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Rube Lives?

Each year since 1983, Purdue University in West Lafayette, Indiana, has sponsored the National Rube Goldberg Machine Contest. For those not familiar with the Sunday cartoon, it was a fixture in a lot of papers for more than half of this century. Rube Goldberg drew machines or devices that took very elaborate and complicated steps to perform simple tasks. Examples would be a machine that takes 15 steps to turn on a light or an equally complex device that toasts bread. The devices he created had lots of pulleys, fulcrums, pivots, relays, fans, incline planes, and sometimes real mice. The machines, when you studied them long enough, could be made to perform the task that Rube had in mind. They were wonderful pieces of creative art that often took some concentration to unravel.

This year's contest, held in the Elliott Hall of Music on the Purdue campus, had the stated objective of creating a machine/device that screwed in a lightbulb. The rules were simple. Each machine had to have an identifiable central theme. You could build your machine out of anything, but it had to take at least 20 steps before the bulb was screwed in. The machine's physical dimensions had to measure 5' x 5' x 6' and could use flying objects within that space, but not explosives or combustible materials.

This year's winner is Hofstra University in Hempstead, New York. Their theme is the Addams Family, and according to their handout, (no, I didn't get to actually see it) the machine takes the following steps to screw in the lightbulb. When a hangman's noose is pulled, a barricade is raised that sends a model car down a track. The car has a tined fork in front that pops a balloon, allowing the remnants of the balloon to be pulled through a retaining ring that has prevented a guillotine blade from falling. The now- freed blade speeds downward and neatly chops off the head of a Pugsley doll. The head, sans Pugsley, rolls down a trough and lands on a switch that activates a small motor for an elevator. The elevator, holding a metal ball, moves upward and forward, finally releasing the ball onto a track that ends between two electrical contacts. The ball completes the circuit that activates a dinosaur that walks into a switch that turns on two electric trains that are on a collision course. The ensuing crash forces one train off the tracks and into a basket that falls and depresses another switch that turns on a fan. The fan blows a magnetically levitated sailcar across a bridge, where the car hits a switch that releases a plastic spider on a string. The string pulls up a gate that releases several marbles. The marbles trigger another fan, causing an Archimedes' screw to turn, pulling a string that activates a mousetrap. The trap knocks a brace out from under a can of fake blood that spills into a funnel. The blood runs through the funnel into a section of clear tubing (that just happens to spell *Hofstra*) and drains into a jar full of plastic eyes. The eyes float, rise, and hit a switch that allows a toy witch to pull a string on a rattrap. The bar of the trap activates the trigger on a toy gun that fires a rubber dart at a domino series of tombstones that end at the next rattrap. This trap springs, pulling a cable that releases a deadbolt from a spring-loaded box. The lid opens and the famous "Thing" emerges holding a light bulb. Thing rises and rotates clockwise until it screws the bulb into the mouth of a waiting and electrified Uncle Fester.

Wonderfully creative and only 27 steps to screw in the bulb.

I can hardly wait for the next generation of multipurpose dental bonding agents.

MAXWELL H ANDERSON
Editor

ORIGINAL ARTICLES

Photoelastic Stress Analysis of Self-threading Pins

J C RAGAIN, Jr • P YAMAN • R G CRAIG

Clinical Relevance
Self-threading pins produce similar tooth stresses with either amalgam or resin cores.

SUMMARY

In this laboratory study six self-threading retention pins were evaluated using the two-dimensional photoelastic technique. The experimental samples consisted of 60 blocks of PSM-1 photoelastic material measuring 1" by 1" by 1/4". The samples were divided into six groups of 10 blocks each, with each group representing one of the pins used in the study. Pins were inserted and cores of amalgam and composite were fabricated over the pins. The samples were observed in the polariscope and photographed after pin insertion and after loading the cores with a constant, compressive force of 20 pounds. Using magnification, fringe orders were counted and rounded to the highest 0.5 fringe order. Each sample was evaluated for apical and shoulder stress. All statistical analyses were done using ANOVA at the *P* = 0.05 significance level. It was concluded from this study that the insertion of self-threading retention pins results in stress at the apical and shoulder areas of the pin. Pin design features, such as shoulder stops, significantly affect the magnitude and location of stress. There were no significant differences in either the apical or shoulder stresses induced when cores were made of either amalgam or composite resin.

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INTRODUCTION

Retention pins are often used in the restoration of teeth with substantial loss of tooth structure. The purpose of retentive pins is to enhance the retention of the restoration so that the remaining tooth substance is preserved and the tooth is maintained in function. However, the stresses generated by the pin/core build-up result in complications that might jeopardize the health of the tooth. Many studies have utilized the photoelastic method to analyze the stresses produced by retention pins (Caputo, Standlee & Collard, 1973; Dhuru, McLachlan & Kasloff, 1979; Irvin & others, 1985).

Photoelasticity is an experimental method used to evaluate the stresses of a structure. Its basis is founded in the property of birefringence, or double refraction. In the two-dimensional method, models of the specimen under investigation are fabricated using a transparent plastic material that possesses this property. When the model is stressed in an instrument called a polariscope and examined in white light, color patterns known as fringes can be observed in the specimen (Mahler & Peyton, 1955).

The fringe patterns can be evaluated to determine the stress distribution in the model. Each fringe order can be thought of as a gradient of the differences in the principle stresses of the model. Fringe order can be highly concentrated, such as at the apex in some retention pins, where the stress gradient is so high that distinguishing the various fringe orders can be difficult. When the fringe orders are thus concentrated, it means that the stress varies rapidly from one area to another (Caputo & Standlee, 1987).

A quantitative evaluation of the stress can be determined by the equation $Q^1 - Q^2 = N(F/T)$. In this equation Q^1 is the principle stress in plane X, Q^2 is the principle stress in plane Y, N is the relative retardation or fringe order, F is the stress optical coefficient that is dependent upon the stress constant of the photoelastic material and the light's wavelength, and T is the thickness of the photoelastic material. As is readily apparent from the equation, the fringe order is directly related to the difference in principle stress (Thorsteinsson, 1990).

This study compared the stress associated with self-threading retention pins with and without shoulder stops, using the photoelastic method.

METHODS AND MATERIALS

The experimental samples consisted of 60 blocks of PSM-1 photoelastic material (Lot #1300, Measurement Group, Inc, Raleigh, NC 27611) measuring 1" x 1" x 1/4" (Figure 1). The samples were divided into six groups of 10 blocks each, with each group representing one of the six pins used in this study (Table 1).

Pin channels were prepared by using the

Table 1. List of Self-threading Retention Pins Evaluated

MANUFACTURER	PIN MODEL	LENGTH	DIAMETER	VENT	SHOULDER STOP	TAPERED APEX
Brasseler USA, Inc Savannah, GA 31419	PS Size 2	5.29 mm	0.52 mm	Yes	Yes	Yes
Vivadent USA Inc Amherst, NY 14228	Filpin Universal	4.58 mm	0.58 mm	No	No	Yes
Whaledent International New York, NY 10001	TMS Link Plus Minim	5.17 mm	0.58 mm	No	Yes	Yes
Whaledent International New York, NY 10001	Max .021	3.78 mm	0.60 mm	No	Yes	Yes
Fairfax Dental Inc Coral Gables, FL 33134	Stabilok Small Dia	4.47 mm	0.62 mm	No	No	No
LD Caulk Milford, DE 19963	Maillefer STP	4.47 mm	0.72 mm	Yes	No	Yes

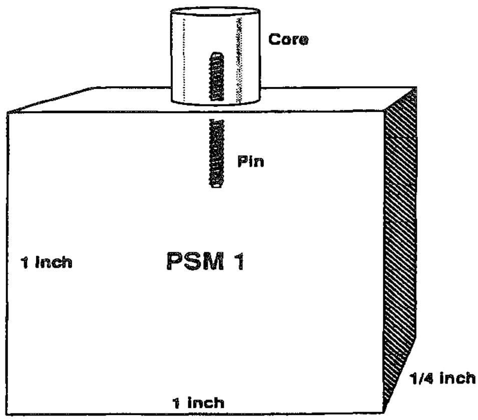

Figure 1. *Diagram of test sample*

appropriate twist drill supplied in the respective pin kits. The twist drills were attached to a contra-angle slow-speed handpiece (Titan II, Star Dental Mfg Co, Inc, Valley Forge, PA 19482) that was mounted in a Jermyn Paralaid paralleling device (Young Dental Manufacturing Co, Inc, Maryland Heights, MO 63043) to ensure parallelism and standardization of pin placement. The location of the pin channel was determined and the block was marked to identify this point. Pin placement procedures followed the manufacturers' instructions.

The samples were placed in a circular polariscope (Model 061, Photoelastic, Inc, Malvern, PA 19355) to determine the baseline stress associated with pin placement. Photographs (Pentax ME Super camera, Asahi Optical Co, Ltd, Tokyo, Japan with a Vivitar 100 Macro lens and a Vivitar 2X Macroconverter, Vivitar Corp, Chatsworth, CA 91311) were taken of each sample at a 2:1 magnification using Kodak ASA 100 color print film (Eastman Kodak Co, Rochester, NY 14650).

Cores were fabricated using a high-copper admixed amalgam (Contour,Sybron/Kerr, Romulus, MI 48174) and an auto-cured core build-up composite resin (Concise, 3M Dental Products, St Paul, MN 55144). Five samples of each core type were fabricated for each pin group. The assignment of core material type to the samples was randomized using a random table of numbers. The cores were fabricated by securing a brass jig to the sample with the retention pin located in the center of the mold. The restorative material was placed around the pin and allowed to set. The jigs were then carefully removed, thus providing uniform cylindrical cores measuring 5 mm in diameter and 4 mm in height. The top of each core was leveled by using a disk placed in a slow-speed handpiece mounted on a dental surveyor (JM Ney Co, Bloomfield, CT 06002) and using a bubble level for standardization.

The samples were again evaluated with the circular polariscope to determine the stresses associated with core fabrication using the same procedures as those for pin insertion.

The samples were then subjected to a consistent, vertical load of 10 pounds (loading mechanism: Model 241, Photoelastic, Inc; measuring gauge #25-141, LS Starett Co, Athol, MA 02134). Photographs were taken of the samples through the circular polariscope as previously described.

After development, the photographs were examined under a stereo microscope (Model Semi SU88, Zeiss Co, Wiesbaden, Germany) at X25 magnification to better evaluate the fringe orders. Fringe orders were counted and rounded to the highest 0.5 fringe order. Each pin was evaluated for stress associated with the lower half of the pin (corresponding primarily with stresses at the apex), and with stresses originating from the upper half (Figure 2). Figure 3 illustrates a sample with high apical stress, and Figure 4 is a photograph of a sample demonstrating high shoulder stress.

