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ABSTRACT

This study compared the relative effectiveness of an automated teaching machine with instructor presented instruction in graduate dental teaching. The objectives were to: (1) determine the effects of 3 laboratory instructional procedures used in combination with 2 lectures on the acquisition of manual operative skills, the learning of information about the skills, the making of visual discriminations, and the identification of instruments; (2) determine reactions of subjects to the modes of instruction used; (3) analyze costs of instruction, personnel time and administrative factors pertaining to use of automated instructional procedures. Subjects were 100 first-year graduate students at the University of Southern California School of Dentistry assigned randomly to 6 different experimental conditions. Results showed no significant differences in the attainment of objective (1) using mixed conventional and machine procedures, but that groups receiving laboratory and lecture by machine only performed at a significantly lower level. Interviews showed the machine-only group felt it needed more instructor help and that the principal value of the machine-mediated teaching was the step-by-step development of the material. (JS)

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U.S. DEPARTMENT OF
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STUDY OF VISUAL AND AUDITORY PRESENTATION IN DENTAL LECTURE AND LABORATORY INSTRUCTION

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U.S. DEPARTMENT OF
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SUMMARY

This study investigated the problem of discovering how the teaching of perceptual-motor skills required in dental operative techniques and the cognitive knowledge of these techniques could be accomplished by mechanical means. Two sets of variables were studied: two modes of presenting the lecture and three modes of presenting the laboratory instruction.

Objectives

The purpose of the study was to compare the relative effectiveness of machine-presented sound-slide presentations of lecture and laboratory instruction with instructor-presented instruction in graduate dental instruction. The specific objectives of the study were:

1. To determine the effects of three laboratory instructional procedures used in combination with two lecture procedures upon the acquisition of manual dental operative skills, the learning of information about the operative techniques, the making of visual discriminations, and the identification of the operative implements used.

2. To determine the reactions of the subjects to the modes of instruction used.

3. To analyze the costs of instruction, personnel time, and administrative factors pertaining to the use of automated instructional procedures.

Procedure

A five-week unit of instruction (consisting of a one-hour lecture and a three-hour laboratory each week) on the preparation of the cavity for the Class II silver amalgam restoration was produced for presentation in automated form. This comprised five color slide presentations augmented by tape-recorded sound and selected 8mm color motion picture film loops. These automated lessons were presented to 100 first year graduate students in the University of Southern California School of Dentistry assigned at random to six different experimental conditions. One-half of the subjects received the lecture as a group in the conventional "live" way in the lecture hall, and the other half of the subjects received the lecture individually by means of the automated presentation. A third of each group received the

laboratory instruction in the conventional way under the guidance of dentists (at a ratio of 8 to 1). Another third of the group received the laboratory instruction under the control of the automated machine presentation with a single dentist as supervisor (at a ratio of 12 to 1). The final third of the group received the laboratory instruction under the control of the automated machine presentation only without professional dental supervision except to answer questions not related to their laboratory performance. This combination of variables resulted in a 3 x 2 factorial design. In the sixth laboratory period, a week following the last laboratory session, all subjects prepared a Class II cavity preparation without supervision as a test of their operative skill and took two visual discrimination tests. In addition they were administered a written test covering the content of the lectures. The effects of the six treatment conditions were compared by the analysis of covariance technique. Reactions to the instruction were obtained from the analysis of responses during personal interviews.

Results and Conclusions

The results and conclusions are summarized for the major comparisons, the student reactions, and the administrative considerations:

1. No significant differences were found in the acquisition of operative dental skills or learning of cognitive information among groups that received lecture and laboratory instruction under mixed conventional or machine conditions.

2. Those groups which received both lecture and laboratory instruction by machine only without supervision performed at a significantly lower level than the other treatment groups.

3. There were no significant differences among the six groups in the making of perceptual discriminations, the identification of the instruments used, in the making of subsequent laboratory cavity preparations, in subsequent written test performance, or in the final semester laboratory or lecture grades.

4. Interviews of the subjects at the end of the experiment showed (a) that those who used the machine only without supervision in the laboratory felt they could use additional help, (b) that the principal value of the machine-mediated instruction was the step-by-step development of the procedure, and (c) that the disadvantages of the machines were associated with equipment malfunction and that the presentation of the instruction was often too slow in relation to the subjects' pacing needs.

5. The cost of a semester of instruction per student was estimated at $65.60 under the Machine Only and $97.10 under the Supervised Machine laboratory conditions. Under normal Conventional laboratory conditions the cost was estimated to be $87.30 per student.

CHAPTER I

INTRODUCTION

This study was directed toward the problem of discovering how the teaching of perceptual-motor skills required in dental operative techniques and the cognitive knowledge of these techniques could be accomplished by mechanical means. This is a problem of considerable importance in a profession where highly skilled dentists are required to teach purely technical skills and where there is a growing shortage of professional personnel. The study attempted to determine if automated instructional techniques could be employed to release dentists from teaching these mechanical procedures without a loss in the quality of instruction.

The Problem

The major purpose of the study was to investigate the effects of three different modes of controlling the acquisition of digital skills in the laboratory and two different modes of presenting the content to be learned in the lecture of the skills and knowledges for the cavity preparation of the Class II silver amalgam restoration. The subjects participating in the study were first year graduate dental students.

The study had as its objective, therefore, the determination of the effects of mode of laboratory control of activity and mode of lecture presentation upon the manual performance and cognitive learning of a basic dental operative procedure. The specific objectives studied were:

1. To determine the effects of the three laboratory procedures used in combination with the two lecture procedures upon the acquisition of manual dental operative skills.

2. To determine the effects of the three laboratory procedures used in combination with the two lecture procedures upon the learning of information about the operative technique.

