the teeth in a specific order, i e, mandibular left second molar, mandibular left first molar, mandibular left second premolar, and maxillary left first molar. The teeth were mounted in dental stone in a quadrant fashion and checked to make sure that they were in contact with each other and in proper faciolingual and occlusogingival relationship (figure).

The preclinical inlay course required students to complete eight cavity preparations, arranged in order from the simple to the more complex. All students completed their first three cavity preparations on a typodont with resin teeth. These preparations were a class 1 inlay, class 5 inlay, and a class 2 inlay. Resin teeth were used for these preparations because of the previously noted difficulties in obtaining sufficient numbers of natural teeth and fiscal constraints.

The next three preparations were completed on either the ceramic or corresponding natural teeth according to the simulation condition assigned. The procedures performed were as follows: MO or DO inlay, MOD onlay, and MO or DO inlay with lock.

All subjects completed another preparation on a maxillary first premolar resin tooth that was chosen in order to reinforce the student's use of indirect vision. Training was completed by preparing an MO or DO inlay with pin on either a ceramic or natural tooth. The students were asked to keep a log of the amount of time spent on each procedure. At the conclusion of the course each student completed a practical examination of moderate complexity (a class 2 inlay preparation), on the typodont using a resin tooth. In addition, those students who had used the ceramic teeth were asked to submit a written evaluation of the teeth.

A total of 10 faculty members with at least 8 years of experience teaching preclinical operative dentistry participated in the course. This involved both instruction at the laboratory bench and daily evaluation of the eight preparations students completed. The practical examination was evaluated by two of the faculty members, who were unaware of the students' level of dexterity or the type of simulator used for training. Each of the eight cavity preparations and the practical examination was evaluated for outline form, depth, resistance form, retention form, and enamel finish using a three-point criterion reference rating scale, (3 = ideal; 2 = clinically acceptable; 0 = clinically unacceptable). Reliability and validity of the scale have been demonstrated in a previous study (Hinkelman & Long, 1973). This rating scale was utilized in the teaching/evaluation for clinical operative dentistry. For the practical examination, the scores (3, 2, or 0) of the two faculty members for each of the five evaluated criteria were summed and averaged to obtain a total practical examination score.

Training sessions had been held to introduce the instructors to the use of the rating scale and to monitor their accuracy and agreement. The mean difference in overall scores for quality between judges was 0.014 and ranged from -0.50 to +0.50 with 77 of the 87 differences in the range of -0.20 to +0.20.

The study was designed as a 2x2 factorial with dexterity as one factor, and type of simulator as the other. Scores for quality on the practical examination were analyzed using a 2x2 ANOVA, while the time measures were analyzed using a 2x2x4R ANOVA, in which each procedure was treated as a repeated dimension. The statistical program BMDP4V, univariate and multivariate analysis of variance and covariance (Dixon, 1992), was used to perform the analyses. Complete data (for quality scores and time for all four procedures) were available for 87 subjects.

RESULTS

Table 1 presents the means and standard deviations of the practical examination scores. There were no statistically significant differences for the main effects of simulator ($F = 1.98$; $P = 0.16$). Students who practiced on ceramic teeth obtained a mean score of 2.81, while those who practiced on natural teeth obtained a mean score of 2.77. While statistically significant differences were observed for the main effects of dexterity ($F = 4.86$; $P = 0.03$), the magnitude of the differences was small. Students in the high-dexterity group obtained a mean score of

Table 1. Practical Examination Scores

Simulator Teeth	n	Dexterity High	Dexterity Low	Total
Ceramic	46			
Mean		2.87	2.76	2.81
SD		0.09	0.2	0.16
Natural	41			
Mean		2.78	2.76	2.77
SD		0.15	0.13	0.14
Total	87			
Mean		2.83	2.76	
SD		0.12	0.17	

Table 2. Time to Complete Procedures

Simulator Teeth	n	MOD Inlay	Inlay	Inlay with Lock	Inlay with Pin
Ceramic	46				
Mean		74.67	48.13	48.41	48.74
SD		26.14	25.39	23.92	23.54
Natural	41				
Mean		69.54	46.32	51.51	58.85
SD		31.26	18.23	23.24	28.92
Total	87				
Mean		72.25	47.28	49.87	53.51
SD		28.61	22.19	23.52	26.55

2.83, while those in the low-dexterity group had a mean score of 2.76. There was no statistically significant interaction between simulator and level of dexterity ($F = 1.73$; $P = 0.19$).