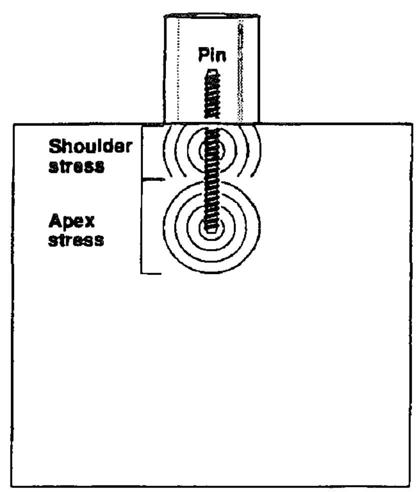

Figure 2. *Separation of shoulder and apical stress for evaluation*

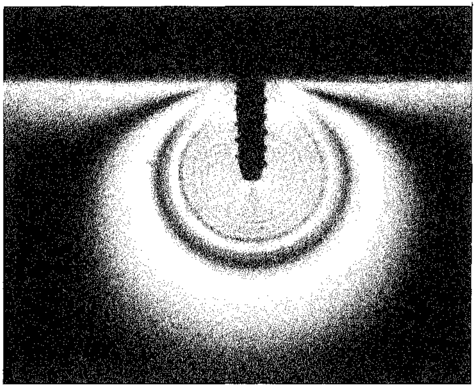

Figure 3. *Sample with high apical stress*

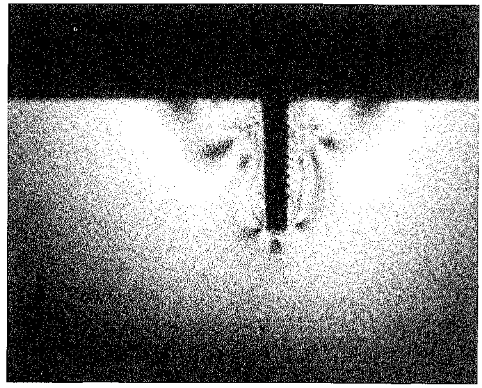

Figure 4. *Sample with high shoulder stress*

RESULTS

The mean values of the fringe order measured at the pin shoulder area were calculated. Repeated measures ANOVA at the $P = 0.05$ significance level and the Scheffé comparison between groups were used to evaluate the data. It was determined that there is a significant difference between pin types with respect to shoulder stress after pin insertion, $P = 0.0001$ (Figure 5). The Brasseler pin showed the highest stress, and the Filpin pin demonstrated the lowest.

Shoulder stress was increased with all pins during core loading, and there proved to be a significant difference between the pin types, $P = 0.0001$ (Figure 5). Again, the Brasseler pin demonstrated the overall highest shoulder stress, and the Filpin pin showed the lowest shoulder stress.

Interaction between pin and core types in regard to shoulder stress during pin/core system loading was statistically analyzed using two-factor ANOVA, and it was determined that there was no significant difference between the two core materials, $P = 0.692$ (Figure 6).

Apical stress was evaluated and statistically analyzed in the same manner. It was determined that there is a significant difference between pin types with respect to the apical stress upon pin insertion, $P = 0.0001$ (Figure 7). The Brasseler and the Max .021 demonstrated the least insertion stresses. The Filpin, STP, and Stabilok pins demonstrated the highest stresses. The insertion stress for the Link Plus pin was approximately midrange.

Apical stress upon core loading proved to be significant, $P = 0.0001$ (Figure 7).

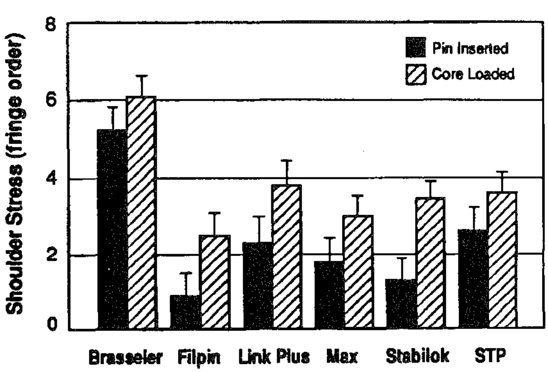

Figure 5. *Graphic representation of shoulder stress with pin inserted and core loaded*

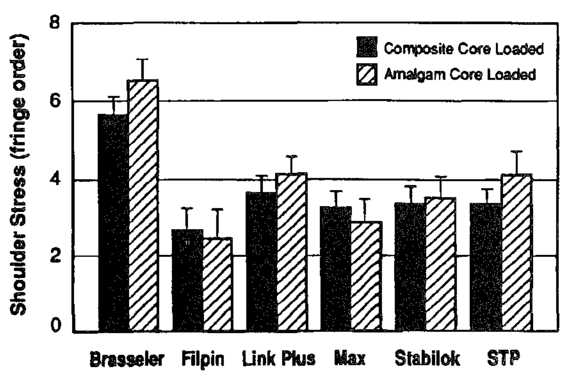

Figure 6. *Graphic representation of shoulder stress for composite and amalgam cores loaded*

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Perceived Trends in Operative Dentistry Skills: A 10-Year Comparison

F E PINK • G E SMITH

SUMMARY

In this study a random sample of 357 members of dental examiner boards in the United States was surveyed to determine the perceptions of candidate ability on examinations for dental licensure. A response rate of 82% was achieved. Data from this survey were compared to a similar survey conducted 10 years ago. Analysis and comparison of these two surveys indicate that candidate ability in operative dentistry has continued to decline as perceived by dental examiners in the United States over the past decade.

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INTRODUCTION

In 1980 the journal *Operative Dentistry* published the results of a survey of state board examiners' perceptions of candidate ability as demonstrated on dental examinations for licensure (Smith, Bomberg & Bauer, 1980). Two-thirds of all respondents believed at that time that the skills in operative dentistry of recent dental graduates had declined during their tenure as examiners.

Many concerns have continued to surround the issue of dental licensure examinations during the past decade: the passing of candidates, the degree of preparedness of candidates, patient selection, and so forth (Allen, 1992; Dugoni, 1992; Hutchinson, 1992; Nash, 1992; Bales, 1988, 1990a,b; Hamilton, 1983), which testify to the complexity of the topic and the subjectivity of it. The purpose of this paper is to report on a 10-year follow-up survey of dental examiners and to compare the perceptions of examiners now to those of 10 years ago.

METHODS AND MATERIALS

The questionnaire used for this project was patterned after, and refined from, the one presented in the *Operative Dentistry* article by Smith and others (1980) and then mailed to 357 board members across the United States. The sample was compiled from listings of state dental board examiners provided by the various states. These examiners represented regional as well as separate state board examinations. The questionnaire contained a letter of introduction with statement of anonymity, a stamped, self-addressed return envelope, a one-page demographic questionnaire, and finally the three-page clinical skill questionnaire arranged as Likert scales covering the areas of general clinical skills, amalgam, cast gold, direct gold, composite resin preparation and restoration, and general operative performance skills. A follow-up letter and second questionnaire were mailed to nonrespondents three weeks following the initial mailing. Data from the questionnaires were managed and analyzed with a desktop PC utilizing Systat software (Systat, Inc, 1990).

Kruskal-Wallis statistics, the nonparametric equivalent of a one-factor ANOVA, were utilized to analyze relationships in the data. The significance level was set at $P \leq 0.05$. Furthermore, it will be noted that all the tables report a column of the median response for each category. This median was calculated by removing those responses in the "not applicable" column, leaving a three-choice ordinal scale. Calculation of the median for any particular skill question will identify the category with over 50% of the responses in a three-choice scale. By definition the median is the middle response for a set of data, therefore, if only three choices are possible the calculated median accounts for at least 50% of the responses for that question.

The authors felt it important to report the "not applicable" column as an indication of the context of current board examinations. However, calculation of the median for the data not including the "not applicable" responses allows for a clear understanding of what 50%+ of the respondents felt the current skill levels were.

RESULTS

Of the 357 survey packets mailed, 292 questionnaires (82%) were returned with adequate information provided to be included in the study. Of the 292 questionnaires returned, approximately 81% of the examiners considered themselves general dentists, with the remaining 19% spread among the different specialties (Figure 1). The examiners reporting ranged in age from 31 to 71+ with 35% in the 51-60 age group (Figure 2). The tenure for the examiners spanned 1-30 years, and 44% had been examiners for 1-5 years (Figure 3) with a mean tenure of 8.1 years as

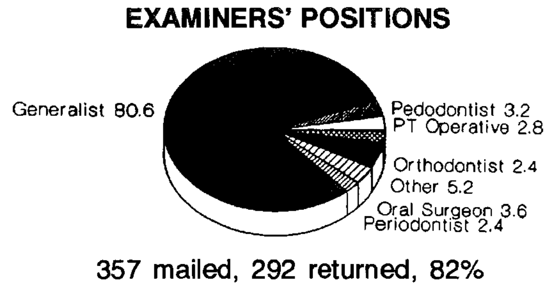

Figure 1. *Analysis of the types of dental practice in which the examiners surveyed in this study are engaged reveals that 80.6% are engaged in general practice.*

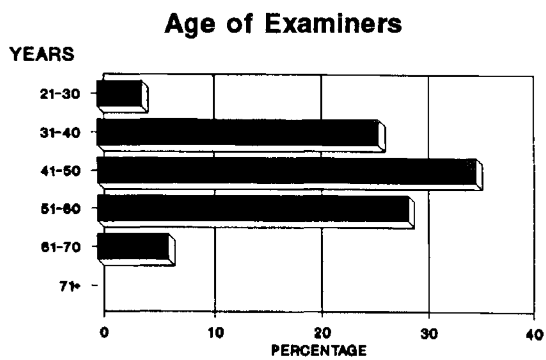

Figure 2. *Analysis of the age of responding examiners indicates that the majority of examiners are in the 40- to 51-year-old age group.*

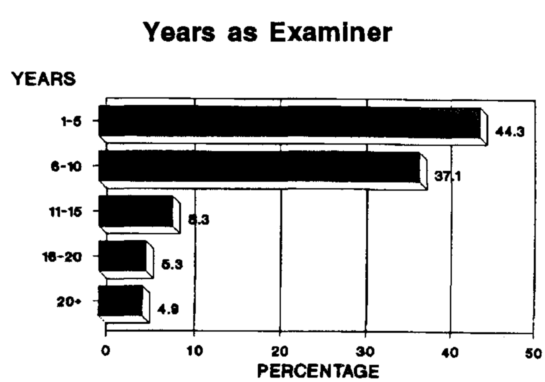

Figure 3. *Analysis of the years of experience of current examiners indicates that most respondents have 10 or less years of experience as dental examiners.*

examiner. Eighty-six percent of the respondents had served as examiners within the last three years, which also was the inclusion criterion for completion of the rest of the clinical skills questionnaire.

The first question of the survey asked the examiner to identify trends in clinical skills of the candidates. The scale employed was: improved, no change, worsened, and not applicable. Almost all, 98.2% of the examiners, responded to this clinical skills question (Table 1), and 50.2% believed operative skills were decreasing, with a reported median response of "worsened" skill. A significant percentage of responses for the other skills in this category indicated there had been no change in candidate ability for the other skills listed. Predictable percentages for categories "not observed" were reported for oral surgery, pedodontics/orthodontics, basic science, and crown and bridge, as well as others. The authors feel this is an indication of the sincere nature with which the respondents completed the questionnaire, lending reliability to answers surveyed.

The second question asked the examiner to identify errors in technique for amalgam preparations and restorations (Table 2). The scale employed for this section was: "often," "seldom," "never," and "not applicable." A significant number of examiners identified errors as deep preparations (61.7%) with median response of "often," wide approximal boxes (50.2%) with median response of "often," and improper occlusal anatomical form (46.0%), although this feature was not significantly different from the "seldom" category. The other errors listed were marked as "seldom" occurrences in the examiner's experience.