3. To determine the effects of the three laboratory procedures used in combination with the two lecture procedures upon the making of visual discriminations and visual identification of the operative im-plements used.

4. To determine the reactions of the subjects to the modes of instruction used.

5. To analyze the costs of instruction, personnel time, and administrative factors pertaining to the use of automated instructional procedures.

Review of Related Research

Despite the fact that the literature pertaining to instructional media contains many studies related to the teaching of perceptual-motor skills and knowledge of facts and concepts--most completely reviewed by Hoban and van Ormer (1950), Allen (1960), and Lumsdaine (1963)--there is a dearth of previous experimental research bearing directly on the major problem being studied. The research will be considered under three headings: teaching perceptual-motor skills, teaching facts and concepts, and teaching dental skills.

Teaching Perceptual-Motor Skills

There is ample research evidence that motion picture films are effective in teaching perceptual-motor skills. Studies by McClusky and McClusky (1924), Freeman and others (1924), VanderMeer (1945), Hirsch (1953), VanderMeer and Cogswell (1952), Jaspen (1950a, 1950b), and Stein (1958) demonstrated the values of filmic presentation in the teaching of subjects ranging from handwriting to rifle marksmanship. Roshal (1961) compared a motion picture on how to tie knots with a series of still pictures and found the film to be significantly more effective, particularly where there were frequent transitions and rapidity of change.

There was less evidence, however, supporting the use of still picture presentation, with or without sound accompaniment. Lasser (1954) tested the effectiveness of a filmstrip versus a motion picture film in teaching a simple performance task of repairing a broken sash cord in a window and found no significant differences in group performance except for one sub-operation on which the film group was superior, presumably because the film had continuity. The Videosonic Systems Division of the Hughes Aircraft Company has claimed a 33% increase in productivity, a 60% reduction in rejects, and a 50% cut in learning time for electronic equipment assemblers using equipment similar to that employed in this study (1962).

Teaching Facts and Concepts

The instructional media research relating to the teaching of facts and concepts has been so completely reviewed elsewhere (Hoban and van Ormer, 1950; Allen, 1960; Lumsdaine, 1963) that the details will not be repeated in this review. The evidence clearly sup-

ports the conclusion that both films and still pictorial presentations can teach factual information and concepts effectively over a wide range of subject matter content, age ranges, abilities, and conditions of use. The learning of the factual information and concepts presented in the lecture portions of this study fall within the range of the findings from the past research.

Teaching Dental Skills

Of direct application to the purpose of the present study in dental operative training, York and Erlandson (1958) taught part of the porcelain jacket and crown technique by motion picture film alone, demonstration alone, and film and demonstration together. The combined film and demonstration method was significantly better than the film alone method. In a pilot study, Golden, Eidson and Crumpler (1963) of the University of Southern California School of Dentistry studied the use of the slide-tape technique in teaching a unit of work from a graduate dental course in "Class V Gold Foil Fillings," comparable to the experimental method used in the present study. Only eight dental students were involved, four in the slide-tape individual instruction group and four in an instructor-presented illustrated lecture group. After one hour of instruction both groups performed a laboratory demonstration of proficiency and quality in completing the gold foil filling. Findings revealed no differences in performance by either of the two groups.

Barber (1964) studied the possibility of using tape and slides as a method of teaching predodontics to third-year dental students. He compared groups receiving three periods of laboratory instruction in the construction and use of the band-loop space maintainer, a bilateral acrylic space maintainer, the anterior inclined plane for the correction of an anterior cross-bite, and the Hawley retainer. The performance of three randomly assigned groups was compared: (1) a conventional teacher-oriented presentation with high teacher participation during the student's performance, (2) a reduced teacher presentation and participation, and (3) a sound-slide presentation of procedures with teacher participation related only to the audiovisuals used. The students in the second and third groups performed significantly better than the conventional group on four construction projects. Although not directly comparable to the present study, the conventional group was somewhat comparable in method to the conventional laboratory group and the third sound-slide group to the supervised machine laboratory in this study.

Vanek and others (1967) studied the use of a programed instructional sequence using color slides as a method of teaching the Class I cavity preparation and restoration of pit and fissure defects. The conventional method, in which students received a series of lectures and were assisted in the laboratory by instructors, was compared with an experimental method in which the students received all instruction

by means of a linearly programed workbook and 114 color slides. No significant differences in performance on a number of measures of a final cavity preparation were found between the two groups, and the experimental group completed the criterion cavity preparation in significantly shorter time. Although the study varied from the present study, the conventional group was somewhat comparable to the conventional laboratory group and the experimental group to the machine only laboratory group in this study.

CHAPTER II

METHOD AND PROCEDURE

Controlled experimentation was used to assess the combined effects of two variables upon dental laboratory performance and visual discrimination by first-year graduate dental students.

Experimental Design and Method

Two sets of independent variables were manipulated in the study: three laboratory modes of controlling the acquisition of digital perceptual-motor skills and two lecture modes of presenting the content to be learned. The effects of these variables upon the cavity preparation of the Class II silver amalgam, upon the making of visual discriminations, and upon the learning of factual and conceptual content were compared by means of a 3 x 2 factorial experimental design, which combined each laboratory condition with each lecture condition.

Experimental Variables

Laboratory Presentation Modes. Three different methods of controlling the laboratory instruction were employed:

1. Conventional, in which the laboratory instruction was supervised by practicing dentists at a ratio of one dentist to about eight students. This was the conventional form of instruction, and the students had access to instructional assistance in the form of answers to questions and advice on the performance of the cavity preparation. These instructors often demonstrated (on the student's own preparation) how to perform the operation.