Analysis of the amount of time required to complete the laboratory procedures revealed no statistically significant differences for either the main effects of dexterity, ($F = 1.58$; $P = 0.21$) or simulator ($F = 0.20$; $P = 0.66$). Statistically significant differences were found among the four procedures ($F = 25.38$; $P < 0.001$). Whether practicing on natural or ceramic tooth simulator, and regardless of the level of dexterity of the student, the MOD onlay required significantly more time to complete than did any other procedure (Table 2). There were no statistically significant interactions observed among any of the factors for the dependent variable time.

DISCUSSION

The results of this study demonstrate that practice with ceramic teeth produced outcomes that were at least as good as those found when students practiced on natural teeth. It must be pointed out that the evaluation scale employed appeared to exhibit a ceiling effect. As may be noted in Table 1, the lowest mean score for any of the four groups was 2.76 out of a maximum possible score of 3. In fact, only one of the 87 students obtained a score that was less than clinically acceptable, that is, 1.9, while 25 students of the 87 exhibited scores of 2.9 or higher.

The design of the present study did not permit a determination as to whether these high scores were the result of instructors indiscriminately assigning high grades to all students, a measurement limitation of the instrument used, or the fact that, as the result of the amount of practice, student performance was uniformly excellent.

The amount of time students reported for the preparation of the four laboratory procedures did not differ significantly among students who practiced with ceramic or natural teeth. Students who were taught with ceramic teeth actually spent an average of 1.5 less minutes in practice.

Students were also asked to provide an open-ended evaluation of the ceramic simulators. They were requested to provide specific comments on tooth anatomy, cutting characteristics, and any problems they encountered with the teeth.

Written evaluations of the ceramic simulators revealed that students perceived the ceramic teeth to be as good or better than natural teeth because of their anatomic uniformity. They also appreciated the fact that using ceramic teeth relieved them of the responsibility of acquiring natural tooth simulators.

Ceramic teeth are appreciably more expensive to purchase than resin teeth. This issue was discussed with the students, and the overwhelming majority voted to purchase the ceramic composite teeth if it would relieve them of the responsibility of acquiring acceptable natural tooth simulators.

CONCLUSION

Given that there were no significant differences for either the measure of quality or practice time, that student comments regarding the use of ceramic teeth were quite favorable, and that the physical properties of ceramic teeth more closely resemble that of natural teeth, it is concluded that the ceramic-coated teeth present an acceptable alternative for use as a simulator in preclinical teaching.

Acknowledgment

This study was supported by a grant from the University of Pittsburgh Office of Research.

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Award of Excellence

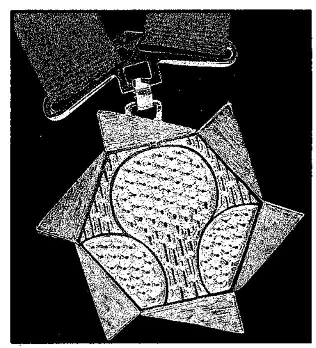
It is a sincere pleasure to honor Jens Martin Anderson with our Academy of Operative Dentistry's Award of Excellence. I have known Marty for many years, since he was a student at the University of Washington 30 years ago. Several years ago I had the pleasure of teaching a two-week Ferrier Gold Foil course with Marty, and a few weeks ago I watched him place a beautiful class 2 gold foil restoration in an upper molar at the George Ellsperman Gold Foil Study Club. He can demonstrate clinically what he teaches.

Marty is an exceptional person. He was president of our Academy in 1988, and he has been managing editor of our journal, *Operative Dentistry*, since its inception in 1976. This is an outstanding record.