The third question asked the examiner to identify errors in cast gold preparations and restorations (Table 3). The scale was the same as reported for amalgam procedures. The existence of faulty margins was the only significant error, chosen by 47.6% of the examiners, with a median response of "often." Again here, respondents seemed to note a trend toward deep preparations, as in amalgam preparation skills, with 44.1% of the examiners choosing the "often" category. For all other possible errors listed, the "seldom" category was chosen by the majority of the examiners. The majority of respondents

Table 1. Trends in Clinical Skills

	Improved	Same	Worse	N/A	Median
Operative	13.8	34.1	50.2	1.8	worse
C & Bridge	6.1	30.2	25.5	38.2	same
Periodontics	23.7	40.3	16.1	19.9	same
DX & TX Plan	16.3	45.2	20.2	18.3	same
X-ray Interp	5.7	58.8	17.1	18.5	same
X-ray Techn	6.1	50.9	12.7	30.2	same
Oral Path	14.0	38.2	10.6	37.2	same
Oral Surg	2.9	13.7	3.4	79.9	same
Pedo/Ortho	4.5	13.4	2.5	79.6	same
Basic Science	10.8	31.9	14.2	43.1	same

Table 2. Errors in Amalgam Procedures

	Often	Seldom	Never	N/A	Median
Prep Deep	61.7	32.2	5.6	0.5	often
Prep Shallow	43.2	48.4	8.0	0.5	seldom
Retent Deep	27.5	55.1	16.4	1.0	seldom
Retent Shallow	41.3	49.0	7.2	2.4	seldom
Wide Approx Box	50.2	39.3	10.0	0.5	often
Cusps Weakened	28.0	55.6	15.5	1.0	seldom
Caries Remains	20.7	58.7	19.7	0.9	seldom
Exposed Pulp	19.8	59.9	18.9	1.4	seldom
Adj Damage	33.3	52.6	12.2	1.9	seldom
Poor Occl Anat	46.0	44.1	8.5	1.4	seldom
Poor Approx Anat	34.7	53.5	10.8	0.9	seldom
Contact Absent	22.0	57.5	19.2	1.4	seldom
Occl Inadeq	12.3	64.2	21.7	1.9	seldom

Table 3. Errors in Cast Gold Procedures

	Often	Seldom	Never	N/A	Median
Prep Deep	44.1	47.9	4.7	3.3	seldom
Prep Shallow	33.6	54.5	8.5	3.3	seldom
Proper Bevel	38.3	45.0	12.9	3.8	seldom
Cusps Weakened	22.4	55.2	17.6	4.8	seldom
Inadeq Reduct	26.2	48.1	17.1	8.6	seldom
Exposed Pulp	15.0	55.9	20.7	8.5	seldom
Caries Remains	13.5	56.3	20.5	9.8	seldom
Faulty Margins	47.6	42.9	3.3	6.1	often
Improper Occl	27.8	52.4	13.7	6.1	seldom
Incorrect Anat	30.8	48.3	16.6	4.3	seldom

reported on cast gold findings, verifying the emphasis on amalgam and cast gold on state board examinations.

The fourth question asked the examiner to identify errors in direct gold preparations and restorations (Table 4). The scale used was the same as for the other questions on specific procedures. Only 45% of the examiners reported in this area, which showed the decreased use of direct gold testing techniques on current state board examinations. Errors that were marked by a majority of the examiners as occurring "often," shown by a similar median response, included poor cavosurface margins, poor restoration finish, and porosity of the finished material. Responses for correct outline form were evenly distributed between "often" and "seldom" for a total of approximately 41% of the responses in that category with a median response of "seldom."

The fifth question asked the examiner to identify errors in composite resin preparations and restorations (Table 5). The scale used again included "often," "seldom," "never," and "not applicable." Approximately 57% of the respondents had observed these procedures during board examinations. There was a trend toward errors in correct outline form occurring "often," but a median response of "seldom" was calculated. All other responses had a majority of examiners choosing the "seldom" category for the possible errors listed.

The sixth and final question addressed the examiners' opinion on changes in overall operative skills by the candidates (Table 6). The scale used for this question was: "improved," "no change," "worsened," and "not applicable." It is important to point out that the "not applicable" category was marked in the same proportion as in the separate sections for the earlier questions on similar areas of concern. These categories were included to verify reliability of the responses through completion of the questionnaire, and in fact support that hypothesis. The responses show a significant majority of examiners that identified a "worsening" of skills in the areas of direct gold preparation (24.1%). There was a trend toward "worsening" skills in amalgam preparations (40.3%), and cast gold preparations (45.1%), but the median response was "no change." All other operative skills listed were assessed by the majority of

Table 4. Errors in Direct Gold Procedures

	Often	Seldom	Never	N/A	Median
Proper Outline	20.7	20.2	3.4	55.7	seldom
Retention Deep	15.0	28.5	2.4	54.1	seldom
Retent Shallow	17.6	23.9	3.9	54.6	seldom
Poor Cavosurf	22.9	19.5	2.9	54.6	often
Poor Finish	29.1	13.6	2.4	54.9	often
Mat'l Porosity	26.1	15.9	3.4	54.6	often

Table 5. Errors in Composite Resin Procedures

	Often	Seldom	Never	N/A	Median
Proper Outline	25.6	22.7	8.5	43.1	seldom
Retention Deep	10.9	33.2	13.3	42.7	seldom
Retent Shallow	19.9	26.5	10.9	42.7	seldom
Poor Cavosurf	19.4	28.4	9.0	43.1	seldom
Poor Finish	18.5	28.9	9.0	43.6	seldom
Mat'l Porosity	9.0	33.6	14.2	43.1	seldom

Table 6. Changes in Operative Dentistry Skills

	Improved	Same	Worse	N/A	Median
Amalgam Prep	14.8	42.6	40.3	2.3	same
Cast Gold Prep	10.2	40.0	45.1	4.7	same
Dir Gold Prep	1.5	18.0	24.4	56.1	worse
Composite Prep	16.0	28.6	12.6	42.7	same
Amalgam Rest	14.4	55.6	27.8	2.3	same
Cast Gold Rest	7.9	46.7	38.8	6.5	same
Dir Gold Rest	2.5	16.7	24.1	56.7	worse
Composite Rest	15.3	35.4	7.7	41.6	same
Patient Manage	9.8	63.6	8.9	17.8	same
Rubber Dam	15.5	61.0	15.5	8.0	same
Diagnosis	11.5	54.1	15.8	18.7	same
Anesthesia	6.6	60.6	2.3	30.5	same
Caries ID	3.2	63.9	26.9	6.0	same
Caries Removal	5.1	67.9	23.3	3.7	same
Bases/Liners	19.0	51.7	24.6	4.7	same
Mat'l Used	9.9	65.6	16.0	8.5	same
Understand Occl	7.6	63.8	19.5	9.0	same
Lab Procedure	5.7	36.2	28.6	29.5	same
Organization	10.3	55.6	23.8	10.3	same
Professional	17.7	42.8	31.2	8.4	same

the examiners as having no change in skills by the examiners.

The data for question six, changes in performance skills in operative dentistry, were further analyzed and stratified by examiner age group (Figure 2). It is interesting to note that no significant differences were found in the operative performance skills of board candidates based on examiner age ($P > 0.05$).

DISCUSSION

A review of the responses to this survey indicates that the decline in operative dentistry skills noted 10 years ago (Smith & others, 1980) has continued. Although the trend in declining skill reported in this latest survey was observed by 50.2% of the respondents compared to 87% in 1980, only 13.8% of the respondents noted an improvement in operative dentistry skills. While the perceived ability in operative dentistry demonstrated by recent candidates for licensure continues to decline, it does so at a lesser rate than reported in 1980. The same may be said of skills in fixed prosthodontics. Skills in periodontics, on the other hand, continue to improve: a trend noted in 1980 as well.

Errors in cavity design for silver amalgam and cast gold restorations contribute in a major way to the decline in overall skill in operative dentistry as perceived by examiners. Fewer licensing boards utilize the direct gold restoration as a testing medium, and examiners report only modest declines in candidate ability in rendering care with composite resin restorations, in which technical errors, although real, may take more time to become evident.

Technical skill, in the present study, regarding cavity preparations for silver amalgam demonstrated errors most frequently attributed to excessive cavity depth, excessive cavity width, inadequate cavity depth, shallow retention form, and damage to adjacent teeth in declining degrees of frequency. Poor anatomy was cited as the most frequent fault in the amalgam restorations examined. The responses in the 1980 survey were similar, and in both surveys examiners reported excessive depth of preparations as the most frequent error and overcutting in the width of preparations as a close second. Perceived leaving of caries declined as an error in the present study, 14.0% as opposed to 32% in 1980.

When reviewing the observations regarding cast gold procedures, one is struck again by the similarities in the two surveys conducted 10 years apart. Cavity depth continues to be a major problem, followed closely by cavity width, margin finish (bevels), and cuspal reduction, which is often reported to be inadequate in depth. Faulty fit, marginal adaptation, and occlusion also continue to be problems often regarding the final restorations.

When one views the report of this survey for changes in overall operative skills, it is interesting to note that it is only in the composite resin cavity preparation and restoration section that the number of responses with "improved" ability exceeds the number with perceived "worsened" ability, and then only slightly. These procedures may be considered somewhat less demanding and may be also more difficult to evaluate; however, the technique sensitivity of tooth-colored restorative systems is of some concern, and it may be hypothesized that errors in technique with these restorations are potentially more harmful than technical errors with amalgam restorations. In all amalgam and cast gold procedures skills, over 80% of examiners responding indicated that these candidate skills had remained the same or worsened.

CONCLUSIONS

The results of the current survey indicate there is room for improving candidate performance on examinations for licensure, particularly in the area of clinical skill in operative dentistry and fixed prosthodontics procedures. Further, comparison of the two surveys taken 10 years apart indicates that candidates have been perceived to demonstrate declining restorative skills for over 10 years. Suggestions that can be made, based upon these two surveys are the following.

1. There has continued to be a decline in candidate ability as perceived by examiners of dental licensing agencies over a 10-year period.

2. There may be a need for improved dialogue between restorative dentistry educators and board examiners.

3. Dental educational methodology needs to be improved and curricular changes considered to strengthen the ability of recent graduates in the field of clinical restorative dentistry. Schools of dentistry need to consider increased curricular emphasis on restorative dentistry.

4. Examiners need to be encouraged to develop the most highly reliable testing mechanisms to evaluate candidate competency.

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The Effect of Cavity Wall Taper on Fracture Resistance of Teeth Restored with Resin Composite Inlays

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Clinical Relevance
A 4° cavity wall taper appears optimal for teeth restored with indirect composite resin restorations.

SUMMARY

The effect of a range of cavity wall tapers on fracture resistance of teeth restored with an indirect composite restoration (ICR) system has been investigated, using two methods of application of the fracturing force. The fracture load data are similar in both cases, and in neither case does ANOVA suggest a statistically significant difference in performance with cavity taper. However, the mean values are lower for the 6° taper specimens, and linear regression suggests a significant decrease, which is confirmed by the mode data for the bar loading condition, which indicates a greater incidence of severe fractures for the 6° taper. Since technical difficulties were encountered in the construction of inlays for the 2° taper preparations, the most appropriate taper of the range assessed would appear to be 4°, at least when considered with regard to fracture resistance.

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INTRODUCTION

The development and introduction of new restorative materials and techniques entail the need to evaluate the laboratory properties of the material and its performance in clinical service when used according to the prescribed technique. The conditions under which an optimum result may be obtained should also be examined. Such examinations should involve, among many other evaluations, an assessment of the influence of preparation designs and dimensions with particular regard to the fracture resistance of the restored teeth.

Aspects of the development, contemporary status, and rationale for indirect composite restorations (ICR) have been reviewed by Burke and others (1991b).

The principal indications for ICRs have been considered to include: teeth in which moderate to large tooth-colored restorations are required, sufficient tooth substance is available for bonding, the cavity has no marked undercuts, the restoration will be occlusally protected, and there is no evidence of pathological tooth wear (Burke & others, 1991b). The patient should be a regular dental attender, who maintains a good standard of oral health, and who is prepared to accept a restoration of unknown life expectancy.

With regard to preparation design for ICRs, a review of manufacturers' recommendations has shown wide diversity of opinion; however, a number of principles may be applied (Burke & others, 1991b). Many factors may influence the application of these principles, and some of these have previously been investigated using fracture-resistance techniques (Burke, Watts & Wilson, 1991a). From previous experience in this field and a recent review of tooth fracture (Burke, 1992), two methods of application of force are favored by the authors involving the use of either a 4 mm steel sphere or 4 mm steel bar.