2. Machine, in which the laboratory instruction was controlled by an automated step-by-step program of the operation to be performed presented on a teaching machine that projected colored slides augmented by audio directions. In addition, repetitive 8mm silent motion picture film loops demonstrated certain operations. No professional dental assistance was given, but a supervisor was present to answer questions unrelated to the laboratory operation.

3. Supervised, in which the "Conventional" and the "Machine" conditions were combined, but in which there was a ratio of only one dentist to about twelve students.

Lecture Presentation Modes. Two different methods of presenting the lecture instruction were employed:

1. Conventional, in which the lecture portion of the course was presented in a lecture hall by a professional faculty member using the same color slides and motion pictures employed under the "Machine" conditions.

2. Machine. [illegible]hich the lecture portion of the course was presented to each subject individually by means of the teaching machine and utilizing the same color slides (augmented by audio narration) and 8mm film loops.

Experimental Design

The design of the study called for the development of the five experimental sound slide treatments, the administration of these treatments to the subjects under controlled conditions, the administration of the criterion performance measures, and the comparison of the performance data by means of appropriate statistical techniques. The subjects were assigned at random to the six experimental treatments.

Comparisons of the performance data were made for the combinations of the two independent variables constituting a 3 x 2 factorial design. This resulted in the following six experimental groups: Conventional Lecture/Conventional Laboratory, Conventional Lecture/Supervised Machine Laboratory, Conventional Lecture/Machine Laboratory, Machine Lecture/Conventional Laboratory, Machine Lecture/Supervised Machine Laboratory, and Machine Lecture/Machine Laboratory. Group performances were compared by means of the analysis of covariance statistical technique with score on the Manual portion of the Dental Aptitude Test used as the control variable. These comparisons were made for scores on the Class II laboratory preparation, Class II written test, cavity discrimination test, tool identification test, and on laboratory and lecture performance following the experimental treatments. In addition, qualitative reactions of the subjects to the treatment modes were obtained by means of personal interviews.

Experimental Population

The total experimental population consisted of the entire class of 100 first year graduate students in the University of Southern California School of Dentistry. There were 98 male and 2 female students in the group.

The subjects were distributed to the six experimental treatment groups by using a table of random numbers. An analysis of variance was performed to determine if the distribution of subjects had been random. The mean scores, standard deviations, and homogeneity of means for the Academic and Manual portions of the Dental Aptitude Test and for the

Undergraduate Grade Point Average are presented in Table 1. The F values for the analysis of variance were not significant, confirming the validity of the randomization procedure and attesting to the comparability of the treatment groups for these learner characteristics.

Development of the Experimental Stimulus Materials

The experimental audiovisual stimulus materials were presented by means of an automated teaching machine as 2" x 2" color transparency slides synchronized with magnetic audio tape. In addition, repetitive 8mm silent film loops were presented by means of rear-screen projection. A sample from one of the lessons is shown in Appendix A.

The development of the stimulus materials followed a careful study of the course of study and terminal behavioral objectives of the course in Freshman Operative Dentistry at the University of Southern California. These outlines and objectives were supplied by Harry C. Quint, DDS, of the U.S.C. School of Dentistry faculty, subject matter specialist in charge of the freshman operative program.[1] The outline for the lectures and laboratory sessions are shown in Appendix B. Meetings were held with Dr. Quint and his staff to determine the type of drawings and photographs that would best illustrate each lesson.

Original drawings and close-up photographs of actual teeth in various stages of preparation were made following the guidelines established at these meetings. All drawings, titles, and photographs were produced as 35mm color slides and then presented to Dr. Quint and his staff for final evaluation and selection of the actual slides to be presented in each lecture and laboratory session. Dr. Quint then wrote the lecture and laboratory script to accompany the slide presentations. The slides were then sent to a photographic laboratory for duplication in the number required for display to the subjects. These slides were then mounted in magazines to fit the display device.

The scripts and slides were used by Eldon Parminter, DDS, of the U.S.C. School of Dentistry faculty, who was responsible for the presentation of the "live" and "recorded" lectures. With the aid of the prepared text and the final visual material, Dr. Parminter prepared a master tape recording of each presentation. These master tapes were edited and duplicated in the number required and returned to the University mounted in cartridges to fit the display device.

The 8mm loop films used had been produced earlier. Seven film loops were prepared for each of the laboratory sessions. These included one motion picture loop that showed the complete cavity prepara-

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[1]Acknowledgment is made to Drs. Harry C. Quint, Robert Buchanan, and Eldon Parminter for their assistance on the study.

TABLE 1

MEAN SCORES, STANDARD DEVIATIONS, AND HOMOGENEITY OF MEANS FOR LEARNER CHARACTERISTICS (ANALYSIS OF VARIANCE)

		Academic Dental Apt.		Manual Dental Apt.		Undergrad. Gr. Pt. Ave.	
	N	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
Conventional Lecture/ Conventional Laboratory	15	5.40	.83	6.27	1.39	2.81	.30
Conventional Lecture/ Supervised Laboratory	18	5.28	1.32	6.06	1.55	2.87	.27
Conventional Lecture/ Machine Laboratory	16	5.19	1.05	5.94	1.12	2.96	.37
Machine Lecture/ Conventional Laboratory	16	5.00	.89	6.31	1.01	2.98	.36
Machine Lecture/ Supervised Laboratory	18	5.33	.91	6.06	1.31	2.89	.30
Machine Lecture/ Machine Laboratory	17	5.41	1.23	6.00	1.50	2.82	.34

	df	SS	MS	F	Prob.
ACADEMIC DENTAL APTITUDE					
Between Means	5	1.94	.39	.346	--
Within Groups	94	105.77	1.13		
Total	99	107.71			
MANUAL DENTAL APTITUDE					
Between Means	5	1.80	.36	.203	--
Within Groups	94	167.20	1.78		
Total	99	169.00			
UNDERGRADUATE GRADE POINT AVERAGE					
Between Means	5	38.22	7.64	.724	--
Within Groups	94	992.34	10.56		
Total	99	1030.56			

tion for that tooth. In the other six loops this film was broken down into the following shorter segments: Occlusal Cuts, Initial Proximal Cuts, Boxing the Proximal, Hand Instrumentation, Retention, and Finishing.