J Martin Anderson

Marty is serious and dedicated to his profession, and he appreciates art, though not only in dentistry. He set up a complete antique car restoration shop, including metal lathes, welding equipment, painting areas, etc, which helped him win two first-prize awards at the prestigious Pebble Beach Concourse Car Show, not to mention other shows. He also once picked up a lifesize statue in Indiana of a Viking, but with the arms broken off, a Norwegian Venus de Milo. So of course he set to work restoring the arms. He found a fellow with great biceps. Unfortunately the fellow's arms were very hairy, and even with vaseline, the plaster impression took off the hair. The volunteer had a painful experience; one arm was enough for him. The second volunteer did just fine. So in the driveway garden at Marty's house stands a great and now complete work of art.

In 1995 the National Board Exam, Part II, found University of Washington students first overall in the United States in the categories of Operative Dentistry and Prosthetics. In addition, 100% passed the Western Regional Board. Who taught these people? It was Marty Anderson. These are concrete results. His students have selected him for outstanding teacher awards. He has given the commencement address at graduation. He was elected president of the school alumni association, receiving the Distinguished Alumnus Award in 1994. Marty has lectured nationally and has presented many fine chair clinics. He has three very large new and sophisticated restorative manuals to his credit. I would urge fellow dental educators to see them. They are unique and well worth inspection.



Marty gets results. If he told you we may start a space shuttle service between Earth and Mars, it would happen. Buy a ticket. I was surprised and delighted when a philanthropist donated several hundred dollars to the Gold Foil Academy, but Marty far outdid that: He secured a record $600,000 endowment for Restorative Dentistry.

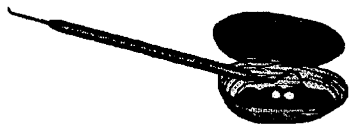
So to summarize, Marty is truly a worthy choice for the Award of Excellence. His membership in the Restorative Academy, the Gold Foil Academy, CAIC, and others, his teaching record (Omicron Kappa Upsilon) over 30 years, his fine private practice, his commitment to his community all attest to it. This is a fitting reward for a deserving person.

It is a great pleasure to present our Academy's Award of Excellence to J Martin Anderson.

BRUCE B SMITH

DEPARTMENTS

OPERATIVE PEARLS



In issue 21(5) of *Operative Dentistry*, a notice was placed concerning the initiation of a "clinical tips" section. At the last Editorial Board meeting, initiation of this section was approved. Therefore, this is the initial offering of "Operative Pearls," with two pearls that are meant to stimulate our readers to submit their wonderful, yet secret, tips for practicing at a higher level.

Please send me your "pearls" and/or comments regarding this section via FAX (206) 543-7783 or e-mail <rmccoy@u.washington.edu>.

GINGIVAL HEMORRHAGE

Contributor: Dr Myron Warnick, Seattle, WA

Problem: Gingival hemorrhage

Solution: **Use Monsel's Solution**

Procedure: Have your pharmacist prepare a 15% solution of ferric subsulphate (Monsel's solution). When hemorrhage occurs proceed as follows:

1. Dispense 3 or 4 drops of Monsel's solution into small plastic cup.
2. Apply solution to bleeding area with a small cotton pellet or a blue "Multi-brush" applicator (Ultradent Products, Inc, 505 W 10200 South, South Jordan, UT 84095). Hemostasis is best accomplished by a light rubbing (burnishing) motion on the sulcular tissues.
3. After bleeding is controlled, flush out the area with water spray.
4. If debris or coagulum remains, using a small cotton pellet or a "Multi-brush" applicator, clean the preparation with a chlorhexidine solution, e g, "Bisco Prep Cleanser" (Bisco Dental Products, 1500 W Thorndale Ave, Itasca, IL 60143).

Comments: Solution is very inexpensive compared to commercial products, but works as well. Action is immediate. Unpleasant taste. Not recommended for cord soaking due to brown staining of cord.