While previously published studies (Burke & others, 1991a) and related investigations (unpublished data) have investigated the effects of cuspal coverage and alternative luting procedures for ICRs (Burke, Wilson & Watts, 1992), much remains to be investigated regarding optimum features for ICR preparations, including the optimum degree of cavity wall taper.

It is the purpose of the present in vitro investigation to evaluate the effect of cavity wall taper upon the fracture resistance of maxillary premolar teeth restored with moderate-sized, three-surface, mesio-occlusal-distal ICRs of a fine-particle hybrid resin composite restorative material.

METHODS AND MATERIALS

Forty sound maxillary premolar teeth of normal morphology, which were found on visual examination and transillumination to be free from caries, defects, and cracks, were divided at random into four equal groups of 10 teeth each. The mean maximum buccolingual width (BLW, i e, the distance from the maximum convexity on the buccal surface to the maximum convexity of the palatal surface) of teeth within and between each group varied by no more than 2.5%. Any deposits of calculus or remaining soft tissue remnants were carefully removed from the selected teeth using a hand scaler.

Following 24 hours' postextraction storage in buffered formal saline, the teeth were stored in either water of room temperature (20 °C) or maintained in moist (100% humidity) conditions, except when it was necessary to dry the teeth for elements of the experimental procedure. Each tooth was fixed, using a light-cured resin composite, with its long axis vertical and crown uppermost, in a stainless steel mold (15 mm x 15 mm x 15 mm) with a central cylindrical hole of 12 mm in diameter. The resin extended to within 2 mm of the amelocemental junction (ACJ) of each tooth.

Following an examination of "typical" inlay preparations in extracted teeth, a standardized three-surface, mesio-occlusal-distal (MOD) preparation was described with the following principal features:

Width of approximal boxes	1/2 BLW
Occlusal isthmus width (measured midway from the mesial and distal surfaces of the tooth)	1/3 BLW
Occlusal isthmus depth (measured from buccal cusp tip)	4 mm
Position of gingival margins	1 mm above ACJ
Mesiodistal width of the gingival floors	2 mm
Pulpoaxial line angle	bevelled

Preparation of Teeth

Preparations of the above design were completed in each tooth. The initial phase of the preparation was completed using a parallel-sided, round-ended diamond fissure bur (Bayer 838/014) operating in a high-speed handpiece under water coolant. The preparation was carried out under simulated surgery conditions using X2.5 magnifying loupes, with the preparation dimensions being checked using RS Vernier calipers. A cavity wall taper (i e, the angle between one cavity wall and the vertical axis of the tooth [Figure 1]) of either 2° (Group 1), 4° (Group 2), or 6° (Group 3) was then added to the preparation using Bredent tapered diamond burs (Bredent, Senden, Germany) held in a laboratory handpiece, mounted in a Bachmann design parallelometer (Cendres et Metaux SA, Bienne, Switzerland), and operating at 8000 revs/min without water coolant.

A base of Ketac Bond (ESPE, Seefeld, Oberbay, Germany) was then placed in each preparation, covering the dentin on the pulpal and gingival floors and the axial walls, as diagrammatically illustrated in Figure 2. Fifteen minutes after placement, the bases of Ketac Bond were trimmed to a thickness of 0.5 mm. Great care was taken during this procedure, which was completed using X2.5 magnification, to avoid altering the cavity wall taper or introducing any undercut features.

Construction of Inlays

A one-stage impression was taken of each prepared tooth using a polyvinylsiloxane putty and light-bodied paste (President, Coltene AG, Altstätten, Switzerland) carried in a plastic tray painted with Coltene tray adhesive. Models and dies were cast in Velmix stone (Sybron/Kerr UK Ltd, Peterborough, England) between 1 and 24 hours of recording the impression. The ICRs were fabricated in a fine-particle hybrid resin composite (Brilliant, Coltene AG) by one technician employing a standardized technique and using the composite in accordance with the manufacturer's instructions.

Inlay Placement

Following any adjustments necessary to fully seat the ICRs, the marginal fit of each inlay was subjectively assessed as would occur in the clinical situation. Any restoration considered unsatisfactory or which required other than minimal fit/surface adjustment was rejected. In the single case in which this occurred,

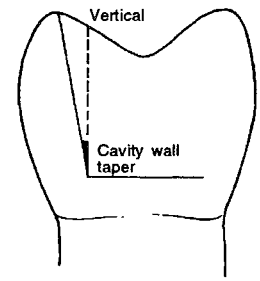

Figure 1. *Diagrammatic illustration of cavity wall taper*

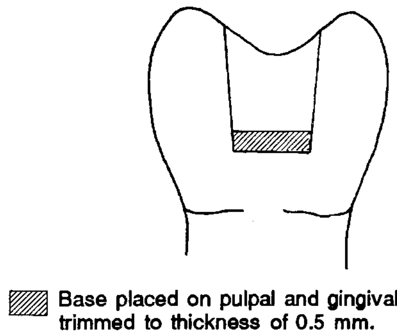

Figure 2. *Diagrammatic illustration of the base placed in each preparation*

a new ICR was made using a new impression. The fitting surface of each inlay was cleaned by application of 37% phosphoric acid gel for 30 seconds, followed by washing with water (30 seconds) and thorough drying. After cleaning with a slurry of pumice in a rubber cup, washing, and drying, the enamel margins of the preparations were etched with Coltene etching gel (Coltene AG) for 60 seconds, as initially advised by the manufacturers of the ICR system, washed with water (30 seconds), and then thoroughly dried. The adequacy of the etch was confirmed visually.

Dual-cure resin composite luting material (Coltene Duo-Cure, Coltene AG) was mixed and applied to the tooth and inlay, following application of Duo-Bond resin (Coltene AG) to wet the surfaces of the preparation. The inlay was seated using gentle pressure. Excess luting composite was removed by wiping sponge pellets across the affected lengths of the margins from the adjacent tooth surface onto the inlay surface to minimize drag-out of the composite luting material from the underlying tooth/restoration interface, and in each case, the lute was cured with a light-activating unit (Luxor, ICI Dental, Macclesfield, UK) for 40 seconds of exposure for each of the mesial, distal, and occlusal aspects of the tooth being restored. Any remaining excess luting composite was removed by carefully working 30 gm-grit diamond finishing burs (Composhape, Intensiv SA, Viganello-Lugano, Switzerland) operating at high speed under water coolant across the inlay margins.

Fracture Testing

Each restored tooth was stored under water at room temperature (20 °C) for a minimum of 4 hours prior to testing, to allow for any immediate postcure polymerization of the lute.

The restored teeth were subjected to compressive loading at a crosshead speed of 1 mm per minute on a Universal Testing Machine. Two methods of application of force were utilized. In Groups A 1, 2, and 3 a 4 mm steel ball bearing was used, and in Groups B 1, 2, and 3 the force was applied by means of a 4 mm-in-diameter stainless steel bar. In all cases the force was applied to the occlusal surface of the restoration. The force (N) to cause fracture was recorded, as was the mode of fracture, using a classification devised for the present and related investigations (Figure 3).

Two groups of 10 sound, unprepared, maxillary premolar teeth, of similar dimensions to the teeth included in the test groups, were tested by way of controls with the load being applied via a 4 mm steel sphere (Group A) and a 4 mm bar (Group B).

RESULTS

The mean fracture load (kN) to induce fracture of the restored teeth in the 2°, 4°, and 6° preparation wall taper groups loaded via a 4 mm steel sphere are shown in Figure 4. The corresponding results, relating to mean fracture load applied via a 4 mm steel bar, are shown in Figure 5, together with the results for the mean fracture load required to induce fracture in the control group. The results

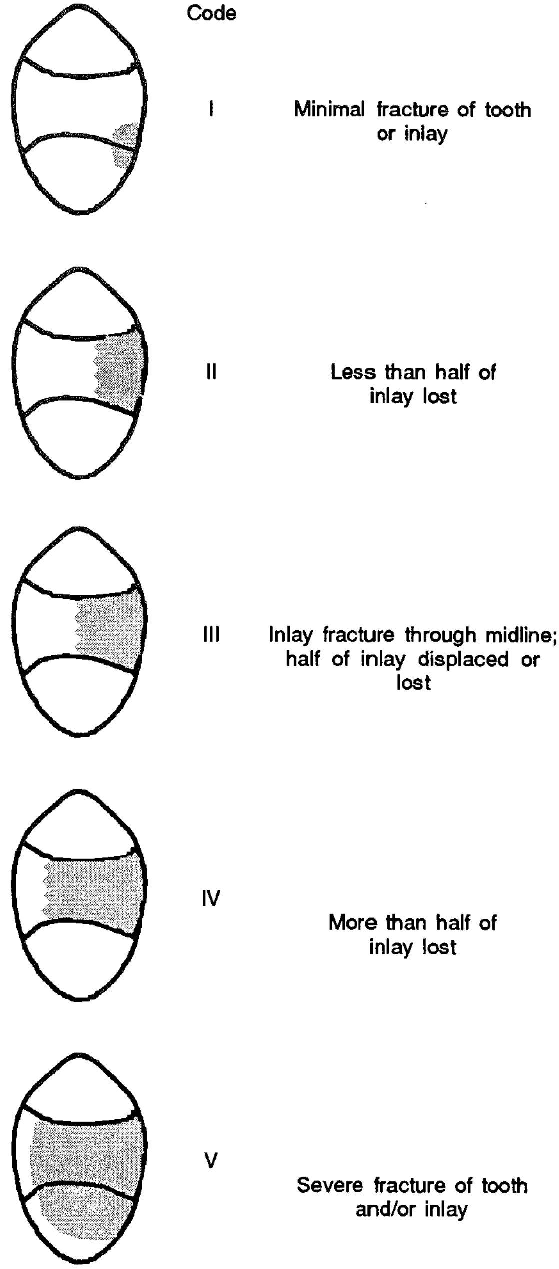

Figure 3. *Classifications of fractures*

relating to fracture mode are shown in Figures 6 and 7. While the numbers of (severe) Mode V fractures observed when the fracturing force was applied via a steel sphere were 2, 1, and 0 for the 2°, 4°, and 6° preparations respectively, the numbers of (severe) Mode V fractures observed when the fracturing force was applied via a steel bar were 2, 3, and 3 for the 2°, 4°, and 6° preparations respectively.

DISCUSSION

The present study is one of a series to investigate the effects of variations in preparation design and dimensions on the fracture resistance of teeth restored with different ICR systems. Previously published findings from this series of investigations included those reported by Burke and others (1991a) and Burke and others (1992).