Instrumentation

The machine lectures and laboratory presentations were displayed to the subjects on the Videosonic Model 901 "Edutrainer," manufactured by the Videosonic Systems Division of the Hughes Aircraft Company. These machines displayed 2" x 2" color slides on a rear screen and transmitted the tape recorded audio narration through earphones. The audio tape, which was packaged in a repetitive loop, was coded to activate the slide changes. The slides were packaged in cartridges holding 36 slides. The 8mm repetitive loop films were packaged in Technicolor cartridges and displayed on Technicolor Model 600A rear-screen projectors.

The subjects using the machine modes sat at their laboratory benches (for both the lecture and laboratory sessions) and listened to and looked at the automated presentations. During the lecture they took notes. During the laboratory session they performed the operations as directed in the presentations. The programs were so coded as to present a sequence and then stop automatically to permit the subject to perform the operation. When he was ready to proceed, he pushed an "Advance" button, and the next sequence of instruction was presented.

The Measuring Instruments

Five types of data relating to student performance were obtained by means of ten different measuring instruments. These instruments consisted of digital skill, cognitive, perceptual discrimination, qualitative, and learner characteristics measures. In addition, data were obtained on several administrative factors relating to the conduct of the course.

Digital Skill Performance Measures

The development of perceptual-motor digital skills in the preparation of a cavity for filling was the major objective of the instructional sequence. Four measures were made of the acquisition of these skills.

Class II Cavity Preparation. This was the principal performance measure and entailed the preparation of a cavity for filling without instructional assistance. It was conducted one week after the fifth and final laboratory exercise on the Class II cavity preparation by all subjects and had to be completed within a three-hour time limit.

These preparations, which were identified only by student numbers, were graded by twelve different dentists, including laboratory instructors, the lecturer, the laboratory supervisors, and one dentist who did not participate in the instructional program. The grades given by these graders were transformed into standard scores in order to make them comparable, and a mean standard score was obtained for each subject's preparation. This mean standard score was the figure used in the analysis.

Inlay and Onlay Laboratory Preparations. These cavity preparations were made following the next sequence of instruction, but under the conventional instructional conditions, and were graded by the staff in the same way as the Class II preparation. However, the grades were not transformed into standard scores, and the scores used in the analyses were those recorded in the instructor's grade book. These two preparations were separately analyzed in order to determine whether or not the type of instruction used during the experimental laboratory and lecture period had any effects on subsequent laboratory performance.

Semester Laboratory Grade. The final laboratory grades for the entire semester were analyzed in order to determine whether or not the type of experimental laboratory and lecture instruction was related to total laboratory performance.

Cognitive Performance

The learning of cognitive information about various aspects of operative dentistry was measured by means of written tests prepared by the instructors of the course and administered to the entire group in the lecture classroom.

Class II Written Test. This written test was the principal cognitive performance measure and entailed the answering of objective questions related to identifications, nomenclature, principles, relationships, and procedures in the Class II cavity preparation. The scores used in the analysis were those recorded in the instructor's grade book.

Inlay-Onlay Written Test. This was a similar written test and followed the completion of the sequence on the inlay and onlay cavity preparations conducted after the experimental laboratory and lecture activity.

Semester Lecture Grade. The final lecture grades for the entire semester were analyzed in order to determine whether or not the type of experimental laboratory and lecture instruction was related to total performance on the lecture tests.

Perceptual Discrimination

The acquisition of visual discriminations relating to color, form and texture cues and to the identification of the instrument used was measured by two tests.

Cavity Discrimination. A total of ten cavity preparations (similar to those prepared during the experiment) were mounted, and two were given to each subject on a random basis. The subject was told to make a critique of the two preparations on a critique form similar to that used during the regular instruction. These preparations were also rated on the critique form by the two professional dentists supervising the instruction of the course, and these ratings were used as scoring keys for grading the student responses. Because the supervising dentists did not agree on every element on the critique form, only those parts where agreement was obtained were used in scoring the student critiques. These responses were transformed into standard scores to make them comparable, and these standard scores were used in the analysis. Each preparation was scored for "overextension" or "underextension" and for rating ("excellent," "good," "satisfactory," "unsatisfactory") on the occlusal cut (outline and finish), the proximal outline form (buccal, lingual, gingival, and finish), the proximal walls (buccal, lingual, gingival, axial, and finish), the retention (buccal, lingual, and gingival), and the cut of the pupal wall. In addition, the instrumentation and cavo finish were rated on the "excellent" to "unsatisfactory" scale.

Tool Identification. Five different tools used, and not used, in the Class II cavity preparation were mounted on five different cards in a random order and given to each subject on a random basis. Each subject was required to write the name of the instrument, the number of the instrument, and its use in the Class II cavity preparation on a special response form. The two supervising professional dentists specified the uses of each tool, and these descriptions were used in scoring the student responses. One point was given for the correct identification of the tool and one point was given for each correct listing of use of the tool (either one or two points depending upon the tool), totalling a maximum of 12 points. These scores were totalled, and the totals were used in the analysis. The tools used in this test were the Enamel Hatchet, the Gingival Marginal Trimmer, the Binangle Chisel, the #10-4-14 Hoe, and the #10-4-8 Hoe (not used in the Class II preparation).