SYRINGING IMPRESSION MATERIAL

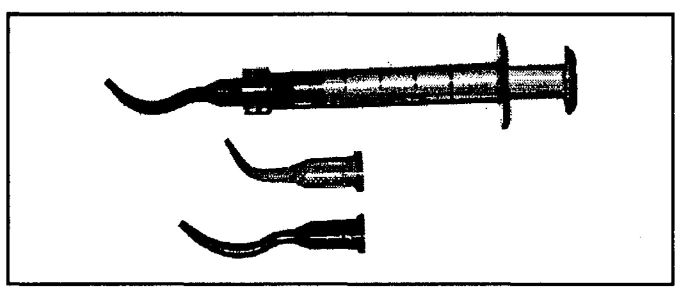
Contributor: Dr Myron Warnick, Seattle, WA

Problem: Inefficient syringing of impression material

Solution: **Use a cost-effective disposable syringe**

Product: A 1.25 cc plastic disposable syringe (Ultradent Corporation, Inc, 505 W 10200 South, South Jordan, UT 84095) has been successfully used in the University of Washington Restorative clinics and has replaced the long-standing Kerr Free-Flo syringe for impressions. The syringe with a Blue Max plastic tip or White Mini tip (Figure) has the following advantages:

Rationale:
1. Light weight and easy maneuvering intraorally,
2. Very smooth plunger action due to nylon/teflon plunger,
3. Minimal plunger force required due to small syringe diameter,
4. Disposable,
5. Acceptable cost (approximately $0.54) for syringe and tip,
6. Readily cleanable for immediate reuse,
7. Can be disinfected for reuse,
8. Syringe capacity for 14 preparations if injected in sulcus only,
9. Easily back-loaded from mixing pad or cartridge tip,
10. Excellent "Luer-lock" bendable plastic tip, and
11. Syringe tip slender and orifice optimal for flow of material.



Disposable syringe with tips

BOOK REVIEWS

MASSACHUSETTS GENERAL HOSPITAL MANUAL OF ORAL AND MAXILLOFACIAL SURGERY

Third Edition

R Bruce Donoff, DMD, MD

Published by Mosby-Year Book, Inc, 11830 Westline Industrial Drive, St Louis, MO 63146, 427 pages, 32 illustrations, $44.95

The third edition of the *Massachusetts General Hospital Manual of Oral and Maxillofacial Surgery* has changed from the spiral-bound version of the first two editions to a softbound edition, making it easier to carry in the pocket of a lab coat or fit into an operatory cabinet drawer.

The preface of this third edition clearly states the purpose of the manual: It addresses issues encountered in the day-to-day management of the oral and maxillofacial surgery patient. This manual does not replace textbooks, journals, or clinical training and experience. However, it serves as a clear and concise reference, easily carried and available. This portable manual is small, lightweight, and packed with many charts, graphs, tables, and treatment algorithms. At 427 pages, the third edition is 43 pages longer than the second edition and enhanced with updated material, including new sections on nerve injuries and the management of medical emergencies in the dental office. This book is the only patient care manual specifically targeted for care of the dental patient, with definitive standards of care for the oral and maxillofacial surgery patient. And by today's standards, it is relatively inexpensive.

This edition is again written by current and former members of the Oral and Maxillofacial Surgery Service of the Massachusetts General Hospital. Most of the contributors hold academic positions at major teaching institutions, and many of them have degrees in both dentistry and medicine. Written for residents and fellows in oral and maxillofacial surgery training programs as well as the practicing oral and maxillofacial surgeon, this manual is an extremely valuable reference for any dentist. It is comprehensive in its approach to discussion of important general patient management protocols.

The book is divided into four well-organized and complete sections. The first section, referenced by light purple pages, contains 18 separate algorithms. These algorithms are flow charts designed as "decision trees," guiding the dental professional in varying clinical situations. Most algorithms relate directly to surgical considerations; however, several apply to patients treated by general dentists for routine operative procedures.

The second and third sections are written in easy-to-read outline format. The second section, entitled "Basic Care of the Surgical Patient," could be changed to "Basic Care of the Dental Patient," as the information is applicable to most all dental patients. The chapters on medications, local anesthetic, and the medically compromised patient are germane to all practicing dentists.

Although much of the material in section three is directed to major oral and maxillofacial surgery, the chapters referencing orofacial pain and odontogenic infections are essential to the general dentist.

The fourth section, including such topics as guidelines for antibiotic prophylaxis and management of medical emergencies in the dental office, is segmented in "to the point" appendices. These references are fundamental to all dentists.

This manual wastes no pages. Comprehensive information, in a simple-to-read arrangement, meets the clinical demands of the general dentist. The sections directly related to oral and maxillofacial surgery serve as an excellent reference. An index in the back of the book allows the dentist to turn to the exact page, locating a concise outline of the topic.