Measurement of a series of inlay preparations indicates that the cavity dimensions used in this study are typical of those completed in clinical practice (Burke & others, 1991b), and that the cavity wall tapers investigated (2° - 6°) fall within the normal range. However, it has been shown by Weed, Suddick, and Kleffner (1984) that much greater tapers may be applied in the clinical situation, while, conversely, the mean taper of 33 dies prepared by one operator for onlays/inlays was 8.6° between the facial and lingual

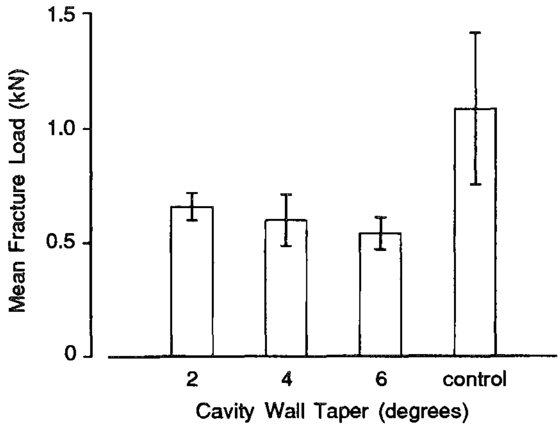

Figure 4. *Fracture strength of teeth restored with ICRs; effect of cavity wall taper. Loading via a 4 mm in diameter steel sphere.*

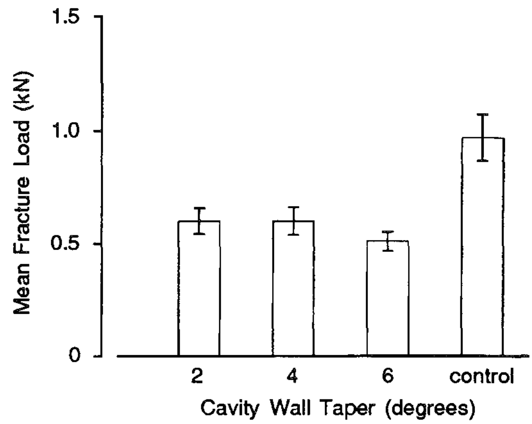

Figure 5. *Fracture strength of teeth restored with ICRs; effect of cavity wall taper. Loading via a 4 mm in diameter steel sphere.*

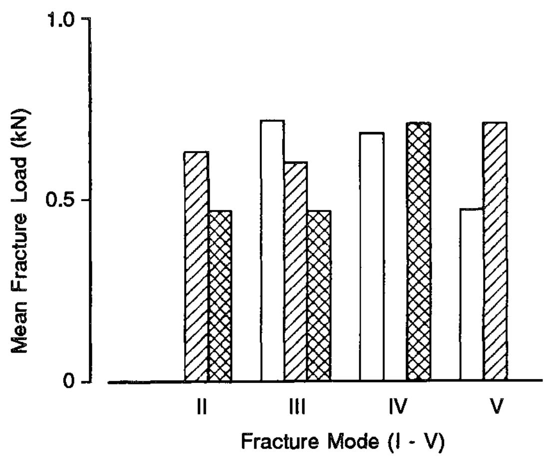

Figure 6. *Cavity taper and fracture behavior of teeth restored with ICRs. Loading via a 4 mm in diameter steel bar.*

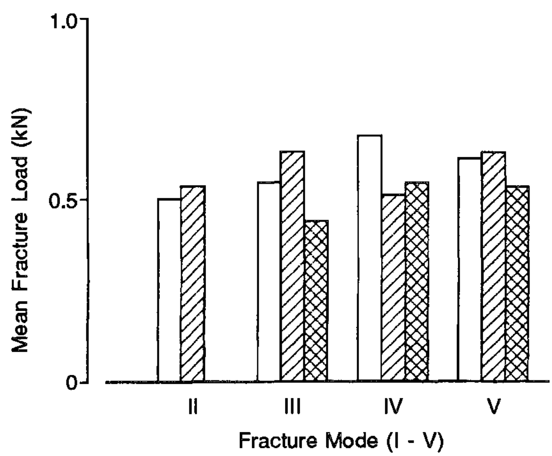

Figure 7. *Cavity taper and fracture behavior of teeth restored with ICRs. Loading via a 4 mm in diameter steel bar.*

walls of the cavity isthmuses when assessed by Kent, Shillingburg, and Duncanson (1988).

In order to enhance the clinical relevance of the investigation, the experimental technique was designed to simulate clinical conditions as closely as possible in the in vitro setting. Furthermore, the forces applied to the teeth corresponded to values that may occur in the mouth (Helkimo & Ingervall, 1978); however, it was not possible to replicate the rates of application of force seen in the mouth or to utilize objects commonly implicated in tooth fracture in vivo (Burke, 1992).

In the present investigation, two methods of application of force were used, a 4 mm steel sphere, and a 4 mm steel bar. Difficulties were experienced in maintaining the steel sphere in position on the occlusal surface of the restorations, and while one possible alternative was the use of two spheres as utilized by Wieczkowski and others (1988), the use of a 4 mm bar that was easily positioned along the mesiodistal fissure of the teeth was considered to be the more reliable technique. However, from the results set out in Figures 6 and 7, it is apparent that a great number of severe Mode V fractures occurred when using the bar, which resembles an opposing cusp less than the sphere. Consequently, it is suggested that both the bar and sphere results must be considered together to gain an overall appreciation of the fracture behavior of the restored teeth.

In the present investigation, the bonding of the ICRs to the remaining tooth tissues could have been expected to largely restore the fracture resistance of the restored teeth. However, as the fracture resistance of the restored teeth was found to be substantially lower than that of the control teeth, the restoration of maxillary premolar teeth with at least the ICR system investigated cannot be expected to restore the fracture resistance of such teeth. This finding complements those of studies by Stampalia and others (1986) and Joynt and others (1987), who compared resistance to fracture in sound teeth, teeth restored with a direct posterior composite system, and teeth restored with amalgam. These workers found that intact teeth were more resistant to fracture than restored teeth, with the results from the study by Joynt and others (1987) indicating that there may be no difference in fracture resistance between teeth restored with bonded posterior composite and those restored with amalgam.

In the present investigation, analysis by ANOVA failed to indicate that cavity wall tapers of 2°, 4°, and 6° in neither the sphere (Groups A 1, 2, and 3) nor bar groups (Groups B 1, 2, and 3) had a statistically significant effect on resistance to fracture ($P < 0.05$). This finding indicates that when a bonding procedure is employed, the effect of cavity wall taper on fracture resistance within variations of 2° - 6° may be of limited importance. However, the fracture mode data for the rod loading groups show a greater incidence of severe fractures of mode IV and mode V for the 6° taper. It therefore appears that, overall, 2 and 4 degrees of taper give a more satisfactory result than 6 degrees, although the pattern of fracture with the loading by the sphere was more uniform with respect to cavity wall taper.

Factors other than fracture resistance must be considered in relation to the optimum cavity wall taper. Among these are the ease, feasability, and practicality of the laboratory and clinical procedures. In the present study a much greater proportion (30%) of the inlays in the 2° taper group required adjustment to achieve satisfactory fit than in the 4° and 6° groups (10% overall). The findings mirror the experience in the laboratory fabrication of the inlays, and indicate that there may be no merit in complicating the ICR procedure given the apparent limited importance of near parallelism to fracture resistance, by attempting to achieve a low cavity wall divergence which, in any case, is believed to be difficult to obtain in everyday clinical practice. For this reason alone, the use of cavities with a 2° taper may not be recommended for ICRs of the type investigated.

Other factors are of importance, and among these is the effect of increasing taper upon resistance and retention form of the preparation. With increasing cavity wall divergence, the bond may become more vulnerable. It is therefore suggested that tapers much in excess of those investigated should, wherever possible, be avoided, at least until such time as uncertainties surrounding such aspects of

ICR preparation have been investigated.

CONCLUSION

It is concluded that:

1. When maxillary premolar teeth are restored with moderate-sized MOD inlays of the ICR system investigated, the fracture resistance of such teeth may only be found to have been restored to circa 60% of that of equivalent sound teeth;

2. Within the range of 2° - 6°, cavity wall taper may be found to have no significant influence on the fracture resistance of maxillary premolars stored with ICRs of the systems investigated; and

3. Overall, of the cavity wall tapers investigated, 4° was considered the best compromise in terms of facilitating the restorative procedures (clinical and laboratory) and limiting severe fractures under loading.

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Microleakage of Class 5 Composite Resin Restorations: a Comparison between in Vivo and in Vitro

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Clinical Relevance
Laboratory microleakage tests of thermocycled resin restorations predict more leakage than that found in clinical restorations.

SUMMARY

The purpose of this study was to determine if a difference exists in microleakage between in vivo and in vitro class 5 composite resin restorations using two variations of a bonding resin (Universal Bond 2 and Universal Bond 3). Class 5 cavities were prepared in 24 matched pairs of teeth on the buccal and lingual surfaces. One tooth of each pair was prepared and restored in vivo and the other in vitro. After preparation and enamel etching, Universal Bond 2 was randomly applied to one surface of each tooth in the pair and Universal Bond 3 to the other surface. Composite resin (Prisma AP.H) was placed in each preparation, light cured, and finished using a standard technique. The in vivo samples were extracted approximately 6 weeks after placement of the restorations. The in vitro samples were thermocycled for 540 cycles (5 to 55 °C/1-minute dwell time). All teeth were stained with silver nitrate and longitudinally divided. The teeth were scored on a ranking system of 0 being no leakage to 4 being leakage to the pulpal wall of the preparation. A Wilcoxon matched pairs signed rank test was performed on the data ($P \leq 0.05$). There were no statistically significant differences in microleakage between restorations using Universal Bond 2 and Universal Bond 3. There were statistically significant differences when comparing the in vivo and in vitro restorations. More microleakage occurred in the in vitro restorations.

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INTRODUCTION

The traditional etched enamel/resin bond is very effective in clinical situations for bonding intraenamel class 3 and 4 restorations. However, class 5 restorations often present a clinical problem, because the gingival margin is frequently on dentin or cementum. When composite resin is placed on dentin or cementum, a high potential exists for marginal gap formation.This gap predisposes the restorative margin to microleakage, recurrent caries, and staining (Crim, Esposito & Chapman, 1985; Erickson & Jensen, 1986; Eakle, 1986; Crim & García-Godoy, 1987; Loiselle & others, 1969). These deficiencies may lead to ultimate failure of the restoration.

In assessing the seal of dental restorative materials, a number of qualitative methods for identifying marginal microleakage are used. These methods include radioactive tracers, dye penetration, bacterial penetration, electrochemical analysis, silver nitrate staining, scanning electron microscopy, and fluorometric assay. Microleakage staining techniques contribute to a better understanding of the microleakage phenomenon: "marginal areas are dynamic microcrevices which contain a busy traffic of bacteria, ions, and molecules" (Myers, 1966).

Comprehensive reviews of microleakage evaluation were presented by Going (1972) and Ben-Amar (1989). Silver nitrate is currently the most commonly used staining technique for microleakage. This technique was first used by Wu and others (1983) to evaluate marginal leakage of composite resin restorations. Dumsha and Biron (1984a,b) used a simplified version of the Wu technique to evaluate in vitro the degree of marginal leakage in class 5 composite resin restorations dentin bonded with Bowen's ferric oxalate agent. Their results indicated that silver nitrate staining provided excellent definition for determining the extent of microleakage. McDonald's (1986) review of the literature supports silver nitrate's effectiveness and justifies its use in evaluating microleakage. Barkmeier and others (1990), Mandras, Retief, and Russell (1992), and Litkowski and Musolf (1992) also successfully used a modified version of this staining technique to investigate microleakage in class 5 composite restorations bonded with Universal Bond 2 (L D Caulk, Milford, DE 19963).

Most microleakage studies employ the technique of thermocycling teeth. Trowbridge's review (1987) of the literature reported that most studies cycled teeth through baths ranging from 4 to 60 °C with dwell times of 1 to 3 minutes. He concluded that longer dwell times were not clinically relevant, because teeth contact hot and cold foods for only a few seconds. Crim, Swartz, and Phillips (1985) found no significant differences in microleakage between four different thermocycling techniques. However, the nonthermocycled control group did exhibit significantly less microleakage than the four experimental groups. Litkowski, McDonald, and Swierczewski (1989) confirmed the results of Crim and others (1985), finding that thermocycling increased microleakage of class 5 composite resin restorations when compared to nonthermocycled samples. Burger, Cooley, and García-Godoy (1992) reported that increasing thermocycling cycles from 100 to 4000 cycles did not adversely affect the bond strength of a composite resin dentin bonded with All-Bond, (BISCO Inc, Itasca, IL 60143). They did not measure microleakage.