Qualitative Measure

During the week immediately following the administration of the performance tests, a random sample of 53 subjects was interviewed in depth regarding their reactions to the mode of instruction, to the machines, to the help given by the laboratory instructor, and to the ways the lecture materials could be improved. These interviews were re-

corded on tape, the tapes were transcribed verbatim, and the responses were categorized and coded. These data were organized into frequency tables and analyzed.

Learner Characteristics

Four measures of the characteristics of the learners were obtained: dental aptitude (academic), dental aptitude (manual), undergraduate grade point average, and medical-dental profession of parent. These measures were used in selecting the covariates for the analysis of covariance.

Dental Aptitude Tests. The scores on the Academic and Manual sections of the Dental Aptitude Testing Program of the American Dental Association, as recorded on the subjects' permanent records, were used to determine the pre-enrollment dental aptitude of each subject. The Academic score showed the average for quantitative reasoning, verbal reasoning, reading comprehension, factual science, and science application. The Manual score showed the average of the space relations and carving dexterity scores.

Undergraduate Grade-Point Average. The undergraduate grade-point average was obtained from the permanent record of each subject.

Profession of the Parent. The subjects' application form showed the profession of the subject's parents. Subjects whose father or mother was a medical doctor, dentist, or nurse were categorized as having a parent in the medical profession.

Conduct of the Experiment

During each of the five weeks of the experiment the subjects assigned at random to the Conventional Lecture treatment attended the lecture in the lecture room, and those assigned to the Machine Lecture received the lecture in the laboratory using the teaching machines. Because of the size of the Machine Lecture group (N=49), one-half the group received the lecture at one time and the other half at another time. The lecture session for each week preceded the laboratory session.

Following each lecture, the three laboratory treatment groups performed the appropriate laboratory exercise. All laboratory sessions were held in the same large laboratory, but the Conventional Laboratory group was confined to one section of the laboratory and was not permitted to view any of the slide or motion picture presentations. The Supervised Machine Laboratory group used the machines in the other section of the laboratory. At a different time, the Machine Only Laboratory used the same machines.

At the conclusion of the five weeks of instruction, during the scheduled laboratory period in the sixth week, all subjects returned to their assigned laboratory benches and completed without instruction the Class II cavity preparation on which they were graded. During this laboratory testing period, subjects were taken to another testing room, several at a time, to complete the Cavity Discrimination and Tool Identification Tests. During the same week, they also took the Class II written test as a group in the lecture room.

Preparation of Data and Statistical Analysis

Scores for all tests and the data on the learner characteristics were recorded on a worksheet together with the student identification number and experimental treatment group. These scores were then keypunched on IBM cards.

A series of descriptive analyses were undertaken to establish the quality of the data, to identify characteristics of the population and interrelationships among selected variables, and to provide a basis for selecting covariates to be used in the comparative analyses. All these analyses were performed on the Honeywell 800 computer, operated by the staff of the Computer Sciences Laboratory, University of Southern California. Factor analytic and covariance programs used were adapted versions of the BMD03M and BMD05V programs, respectively, described in Dixon (1965).

The principal components factor analysis used provided means and standard deviations, a correlation matrix, and a factor matrix useful in the selection of covariates for later analysis. An orthogonal rotation to the varimax criterion was performed on four factors.

Analyses of covariance were undertaken to establish the statistical differences among the experimental variables and to adjust the test scores for differences among the groups in manual dental aptitude.

The qualitative interview data were categorized by codes and prepared for display in frequency tables.

CHAPTER III

RESULTS

Test results were analyzed for performance on the Class II laboratory preparation, the Class II written test, the cavity discrimination test, the tool identification test, and for the laboratory and lecture activities following the conclusion of the experimental treatments. In addition, qualitative responses on the opinion interviews were compared for all groups, and the administrative factors pertaining to the use of automated instructional procedures were considered.

Descriptive Analyses

Selection of Covariate

The covariate for the analysis of covariance was selected by performing correlation and factor analyses of the test scores. Two criteria were used in the selection of the covariate. The first required that the covariate selected be meaningful in the context of the study to members of the educational community who might be using the reported results. The second required that the covariate have a high correlation with the total performance test.

The covariate selected was the score on the Manual section of the Dental Aptitude Test. This covariate was readily measurable by the most widely used test of dental aptitude, thus meeting the first criterion. Examination of Table 2 shows that this covariate had a high loading (.841) on Factor 2, and an examination of Table 3 shows it to have a .165 correlation with performance on the Class II laboratory preparation and a .164 correlation with performance on the Class II written test. Although these correlations were not high, they were higher than those for the Academic Dental Aptitude score, the undergraduate grade-point average, and for the parent's medical profession.

Analysis of Performance

The mean scores for performance on the nine measures taken are presented in Table 4. On the two major criterion measures (Class II laboratory preparation and Class II written test) the most effective treatment was the Conventional Lecture/Machine Laboratory method and

TABLE 2

ROTATED FACTOR LOADINGS USED AS A BASIS FOR SELECTING COVARIATES APPLIED IN THE ANALYSIS OF COVARIANCE (N = 100)

Variable	Factors			
	1	2	3	4
Class II Laboratory Preparation	-.994	.030	.016	.031
Class II Written Test	-.992	.037	.034	.021
Dental Aptitude Test (Academic)	.137	.683	-.178	-.371
Dental Aptitude Test (Manual)	-.166	.841	.154	.137
Grade Point Average (Undergraduate)	.026	-.022	-.972	.090
Parent Medical Profession	.134	.043	.106	-.941

TABLE 3

CORRELATION COEFFICIENTS USED AS A BASIS FOR SELECTING COVARIATES FOR THE ANALYSIS OF COVARIANCE (N = 100)