In the practice of dentistry today, the patient population is aging and surviving longer. Once-acute diseases are now categorized chronic, being managed over the long term with new and ever-changing treatment regimens, including cocktails of medications, nutritional supplements, and home remedies. Today's patient, often educated through diverse multimedia sources, demands that dentists be well qualified to provide innovative treatment options and be prepared for emergency care. This environment brings new challenges to today's dentist.

This book provides critical information, quickly available, to today's practicing dentist who is managing a diverse patient practice. This manual should be in the office, briefcase, or pocket of the practicing general dentist.

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CRITICAL THINKING: UNDERSTANDING AND EVALUATING DENTAL RESEARCH

Donald M Brunette

Published by Quintessence Publishing Co, Inc, Chicago, 1996, 296 pages, 48 illustrations. $38.00 softbound.

This book is intended primarily to serve as a text for courses on information management and critical thinking and is based on a dental school course for undergraduates and dental graduate students at the University of British Columbia Faculty of Dentistry. The author is a professor of oral biology at this institution. The book specifically addresses the instructional requirements for accreditation of dental schools in the U S and Canada, and this reviewer hopes it is the precursor to expanded use of the primary scientific literature within the dental school curriculum. The author also intends the text for practicing dentists and auxiliary staff, although it is unlikely to be read by the typical practitioner or staff.

This book is written in a comfortable, humorous style, generally eschewing the typical manner of statistics texts. Many excellent examples from dental research are included. The book is complex, and topics range broadly from the sources of scientific literature to design and measurement in studies to statistics. A final chapter includes student problems. The chapters on research measurement and design are well done and taken independently could be the basis for helpful instruction for all clinical researchers. Even more clinical examples would have been helpful.

Although the book strives to help the clinical student get the most out of the literature, the examples are chosen primarily to represent problems in the research. More positive examples and illustrations from well-designed clinical studies would have been helpful. The coverage of some critical areas of dentistry is spotty as well: More examples from restorative dentistry and biomaterials were warranted. While the intent is also to encourage skepticism, the when, why, and how to for this activity are missing. The excellent *Users' Guide to the Medical Literature*, which is published regularly in the *Journal of the American Medical Association*, is a good reference in that regard.

The chapter on information seeking is well done but too limited by today's standards when students have direct computer access to systems and interfaces such as Internet Grateful Med. These systems translate user's terminology into the language of the database. In this regard, readers might be interested in the Medline access information on the American Dental Association Homepage *ADA Online* at http://www.ada.org/prac/info/medline.html. It would also have been helpful to discuss building a personal library and constructing a plan for staying abreast of the literature after finishing school, including how to critically evaluate continuing education courses. No mention is made of study clubs and similar ways practicing dentists learn. Also, no mention is made of the availability of materials from government or groups like the cancer societies.

We found the chapter on quackery to be interesting but too easily dismissive of alternative therapies. Skeptical dental students would benefit from a fuller investigation of the dental clinical examples. Similarly, the judgment chapter is excellent, as it really gets at the heart of making clinical decisions based on the clinical scientific literature with all its strengths and weaknesses.

This book would be a valuable dental school course text as well as useful reference for the graduate specialty student or novice clinical researcher. An accompanying casebook of full length studies to read would be a helpful addition.

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QUINTESSENCE OF DENTAL TECHNOLOGY 1996

John A Sorensen, DMD, Editor

Published by Quintessence Publishing Co, Inc, Chicago, 1996. 130 pages, 396 illustrations, $48.00 softbound.

Quintessence of Dental Technology (QDT) 1996 is designed to present new dental technologies that serve to expand the art and science of dentistry. John Sorensen, the editor, is currently ODA Centennial Professor of Restorative Dentistry and Chairman of Fixed Prosthodontics at the Oregon Health Sciences University. In his introductory editorial, Dr Sorensen expresses concern that PPO and HMO dental healthcare systems exist to contain costs and provide profits for stockholders, which indirectly promotes the cheapest possible dental healthcare. He emphasizes that high standards in dentistry are essential to continued growth of our profession and that patients will continue to seek out the highest quality of the dental art form.