To date, few investigations have focused on an in vivo microleakage design. Going, Myers, and Prussin (1968) used neutron activation analysis to compare in vivo and in vitro microleakage systems. In general, in vivo uptake was greater than in vitro, indicating that restorations may leak more clinically than in the laboratory setting. Loiselle and others (1969) used fluorescein to evaluate microleakage in vitro and in vivo in bilaterally paired mandibular teeth. These investigators reported that class 5 amalgams had significantly more leakage in vitro than in vivo. This marked difference in test results indicates that more study is necessary to understand in vitro and in vivo marginal microleakage. The American Dental Association's Council on Dental Materials, Instruments, and Equipment (1989) observed that an insufficient number of composite resin studies exist correlating in vitro and in vivo data.

The purpose of the present investigation was to evaluate microleakage in class 5 composite resin restorations to determine: (1) if

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Microleakage of Class 5 Composite Resin Restorations: a Comparison between in Vivo and in Vitro

D M BARNES • V P THOMPSON
L W BLANK • N J McDONALD

Clinical Relevance
Laboratory microleakage tests of thermocycled resin restorations predict more leakage than that found in clinical restorations.

SUMMARY

The purpose of this study was to determine if a difference exists in microleakage between in vivo and in vitro class 5 composite resin restorations using two variations of a bonding resin (Universal Bond 2 and Universal Bond 3). Class 5 cavities were prepared in 24 matched pairs of teeth on the buccal and lingual surfaces. One tooth of each pair was prepared and restored in vivo and the other in vitro. After preparation and enamel etching, Universal Bond 2 was randomly applied to one surface of each tooth in the pair and Universal Bond 3 to the other surface. Composite resin (Prisma AP.H) was placed in each preparation, light cured, and finished using a standard technique. The in vivo samples were extracted approximately 6 weeks after placement of the restorations. The in vitro samples were thermocycled for 540 cycles (5 to 55 °C/1-minute dwell time). All teeth were stained with silver nitrate and longitudinally divided. The teeth were scored on a ranking system of 0 being no leakage to 4 being leakage to the pulpal wall of the preparation. A Wilcoxon matched pairs signed rank test was performed on the data ($P \leq 0.05$). There were no statistically significant differences in microleakage between restorations using Universal Bond 2 and Universal Bond 3. There were statistically significant differences when comparing the in vivo and in vitro restorations. More microleakage occurred in the in vitro restorations.

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INTRODUCTION

The traditional etched enamel/resin bond is very effective in clinical situations for bonding intraenamel class 3 and 4 restorations. However, class 5 restorations often present a clinical problem, because the gingival margin is frequently on dentin or cementum. When composite resin is placed on dentin or cementum, a high potential exists for marginal gap formation.This gap predisposes the restorative margin to microleakage, recurrent caries, and staining (Crim, Esposito & Chapman, 1985; Erickson & Jensen, 1986; Eakle, 1986; Crim & García-Godoy, 1987; Loiselle & others, 1969). These deficiencies may lead to ultimate failure of the restoration.

In assessing the seal of dental restorative materials, a number of qualitative methods for identifying marginal microleakage are used. These methods include radioactive tracers, dye penetration, bacterial penetration, electrochemical analysis, silver nitrate staining, scanning electron microscopy, and fluorometric assay. Microleakage staining techniques contribute to a better understanding of the microleakage phenomenon: "marginal areas are dynamic microcrevices which contain a busy traffic of bacteria, ions, and molecules" (Myers, 1966).

Comprehensive reviews of microleakage evaluation were presented by Going (1972) and Ben-Amar (1989). Silver nitrate is currently the most commonly used staining technique for microleakage. This technique was first used by Wu and others (1983) to evaluate marginal leakage of composite resin restorations. Dumsha and Biron (1984a,b) used a simplified version of the Wu technique to evaluate in vitro the degree of marginal leakage in class 5 composite resin restorations dentin bonded with Bowen's ferric oxalate agent. Their results indicated that silver nitrate staining provided excellent definition for determining the extent of microleakage. McDonald's (1986) review of the literature supports silver nitrate's effectiveness and justifies its use in evaluating microleakage. Barkmeier and others (1990), Mandras, Retief, and Russell (1992), and Litkowski and Musolf (1992) also successfully used a modified version of this staining technique to investigate microleakage in class 5 composite restorations bonded with Universal Bond 2 (L D Caulk, Milford, DE 19963).

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To date, few investigations have focused on an in vivo microleakage design. Going, Myers, and Prussin (1968) used neutron activation analysis to compare in vivo and in vitro microleakage systems. In general, in vivo uptake was greater than in vitro, indicating that restorations may leak more clinically than in the laboratory setting. Loiselle and others (1969) used fluorescein to evaluate microleakage in vitro and in vivo in bilaterally paired mandibular teeth. These investigators reported that class 5 amalgams had significantly more leakage in vitro than in vivo. This marked difference in test results indicates that more study is necessary to understand in vitro and in vivo marginal microleakage. The American Dental Association's Council on Dental Materials, Instruments, and Equipment (1989) observed that an insufficient number of composite resin studies exist correlating in vitro and in vivo data.

The purpose of the present investigation was to evaluate microleakage in class 5 composite resin restorations to determine: (1) if there is a difference in microleakage between in vitro and in vivo class 5 composite resin restorations using a modified version of the Dumsha and Biron (1984a,b) silver nitrate staining technique; and (2) if there is a difference in the amount of microleakage between class 5 restorations using Universal Bond 2 and Universal Bond 3 (L D Caulk) as bonding agents.

EXPERIMENTAL DESIGN AND METHODS

The patient sample was selected from the University of Maryland Dental School patient pool. The study included 24 patients with paired contralateral anterior or posterior teeth scheduled for extraction. The matched pairs of teeth were unrestored in the cervical third. Each tooth scheduled for extraction was in occlusion to allow for possible tooth deformation during function. Using a randomization method, the paired teeth were divided into two equal experimental groups (Experimental Group 1 and Experimental Group 2).

Experimental Group 1: Approximately 6 weeks prior to extraction, 48 class 5 Prisma AP.H (L D Caulk) composite resin restorations were placed at the cementoenamel junction on the facial and lingual surfaces of 24 teeth. In this study, buccal and lingual tooth surfaces were considered as mirror images. In vitro research by Barnes, McDonald, and Thompson (1991) using the silver nitrate staining technique reported no difference in microleakage between identical class 5 restorations placed on the buccal and lingual tooth surfaces. In the same tooth, Universal Bond 2 primer and bonding agent were used with one restoration and Universal Bond 3 primer and bonding agent with the other. The composition of the bonding agents is identical except Universal Bond 2 has 0.45% glutaraldehyde and Universal Bond 3 has 0.70% glutaraldehyde, an increase in aldehyde levels of approximately 50% by weight (Table 1). The bonding agents were randomly assigned to the buccal or lingual tooth surfaces. This random distribution of bonding agents compensated for potential differences found in the oral cavity on the buccal and lingual surfaces of the involved teeth; i e, tongue contact on the lingual or palatal tooth surface, and occlusal, microbiological, and hygiene differences.

Experimental Group 2: Forty-eight class 5 Prisma AP.H composite resin restorations were placed in vitro in 24 extracted teeth—the contralateral teeth to the restored in vivo experimental samples. As in Experimental Group 1, restorations were placed facially and lingually in the same tooth, one restoration using Universal Bond 2 and the other using Universal Bond 3. The assignment of this group's bonding agents facially and lingually corresponded to the facial and lingual placement of the bonding agents in its matched pair in Experimental Group 1.

Cavity Preparation and Composite Placement Technique

Experimental Group 1: After isolation of the field with a rubber dam, conventional class 5 preparations were made in the facial and lingual surfaces of the same tooth using a #330 tungsten carbide bur in an ultra-high-speed

Table 1. Formulations of Universal Bond 2 and Universal Bond 3 Used in Study Composition (by Weight)

Primer	
Ethanol	64%
HEMA	30%
PENTA	6%
Adhesive	
UDMA resin	94.3%
TEGMA	
PENTA	
Glutaraldehyde	5%
Universal Bond 2 (batch #068190 & #050290)	0.45%
Universal Bond 3 (batch #15290)	0.70%

Definitions

HEMA = hydroxyethyl methacrylate
PENTA = dipentaerythrietol pentacrylate phosphoric acid ester, a patented, proprietary phosphate ester adhesion promoter
UDMA = urethane dimethacrylate
TEGMA = triethylene glycol dimethacrylate

handpiece with air-water spray coolant. The preparation depths were standardized using the depth corresponding to the length of the cutting edge of the #330 bur. All approximal walls were placed at the line angles of the tooth. Each preparation was located in the cervical one-third of the tooth with the gingival margin located at or below the cementoenamel junction. The cavosurface was prepared as a butt-joint margin to aid in standardization of cavity preparation and finishing. After preparation, the tooth was cleaned with a rubber cup and flour of pumice, then rinsed with water and air dried. The enamel margins were etched with a 40% gel of phosphoric acid for 60 seconds, rinsed thoroughly with water for 20 seconds, and gently air dried. Universal Bond 2 or 3 primer and its adhesive were applied following the manufacturer's instructions and cured with a curing light (Prismetics Lite, L D Caulk) for 30 seconds. The composite resin was applied in incremental portions (Figure 1), and each laminate was cured for 60 seconds to ensure complete polymerization. The incremental placement technique was based on a modification of the method described by Crim (1991). The restoration was finished with 12-fluted gold shank finishing burs (Midwest Dental Products Corp, Des Plaines, IL 60018) under water spray followed by polishing disks (Sof-Lex, 3M Dental Products, St Paul, MN 55144). Polishing paste (Prisma Polishing Paste, L D Caulk) applied with a rubber cup was used for the final finish. Finishing was accomplished at the time of placement to simulate procedures most commonly used in private practice. Patients were given standardized oral

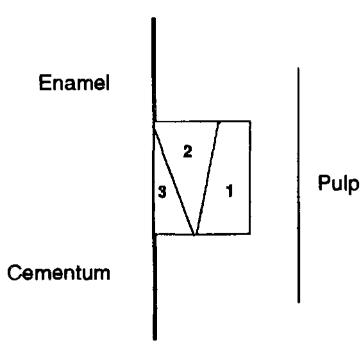

Figure 1. *Composite resin incremental placement technique*

hygiene instructions and dismissed.

Patients were scheduled for extraction of teeth from the experimental groups approximately 6 to 8 weeks after placement of restorations. Prior to extraction, each Experimental Group 1 tooth was evaluated for postoperative sensitivity. Using the criteria described by Cvar and Ryge (1971), the teeth were evaluated for restoration quality pre- and postextraction. Following extraction, all teeth were stored in isotonic saline at 4 °C until restoration (of Experimental Group 2), staining, and sectioning.

Experimental Group 2: The 24 teeth chosen for this group were subjected to the same restoration procedures as the teeth in Experimental Group 1, but postextraction. After the Experimental Group 2 restorations were placed, the teeth were thermocycled 540 times at 5 to 55 °C with a 1-minute dwell time. Group 2 restorations were then evaluated for marginal adaptation and discoloration using the Cvar and Ryge (1971) criteria. All restorations in both groups were placed by the same operator, standardizing the treatment phase.