		1	2	3	4	5	6
Class II Laboratory Preparation	1		.989	-.092	.165	-.053	-.061
Class II Written Test	2			-.076	.164	-.075	-.055
Dental Aptitude Test (Academic)	3				.195	.003	.176
Dental Aptitude Test (Manual)	4					.060	.071
Grade Point Average (Undergraduate)	5						-.121
Parent Medical Professor	6						

TABLE 4

MEAN SCORES AND STANDARD DEVIATIONS ON PERFORMANCE TEST MEASURES FOR TREATMENT GROUPS

	N	Class II Lab Preparation		Class II Written Test		Inlay Lab Preparation		Onlay Lab Preparation		Inlay-Onlay Written Test		Semester Lecture Grade		Semester Lab. Grade		Cavity Discrimination		Tool Identification	
		$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
Conventional Lecture/ Conventional Laboratory	15	6.03	2.44	64.27	21.14	7.13	2.03	7.73	1.83	5.47	2.67	10.00	2.17	8.00	2.70	48.49	11.72	8.33	2.94
Conventional Lecture/ Supervised Laboratory	18	6.12	2.41	64.22	19.56	6.83	2.36	6.89	1.81	5.94	1.55	9.83	2.26	7.83	2.33	49.83	11.91	8.44	2.23
Conventional Lecture/ Machine Laboratory	16	6.80	1.95	70.00	15.54	6.44	2.76	8.00	2.10	5.44	1.71	10.50	2.19	7.69	2.44	50.13	9.61	8.69	2.80
Machine Lecture/ Conventional Laboratory	16	6.12	2.37	63.25	18.75	6.88	2.80	7.19	1.94	6.19	.91	9.75	1.73	7.88	2.42	49.14	8.61	8.63	3.03
Machine Lecture/ Supervised Laboratory	18	6.29	2.42	65.67	19.91	7.00	2.03	7.39	1.75	6.39	1.85	9.50	1.86	7.17	1.82	52.94	9.77	7.78	3.32
Machine Lecture/ Machine Laboratory	17	4.57	1.87	50.53	13.85	6.77	1.95	6.12	2.42	5.18	1.74	9.88	2.32	6.53	1.18	49.47	9.44	7.69	2.87

the least effective treatment the Machine Lecture/Machine Laboratory method.

Two-way analyses of covariance were performed on the nine criterion measures with Manual Dental Aptitude score used as the covariate. The results for each of these analyses will be presented separately immediately below.

Class II Laboratory Preparation

The results of the two-way analysis of covariance for the Class II laboratory preparation are presented in Table 5. No significant differences were found between the two lecture modes or among the three laboratory modes. However, the interaction between Lecture and Laboratory modes was significant at the .05 level, indicating some impairment of laboratory skill acquisition by subjects who received both the lecture and laboratory instruction under the same presentation conditions. This loss was particularly evident for the group that received both the lecture and laboratory by machine presentation only. The difference in performance between the Machine Lecture/Machine Laboratory (4.57) and the Conventional Lecture/Machine Laboratory (6.80) was almost an entire letter grade (C- to B-).

The significance of the differences between the group means for each of the combinations of presentation modes, as determined by t-test, are shown in Table 6. It will be noted that four of the five of the treatment groups showed statistically significant superiority to the Machine Lecture/Machine Laboratory group.

Class II Written Test

The results of the two-way analysis of covariance for the Class II written test are presented in Table 7. No statistically significant differences were found between the two lecture modes or among the three laboratory modes, although the Conventional Lecture method approached superiority over the Machine Lecture method. The interaction between the Lecture and Laboratory modes was significant at the .05 level, indicating some impairment of cognitive learning by subjects who received both the lecture and laboratory instruction under the same presentation conditions. This loss was contributed almost entirely by the group that received both the lecture and laboratory instruction by machine presentation only.

The significance of the differences between the group means for each of the combinations of presentation modes, as determined by t-test, are shown in Table 8. It will be noted that all five of the treatment groups showed statistically significant superiority to the Machine Lecture/Machine Laboratory group.

TABLE 5

COMPARISON OF SCORES ON CLASS II LABORATORY PREPARATION
BY ANALYSIS OF COVARIANCE
(Covariate: Manual Dental Aptitude)

		Criterion		Covariate
	N	$\bar{X}$	σ	$\bar{X}$
Conventional Lecture/ Conventional Laboratory	15	6.03	2.44	6.27
Conventional Lecture/ Supervised Laboratory	18	6.12	2.41	6.06
Conventional Lecture/ Machine Laboratory	16	6.80	1.95	5.94
Machine Lecture/ Conventional Laboratory	16	6.12	2.37	6.31
Machine Lecture Supervised Laboratory	18	6.29	2.42	6.06
Machine Lecture/ Machine Laboratory	17	4.57	1.87	6.00

	df	SS	MS	F	Prob.
Lecture	1	11.17	11.17	2.24	--
Laboratory	2	4.33	2.17	.43	--
Interaction	2	31.09	15.55	3.11	<.05
Within	93	46.59			

TABLE 6

SIGNIFICANCE OF DIFFERENCES BETWEEN GROUP MEANS
ON CLASS II LABORATORY PREPARATION (N = 100)

Experimental Group	N	Co Le/ Co Lab	Co Le/ Su Lab	Co Le/ Ma Lab	Ma Le/ Co Lab	Ma Le/ Su Lab	Ma Le/ Ma Lab
Conventional Lecture/ Conventional Laboratory	15						.10*
Conventional Lecture/ Supervised Laboratory	18						.05
Conventional Lecture/ Machine Laboratory	16						.01
Machine Lecture/ Conventional Laboratory	16						.05
Machine Lecture/ Supervised Laboratory	18						.05
Machine Lecture/ Machine Laboratory	17						

*The group at the left is superior as determined by t-test.