The sections of the book on "New Technology," "Ceramics," "Implants," and "Research" were written by an international group of dentists and dental technicians, and each section effectively introduces new technologies and clinical hints that promote the advancement of the art and science of dentistry. The book is well organized and has numerous color illustrations of exceptional clarity. The "New Technology" section presents CAD/CAM technologies, including DCS President and Procera systems. The computer systems presented in this text are limited to the fabrication of copings only and are not capable of generating occlusal anatomy. Also, laser welding of metal substructures is described. Solder-free metallic connections produced by laser welding should have better corrosion resistance. In addition to discussing Spinell porcelain and ceramic inlay refractory materials, the "Ceramics" section also contains informative articles on "Esthetics," "Tooth Characterization," and "Color Theory." As was emphasized in these articles, it is important to appreciate that the natural appearance of a tooth should also be in harmony with adjacent teeth. The "Implant" section presented variations on the location of screw access openings and new precision soldering techniques for implant-supported metal substructures. As more experience is gained in the field of implantology, the sharing of innovative approaches to problem solving will be increasingly critical for excellence in patient care. An original research study on joining In-ceram porcelain substructures after sectioning was presented in the "Research" section, followed by investigation of concerns with acrylic denture dimensional stability and fracture resistance upon subjecting the denture to a second curing.

At the end of the book an interview with Dr John McLean, who was celebrating his 70th birthday at the International Society of Dental Ceramics, was conducted by Dr Gregory Boyajian. Dr McLean emphasized that metals and metal-ceramics are still the materials of choice for the posterior dentition, and he cautioned against the use of all-ceramic posterior bridges.

This book would be of interest to both dentists and dental laboratory technicians who devote a significant part of or limit their practice to dental ceramics and implantology. *QDT 1996* would also serve as an excellent reference for postgraduate programs in esthetic and implant dentistry. The book provides avenues for future research and would be of interest to those currently involved in dental biomaterials research. Obviously additional financial investments in equipment will have to be justified, and postgraduate training for both dentists and technicians will be necessary to incorporate these new treatment modalities into practice. Although the technologies presented certainly appear attractive, their advantages and disadvantages still need to be further assessed with additional laboratory research and clinical studies.

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ENDOSSEUS IMPLANTS: CLINICAL AND SCIENTIFIC ASPECTS

Georg Watzek, MD, DDS

Published by Quintessence Publishing Co, Inc, Chicago, 1996. 407 pages, 635 Illustrations, $210.00.

Implant prosthodontics has a long and varied history that goes back to about 2000 BC, when homologous teeth were reimplanted. More recently, with the advent of osseointegration, implants have become an everyday part of treating partially and fully edentulous patients. Because of this, several texts have been written detailing all aspects of implant therapies. This book is one of the more recent to be published, bringing to the reader some of the more current trends in surgery, biomechanics, and prosthetic procedures.

The text contains 11 chapters written mainly by faculty members of the Schools of Dentistry at the University of Vienna and the Albert-Ludwigs University. Each of the chapters has an extensive bibliography, which includes research completed by the authors as well as classic implant research. The clinical photography and illustrations, which are plentiful, are outstanding and help greatly in developing an understanding of the concepts they depict. The beginning chapters do a good job of defining the basic concepts, problems, and solutions of implant dentistry. These chapters discuss history, anatomy, treatment planning, and hard- and soft-tissue considerations. The following chapters provide good material to develop rationales for different implant geometries and surface treatments as well as proper biomechanical loading and design for implant constructions. The final chapters deal with the prosthetic aspects of implant dentistry. There tends to be a bit of redundancy in the final chapter, in that certain techniques are shown multiple times, only with the use of different materials. The chapter also repeats concepts previously discussed in other chapters. Even so, the beautiful results shown are organized in a fashion that shows the reader the step-by-step clinical and laboratory procedures in picture and outline form.

Information for implant dentistry is growing very rapidly, and the knowledge is ever changing. Therefore it is of the utmost importance for the implant practitioner to stay on top of this material. This text, although it has more of a surgical bent, will help those on both sides of the implant fence better understand the treatment approaches they render to their patients.

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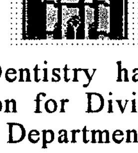

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