Staining and Sectioning

All restored teeth were subjected to silver nitrate ($AgNO_3$) staining either after extraction in Experimental Group 1 or after thermocycling in Experimental Group 2. All restored teeth were completely coated with nail polish except for the restoration and the surrounding 2 mm of tooth surface, and the apices were sealed with wax. The teeth were then placed into a 50%-by-weight solution of $AgNO_3$ for 2 hours. The $AgNO_3$ solution was kept at a constant 37 °C for the in vivo samples to simulate body temperature. This was the only modification made to the staining procedure described by Dumsha and Biron (1984a,b). The teeth then were rinsed with distilled water for 60 seconds and placed in a rapid-developing solution for 2 hours. Using a 1 mm-thick diamond saw, the teeth were divided buccolingually through the center of the restoration into the mesial and distal sections. The cut surfaces of the restorations in the remaining tooth sections were examined under a stereo microscope at X40 magnification by two investigators and scored using a rank order rating scale (Figure 2). Examples of teeth that have been sectioned and stained are displayed in Figures 3, 4, and 5. Prior to rating the study teeth, investigators were calibrated to an 85% level of agreement in the use of these scoring indexes. A random sample of restorations subjected to silver nitrate staining was used for calibration. Any disagreement between raters was resolved by consensus to 100% agreement. In all experimental teeth the mesial tooth section was used to compare Universal Bond 2 and Universal Bond 3, and the distal tooth section was used to compare the in vivo and in vitro composite resin restorations.

Stastistical Tests

A Wilcoxon matched pairs signed rank test as described by Siegel (1988) was performed on the scored data to determine any significant differences between the investigator's eight comparisons at a confidence level of 95%, leading to a significant result when $P \leq 0.05$. The comparisons are presented in Tables 2 and 3. Descriptive data were used to present the average rank leakage score of the raw data (Tables 2 and 3).

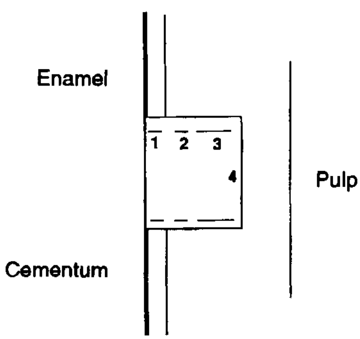

Figure 2. *Rating system for scoring microleakage: 0 = no leakage; 1 = leakage into enamel or its equivalent depth on the cementum surface; 2 = leakage through enamel up to half the depth of the cavity preparation; 3 = leakage over half the depth of the cavity preparation not including the pulpal floor; and 4 = leakage to and along the pulpal floor.*

Figure 3. Example of microleakage scoring system

Figure 4. Example of microleakage scoring system

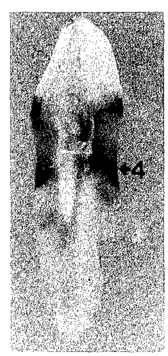

Figure 5. Example of microleakage scoring system

Table 2. Comparison of Leakage between in Vitro and in Vivo Restorations

Comparison	Bonding Agent	Site	Wilcoxon Value	P	Mean Leakage Score In Vivo	Mean Leakage Score In Vitro
#1	UB2	enamel	0.74	0.35	1.40 (n = 22)	1.68 (n = 22)
#2	UB2	cementum	1.66	0.05*	2.0 (n = 22)	2.55 (n = 22)
#3	UB3	enamel	1.66	0.05*	0.95 (n = 21)	1.36 (n = 22)
#4	UB3	cementum	2.52	0.004*	1.95 (n = 21)	2.68 (n = 22)

*Significant ($P \leq 0.05$)
Descriptive data were used to present mean leakage score of raw data.

Table 3. Comparison of Leakage between Bonding Agents

Comparison	Site	Wilcoxon Value	P	Mean Leakage Score UB2	Mean Leakage Score UB3
#1	in vivo enamel	0.94	0.22	1.3 (n = 22)	1.0 (n = 21)
#2	in vivo cementum	1.06	0.16	2.0 (n = 22)	1.7 (n = 21)
#3	in vitro enamel	1.73	0.04*	1.7 (n = 22)	1.2 (n = 22)
#4	in vitro cementum	0.89	0.19	2.5 (n = 22)	2.6 (n = 22)

*Significant ($P \leq 0.05$)
Descriptive data were used to present mean leakage score of raw data.

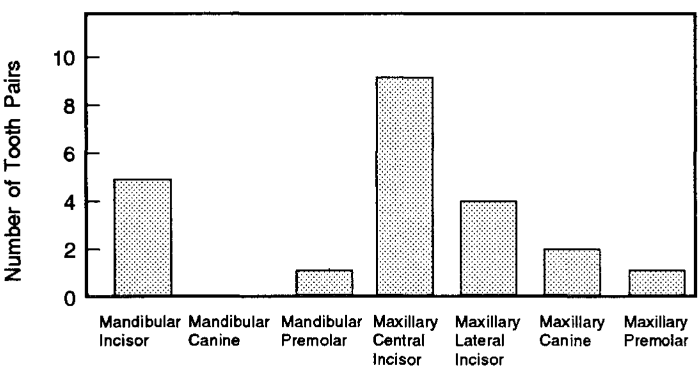

Figure 6. *Distribution of teeth in sample*

RESULTS

Forty-eight restorations were placed in 24 subjects during the course of the study. The age of the patients ranged from 26 to 74 years with a mean age of 53.4. Four patients were 40 years of age and under, 12 were between the ages of 40 and 60, and six were 60 years of age and older. One subject failed to keep the extraction appointment and was dropped from the study. Another pair was lost when the tooth fractured during oral surgery. Therefore, four pairs of restorations were lost (four Experimental Group 1 and four Experimental Group 2). From the remaining 22 subjects, 44 Experimental Group 1 restorations and 44 Experimental Group 2 restorations were evaluated for microleakage. The distribution of paired teeth is reported in Figure 6. The mandibular incisors were not separated into central and lateral incisors in Figure 6 due to the anatomical similarity between them. One restoration was unable to be scored due to problems encountered while sectioning.

Postoperative sensitivity was not reported by any of the subjects and no restorations were fractured or dislodged. No adverse incidents occurred during the study. Using the criteria described by Cvar and Ryge (1971), all Experimental Group 1 restorations were rated Alpha for marginal adaptation and marginal discoloration at insertion, preextraction, and postextraction. Using the same criteria, all Experimental Group 2 restorations were rated Alpha for marginal adaptation and marginal staining after placement and thermocycling. The mean leakage scores as well as the results of the Wilcoxon signed rank test for microleakage are presented in Tables 2 and 3.

The results of this study indicate a significant difference in leakage between restorations in the in vivo and in vitro groups. There was a statistical difference in three of four comparisons using the Wilcoxon signed rank test (Table 2). The comparison between in vivo and in vitro enamel margins using Universal Bond 2 as the bonding agent was not statistically significant. The in vivo versus in vitro comparison of cementum margins using Universal Bond 2 and the comparisons of the in vivo and in vitro enamel and cementum margins using Universal Bond 3 were statistically significant. In these comparisons, it was evident that more leakage was occurring in the in vitro than in the in vivo restorations.

In the statistical analysis of the bonding agents, three out of four comparisons made between Universal Bond 2 and Universal Bond 3 were not significant (Table 3).

DISCUSSION

The results of this study are consistent with the findings of Loiselle and others (1969), who used fluorescein dye to evaluate marginal leakage in vivo and in vitro in class 5 amalgam restorations. Their results indicated massive leakage around amalgam restorations in vitro and relatively little leakage in vivo. In addition, the in vitro samples were not thermocycled, which would have further increased their leakage.

Going, Myers, and Prussin (1968) reported that resin, temporary stopping, and silicate cement restorations leaked more in vivo than in vitro. These differing results may be explained by the dissimilarity in methodology used to conduct the studies as well as the different materials being evaluated. Going, Myers, and Prussin (1968) evaluated leakage in restorations by neutron activator analysis, the penetration of manganese around margins of restorations. The in vitro samples were not thermocycled, which may explain the lack of leakage. The leakage they observed may have been influenced more by the material differences related to a functional environment than the testing environment alone. Litkowski, McDonald, and Swierczewski (1989) reported that thermocycling increases the amount of leakage in composite resin restorations. The discrepancy between these studies indicates that future research is necessary to find a design that is representative of the oral environment. Future studies can modify the in vitro treatment by altering thermocycling techniques, i e, changing the dwell time, altering the number of cycles, and changing the temperatures.

Reviewing the literature in relation to in vivo variables affecting microleakage in composite resin restorations, Erickson and Jensen (1986) demonstrated that cervical margins on cementum displayed an appreciable increase in microleakage when the restored teeth were subjected to occlusal loading. Crim, Esposito, and Chapman (1985), Eakle (1986), and Crim and García-Godoy (1987) concluded that intraoral thermal changes compromise the bond between restorative material and tooth structure and create a potential for microleakage. Both intraoral occlusal loading and thermal changes in vivo appeared to have less effect than in vitro thermocycling in this short-term study.

Marginal staining did not occur in any of the in vivo specimens. Most clinical evaluations to date seldom report marginal staining prior to 1 year. If marginal staining is clinically indicative of microleakage in composite resin restorations, leakage was not occurring in the in vivo samples. However, the in vivo restorations displayed some degree of leakage at the gingival margin when exposed to silver nitrate. Therefore, one may conclude that the absence of marginal staining does not rule out the presence of microleakage. It may be conjectured that marginal staining is due to continuous leakage over a prolonged period of time, not from an increase in the depth of leakage over time.

In the statistical analysis of the bonding agents, three out of four comparisons made between Universal Bond 2 and Universal Bond 3 were not significant (Table 3). The comparison made between in vitro restorative enamel margins using Universal Bond 2 and Universal Bond 3 was the only significant result. The Universal Bond 3 restorative margins were superior to Universal Bond 2. This finding corroborates data by Mandras, Retief, and Russell (1992), who reported that Universal Bond 3 had significantly less microleakage than Universal Bond 2.

Referring to Table 3, the mean in vitro leakage scores for Universal Bond 2 at the enamel and cementum interfaces are 1.7 and 2.5 respectively. These data differed from those reported by Barkmeier and others (1990), who found only two out of 40 restorations using Universal Bond 2 leaked at the cementum, both being scored 1. This difference could be attributed to cavity design, as the thermocycling and staining techniques were almost identical. In the Barkmeier and others (1990) study, nonretentive "V"-shaped preparations were used. This study employed a conventional class 5 cavity design with butt margins. The nonretentive lesion allows for a beveled finish line, which as reported by Litkowski and Musolf (1992) reduces microleakage in composite restorations placed on cementum. Although not statistically significant, there was a reduction in microleakage means when comparing Universal Bond 3 to Universal Bond 2 in three out of the four comparisons. In addition, it may be noted that more microleakage occurred in the enamel in both groups than one would expect. This occurrence might be due to the lack of beveling of enamel in the preparation design or from enamel cracks that may have occurred during extraction of the teeth.

Many studies have utilized in vitro study designs similar to ours to investigate microleakage of composite restorations. This study raises concerns about the clinical applicability of in vitro study designs pertaining to microleakage. Further in vivo versus in vitro studies should be conducted to assess thermocycling and staining techniques to find methods that are more representative of clinical situations.

CONCLUSION

The results of this study indicate the following:

(1) Class 5 composite resin restorations placed and thermocycled in vitro had significantly more leakage than restorations placed in vivo, and

(2) there was no significant difference in the performance of Universal Bond 2 and Universal Bond 3 in preventing microleakage in class 5 composite resin restorations in vitro and in vivo.

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Class 5 Composite Resin Restorations: Margin Configurations and the Distance from the CEJ

L H S HALL • M A COCHRAN • M L SWARTZ

Clinical Relevance
Beveled enamel margins reduce microleakage in class 5 resin restorations.