TABLE 7

COMPARISON OF SCORES IN CLASS II WRITTEN TEST
BY ANALYSIS OF COVARIANCE
(Covariate: Manual Dental Aptitude)

		Criterion		Covariate
	N	$\bar{X}$	σ	$\bar{X}$
Conventional Lecture/ Conventional Laboratory	15	64.27	21.14	6.27
Conventional Lecture/ Supervised Laboratory	18	64.22	19.56	6.06
Conventional Lecture/ Machine Laboratory	16	70.00	15.54	5.94
Machine Lecture/ Conventional Laboratory	16	63.25	18.75	6.31
Machine Lecture/ Supervised Laboratory	18	65.67	19.91	6.06
Machine Lecture Machine Laboratory	17	50.53	13.85	6.00

	df	SS	MS	F	Prob.
Lecture	1	1029.77	1029.77	3.14	<.10
Laboratory	2	347.53	173.77	.53	--
Interaction	2	2208.97	1104.49	3.36	<.05
Within	93	30531.07			

TABLE 8

SIGNIFICANCE OF DIFFERENCES BETWEEN GROUP MEANS
ON CLASS II WRITTEN TEST (N = 100)

Experimental Group	N	Co Le/ Co Lab	Co Le/ Su Lab	Co Le/ Ma Lab	Ma Le/ Co Lab	Ma Le/ Su Lab	Ma Le/ Ma Lab
Conventional Lecture/ Conventional Laboratory	15						.05*
Conventional Lecture/ Supervised Laboratory	18						.05
Conventional Lecture/ Machine Laboratory	16						.01
Machine Lecture/ Conventional Laboratory	16						.05
Machine Lecture/ Supervised Laboratory	18						.02
Machine Lecture/ Machine Laboratory	17						

*The group at the left is superior as determined by t-test.

Cavity Discrimination Test

The results of the two-way analysis of covariance for the cavity discrimination test are presented in Table 9. No statistically significant differences were found between the two lecture modes, among the three laboratory modes, or for the interactions among these variables. Apparently, the type of instruction given in the lecture and laboratory did not transfer to the development of the ability to make color, form, and texture discriminations about cavity preparations prepared by someone else.

Tool Identification Test

The results of the two-way analysis of covariance for the tool identification test are presented in Table 10. No statistically significant differences were found between the two lecture modes, among the three laboratory modes, or for the interactions among these variables. Apparently, the type of instruction given in the lecture and laboratory did not transfer to the ability to identify the instruments used in making the Class II cavity preparation or knowledge of how these tools were used in the operation.

Subsequent Lecture and Laboratory Activities

The results of the two-way analyses of covariance made for the five measures taken following the conclusion of the experimental treatment are presented in Table 11. No statistically significant differences were found between the two lecture modes, among the three laboratory modes, or for the interactions among these variables. Apparently, the type of instruction given in the lecture and laboratory did not transfer to the subsequent laboratory operations, the written tests on these operations, or to the final semester grades given for the total lecture and laboratory performance.

Opinion Interview Responses

During the week following the completion of the experimental phase of the study, a random sample of 53 subjects was interviewed in depth regarding their reactions to the mode of instruction employed. The results of these interviews will be analyzed for the responses to the questions relating to the laboratory instruction, to the lecture instruction, and to the machines used in the study.

TABLE 9

COMPARISON OF SCORES OF CAVITY DISCRIMINATION TEST
BY ANALYSIS OF COVARIANCE
(Covariate: Manual Dental Aptitude)

		Criterion		Covariate
	N	$\bar{X}$	σ	$\bar{X}$
Conventional Lecture/ Conventional Laboratory	15	48.49	11.72	6.27
Conventional Lecture/ Supervised Laboratory	18	49.83	11.91	6.06
Conventional Lecture/ Machine Laboratory	16	50.13	9.61	5.94
Machine Lecture/ Conventional Laboratory	16	49.14	8.61	6.31
Machine Lecture/ Supervised Laboratory	18	52.94	9.77	6.06
Machine Lecture Machine Laboratory	17	49.47	9.44	6.00

	df	SS	MS	F	Prob.
Lecture	1	25.96	25.96	.24	--
Laboratory	2	118.46	59.23	.56	--
Interaction	2	64.38	32.19	.30	--
Within	93	9866.38			

TABLE 10

COMPARISON OF SCORES ON TOOL IDENTIFICATION TEST
BY ANALYSIS OF COVARIANCE
(Covariate: Manual Dental Aptitude)

		Criterion		Covariate
	N	$\bar{X}$	σ	$\bar{X}$
Conventional Lecture/ Conventional Laboratory	15	8.33	2.94	6.27
Conventional Lecture/ Supervised Laboratory	18	8.44	2.23	6.06
Conventional Lecture/ Machine Laboratory	16	8.69	2.80	5.94
Machine Lecture/ Conventional Laboratory	16	8.63	3.03	6.31
Machine Lecture/ Supervised Laboratory	18	7.78	3.32	6.06
Machine Lecture Machine Laboratory	17	7.69	2.87	6.00

	df	SS	MS	F	Prob.
Lecture	1	8.36	8.36	1.01	--
Laboratory	2	2.46	1.23	.15	--
Interaction	2	10.68	5.34	.65	--
Within	93	767.30			