SUMMARY

An in vitro study of 60 teeth examined the cervical microleakage of class 5 composite resin restorations in regard to preparation design and location from the cementoenamel junction (CEJ). Four groups of 15 teeth each were prepared for a class 5 composite resin restoration with the cervical margins finished as follows: a butt joint margin placed less than 1 mm from the CEJ, a beveled margin placed less than 1 mm from the CEJ, a butt joint placed greater than 1.5 mm from the CEJ, and a beveled margin placed greater than 1.5 mm from the CEJ. The teeth were acid etched, treated with an enamel bonding agent, and restored with a microfilled composite resin, and then sectioned for further analysis. The sectioned specimens were evaluated for cervical microleakage by Ca_{45} autoradiography. The butt joint margins placed less than 1 mm from the CEJ had significantly more microleakage than the other groups, indicating that all enamel margins of a class 5 composite resin restoration should be beveled to decrease microleakage regardless of their location relative to the cementoenamel junction.

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INTRODUCTION

The class 5 composite resin restoration is not immune to microleakage. Techniques such as acid etching and the placement of bonding agents have been shown in various studies (Crawford, Whittaker & Owen, 1987; Hembree & Andrews, 1976; Ortiz & others, 1979; Retief, 1973) to decrease microleakage, while other studies (Boston, 1982; Crim, Swartz & Phillips, 1984; Kopel, Grenoble & Kaplan, 1975; Myers & Butts, 1985; Obray, Laswell & Estes, 1979; Qvist, 1985) have indicated that the design of the cervical margin can also be an influencing factor. Unfortunately, there is no universal agreement on the appropriate preparation design for the cervical margin of a class 5 composite resin restoration, and the decision to place a bevel or a butt joint is still controversial.

The rationales for beveling the cavosurface margins of a class 5 composite resin restoration include: providing an increase in surface area for etching (Gwinnett, 1971; Obray & others, 1979), removing the prismless layer of surface enamel (Crim & others, 1984; Myers & Butts, 1985), exposing the ends of the enamel rods to the acid for etching (Buonocore, 1955; Jorgensen & Ono, 1984), facilitating the finishing procedure and achieving a more esthetic restoration (Flynn, 1977; Kopel & others, 1975), and decreasing microleakage (Charbeneau & others, 1988; Hembree & Andrews, 1976; Phillips, 1982).

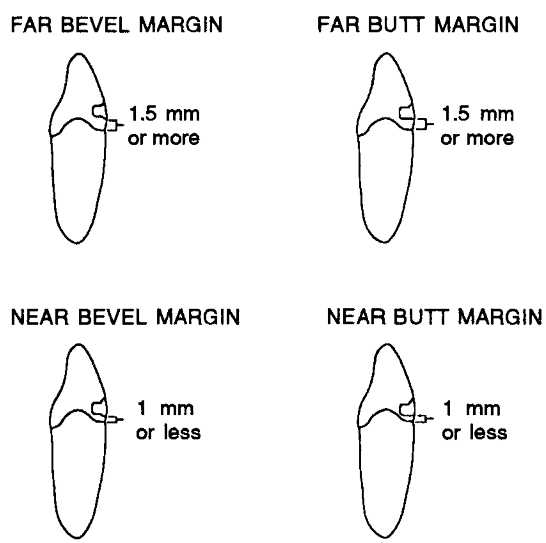
The rationales to prepare the cervical margins of these restorations to a 90° butt margin include: leaving cervical enamel to etch (Qvist, 1985), decreasing the staining by leaving no feather-edge of tooth and/or material (Flynn, 1977), and achieving optimum strength of the restoration (Gilmore & others, 1977).

This conflicting information leaves the dentist in a quandary as to which margin configuration will provide the best clinical result. The purpose of this in vitro study was to examine the influence of cavity design on microleakage in the class 5 composite resin restoration.

METHODS

Four separate groups of 15 human teeth each were used in this study. A standardized class 5 composite resin preparation was prepared on the buccal surface of all 60 teeth with a #330 bur. The occlusal and approximal margins of the preparations were beveled with a #7902 finishing bur. The cervical margins of two groups were prepared near the cementoenamel junction (CEJ) (1.0 mm or less as measured with a periodontal probe), and the remaining two groups' cervical margins were placed far from the CEJ (1.5 mm - 3.0 mm as measured with a periodontal probe). One group near the CEJ and one group far from the CEJ had the cervical margin finished to a 45° bevel with a #7902 finishing bur. The width of cervical bevel was approximately 0.5 mm. The remaining near and far groups had the cervical margin finished to a 90° butt margin with hand instrumentation that utilized a 9-80-4-8 angle former (G-C International Corp, Scottsdale, AZ 85260). The body of the restoration in both beveled groups was positioned more incisally on the facial surface than the body of the restoration in the corresponding butt joint groups. The distances of the near and far groups were determined by measuring from the CEJ to the cavosurface margin, either the butt joint or the bevel, of the restorations. The figure illustrates the four preparation designs of this study.

The preparations were cleansed with 3% hydrogen peroxide, rinsed, and dried. Then the enamel margins were etched for 30 seconds with 37% phosphoric acid, rinsed, and dried. An enamel bonding agent was applied (Enamel Bond Resin, 3M Dental Products Corp, St Paul, MN 55144), and the preparations were filled in two increments with the



Preparation designs

microfilled composite resin, Silux (Silux Paste, 3M), and cured for 40 seconds per increment with a Visilux 2 curing light (Visible Light Curing Unit, 3M). The restorations were finished with Sof-Lex disks (3M).

The specimens were thermocycled for 2500 cycles between two water baths. The hot water bath was maintained at 40 °C ± 2 °C and the cold water bath at 0 °C ± 2 °C. The immersion time in each bath was 30 seconds with a transfer time of 10 seconds between water baths. The teeth were stored in a humidor until the next step.

The teeth were removed from the humidor and prepared for immersion in the isotope according to the technique described by Swartz in 1959. After the immersion procedure was complete, the teeth were prepared for sectioning. Five to seven teeth were placed on a plastic sectioning guide, lingual side down, and secured with green stick compound. The plastic guide plate with the mounted teeth was placed on the sectioning machine platform (Hamco Machines, Inc, Rochester, NY 14692), and the specimens were sectioned into halves. A diamond wafering blade of high concentration (Buehler, Ltd, Lake Bluff, IL 60044) was used to section the teeth sagitally from the incisal edge to the root tip under a continuous water spray.

Then the degree of microleakage was evaluated using standard Ca_{45} autoradiography (Swartz, 1959). The two halves obtained by sectioning each tooth were placed on intraoral radiographic film according to the technique described by Swartz in 1959. After 17 hours of exposure, the specimens were removed and the film developed in an automatic film processor. Each film was then evaluated for microleakage. A standard ridit scale depicting leakage patterns of increasing severity was established. The following numerical ratings were assigned to the various degrees of penetration of the radioisotope on the specimens: rating 1 indicated no visible leakage, rating 2 indicated an insignificant degree of leakage along the occlusal and/or gingival wall of the restoration but not extending to the dentinoenamel junction (excluding any enamel defects present), rating 3 indicated leakage approximately from the dentinoenamel junction up to but not including the axial wall (excluding any enamel defects), and rating 4 indicated leakage that includes the axial wall. It should be noted that a rating of 1 or 2 produced a restoration with no or insignificant microleakage. Three examiners, each experienced in evaluating autoradiographs, made three evaluations of the 120 autoradiographs with an adequate time lapse between examinations. Both the occlusal and cervical margins were evaluated. No significant difference was found with either intraexaminer or interexaminer reliability when subjected to the sign test.

After the autoradiograph technique was completed, the sectioned teeth were examined using a Nikon Measurescope (Nikon, Tokyo, Japan) to determine the actual distance from the CEJ to the gingival margin of the restoration. The actual distance was compared to the ranges as set forth by the study design.

RESULTS

The results of the measurement of the actual distance of the cervical cavosurface margin from the cementoenamel junction showed that two distinct groups were present. The near preparations had their cervical cavosurface margins 1.0 mm or less from the cementoenamel junction. The far preparations had their cervical cavosurface margins 1.5 mm or more from the cementoenamel junction.

The results of the ridit analysis of the occlusal microleakage data are summarized in Table 1. There was not a significant difference in the microleakage of the occlusal

Table 1. Occlusal Margin Data

Group	Categories 1	2	3	4	Number in Group	Ridit Mean	Standard Deviation
Near butt	27	2	1	0	30	0.4615	0.1522
Far butt	24	4	1	0	29	0.4957	0.1875
Far bevel	27	1	1	1	30	0.4651	0.1635
Near bevel	20	7	2	1	30	0.5776	0.2398

R1 = 0.4118; R2 = 0.8824; R3 = 0.9622; R4 = 0.9916
Groups connected by vertical lines are not significantly different ($P < 0.05$).

margins in the four test groups. Table 2 shows that 90% or more of the occlusal margins in all four groups displayed no or insignificant microleakage.

The results of the ridit analysis of the cervical microleakage revealed a significant difference between the four groups. Multiple comparisons were made between the cervical microleakage data by means of the Newman-Keuls test. The data along with a summary of the statistical analysis of these data are presented in Table 3.

The butt joint margins placed less than 1.0 mm from the CEJ were significantly different from all the other groups and exhibited the most microleakage at the cervical margins of the restorations. Table 4 shows that only 60% of the butt joint margins placed less than 1.0 mm from the CEJ displayed no or insignificant microleakage (1 or 2 ridit rating). However, it also shows 83% of the restorations with a butt joint margin placed greater than 1.5 mm from the CEJ had acceptable cervical margins in regard to microleakage. Table 4 illustrates that both beveled groups had acceptable cervical margins.

The far butt joint margins displayed significantly more leakage than the near beveled margins.

DISCUSSION

The class 5 composite resin restoration is not immune to microleakage. Past studies (Boston, 1982; Kopel & others, 1975) have shown microleakage to occur more frequently and to a greater extent at the cervical margins of these restorations. Techniques such as acid etching and the placement of bonding agents have been shown in various studies (Boston, 1982; Hembree & Andrews, 1976; Ortiz & others, 1979; Retief, 1973; Qvist, 1985) to decrease the microleakage of composite resin restorations.

Other research (Crim & others, 1984; Kopel & others, 1975; Obray & others, 1979; Qvist, 1985) has shown that the cavity design of the cervical margin of a class 5 composite resin restoration can affect the amount of microleakage. This study revealed that the butt joint margins placed less than 1.0 mm from the CEJ exhibited the most cervical

Table 2. Percent of 1 or 2

Group
Near butt
Far butt
Far bevel
Near bevel

A ridit rating of 1 or 2 pro
insignificant microleakage.

Table 3. Cervical Margin

	Categorie		
Group	1	2	3
Near butt	8	10	9
Far butt	13	11	5
Far bevel	17	12	1
Near bevel	23	7	0

R1 = 0.2563; R2 = 0.680
Groups connected by ve
different ($P < 0.05$).

Table 4. Percent of 1 or

Group
Near butt
Far butt
Far bevel
Near bevel

A ridit rating of 1 or 2
insignificant microleak

microleakage. Tables 3 and 4 illustrate that the near butt joint margins had significantly more microleakage than the other groups. This would indicate that the bevel may produce a higher degree of clinical acceptability and may be the configuration of choice for the class 5 composite resin restoration. The results from this study agreed with other studies (Crim & others, 1984; Obray & others, 1979; Qvist, 1985) that showed that a beveled cervical margin aids in reducing microleakage more than a 90° butt cervical margin in a class 5 composite resin restoration.

CONCLUSIONS

It can be concluded from this study that all enamel margins of class 5 composite resin preparations should be beveled to decrease the microleakage of the restoration, regardless of the location of the cervical margin from the cementoenamel junction.

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