TABLE 11

RESULTS OF ANALYSIS OF COVARIANCE FOR PERFORMANCE IN LABORATORY AND LECTURE FOLLOWING CONCLUSION OF EXPERIMENTAL TREATMENT (Covariate: Manual Dental Aptitude)

	df	F	Prob.
Inlay Laboratory Preparation			
Lecture	1/93	.02	--
Laboratory	2/93	.22	--
Interaction	2/93	.13	--
Onlay Laboratory Preparation			
Lecture	1/93	2.58	--
Laboratory	2/93	.35	--
Interaction	2/93	3.07	<.10
Inlay-Onlay Written Test			
Lecture	1/93	.67	--
Laboratory	2/93	1.91	--
Interaction	2/93	.66	--
Semester Lecture Grade			
Lecture	1/93	.90	--
Laboratory	2/93	.55	--
Interaction	2/93	.07	--
Semester Laboratory Grade			
Lecture	1/93	2.66	--
Laboratory	2/93	.77	--
Interaction	2/93	.51	--

Reactions to Laboratory Instruction

Three questions were asked in the interview pertaining to the relation between the laboratory activity and the type of instruction employed: "Did you get adequate help from your laboratory instructor?" "What additional help could have been given?" "Did you get enough feedback from your laboratory instructor?" The tabulation of responses to these questions are presented in Table 12.

"Did you get adequate help from your laboratory instructor?" The responses show that 62.3 percent of the subjects felt that the help was adequate and that 34.9 percent felt it was not adequate. All of the subjects in the Conventional Laboratory groups felt the help was adequate, and most of the subjects in the Supervised Machine Laboratory groups felt it was adequate. However, most of the subjects in the Machine Only Laboratory group felt that the help was inadequate.

"What additional help could have been given?" The responses show that the Machine Only Laboratory groups missed the presence of the instructor so they could ask questions and have problems clarified. The Conventional Laboratory and Supervised Machine Laboratory groups appeared to be most satisfied with the instruction the way it was.

"Did you get enough feedback from your laboratory instructor?" The responses showed that both the Conventional and Supervised Laboratory groups received enough feedback, but that the Machine Only Laboratory group did not.

Reactions to Lecture Instruction

Two questions were asked in the interview pertaining to the relation between the lecture and the type of instruction employed: "Did the lecture prepare you for the laboratory work?" "How could the lecture have been improved?" The tabulation of responses to these questions are presented in Table 13.

"Did the lecture prepare you for the laboratory work?" There was almost universal affirmative response to this question, only one respondent answering negatively.

"How could the lecture have been improved?" In general, all Conventional Lecture groups appeared to be satisfied with the lecture as it was, but the Machine Lecture groups felt that it was "too repetitive."

Attitude Toward the Machines

Two questions were asked in the interview pertaining to the values and disadvantages of the videosonic sound-slide teaching machines. The tabulation of responses to these questions are presented

TABLE 12

RELATION BETWEEN LABORATORY ACTIVITY AND TYPE OF INSTRUCTION
(Percentage of Distribution of Scores)

	Co Le/ Co Lab (N=6)	Co Le/ Su Lab (N=10)	Co Le/ Ma Lab (N=9)	Ma Le/ Co Lab (N=8)	Ma Le/ Su Lab (N=11)	Ma Le/ Ma Lab (N=9)
"Did you get adequate help from your laboratory instructor?"						
Yes	11.3	15.1	5.7	15.1	13.2	1.9
No	0	3.8	11.3	0	5.7	15.1
Don't know. No answer	0	0	0	0	1.9	0
"What additional help could have been given?"						
Instructor's presence for questions	1.9	3.8	9.1	0	7.5	15.1
More checks during preparation	0	0	1.9	1.9	1.9	0
Help on instrumentation	0	0	1.9	0	1.9	0
Liked it way it was	5.7	9.1	3.8	11.3	9.1	0
Would have liked machine instruction (or more of it)	1.9	1.9	0	0	0	0
Don't know. No answer	1.9	3.8	0	1.9	0	1.9
"Did you get enough feedback from your laboratory instructor?"						
Yes	7.5	15.1	5.7	9.1	9.1	1.9
No	1.9	3.8	9.1	7.5	5.7	13.2
Don't know. No answer	1.9	0	1.9	0	3.8	1.9

TABLE 13

RELATION BETWEEN LECTURE ACTIVITY AND TYPE OF INSTRUCTION
(Percentage of Distribution of Scores)

	Co Le/ Co Lab (N=6)	Co Le/ Su Lab (N=10)	Co Le/ Ma Lab (N=9)	Ma Le/ Co Lab (N=8)	Ma Le/ Su Lab (N=11)	Ma Le/ Ma Lab (N=9)
"Did the lecture prepare you for the laboratory work?"						
Yes	11.3	18.9	17.0	15.1	18.9	17.0
No	0	0	0	0	1.9	0
"How could the lecture have been improved?"						
Could not be improved	9.1	13.2	13.2	5.7	5.7	7.5
Improve the movies	0	0	0	1.9	0	1.9
Too repetitive. Monotonous	0	3.8	0	5.7	11.9	7.5
Give chance to ask questions	0	0	1.9	0	1.9	0
Don't know. No answer	1.9	1.9	1.9	1.9	0	0

in Table 14.

Values of the sound-slide machines. The predominant value attached to the use of the teaching machines was their step-by-step or self-pacing feature. All groups, or 69.3 percent of all responses, noted this value. Other responses related to the repetition and review capability of the machines and the fact that they presented a better visualization of the content than was possible under normal instructional conditions.

Disadvantages of the sound-slide machines. The responses relating to the disadvantages of the machines were more varied, but centered around the difficulties associated with equipment malfunction and the fact that they were often too slow. It was also noted that the student could not ask questions of the machines.

Administrative Factors

The estimated cost per semester for lecture and laboratory instruction conducted under the automated Supervised Laboratory and the Conventional Laboratory conditions are shown in Table 15. The figures presented for the Supervised Laboratory instruction assume the production of the materials by a production staff in the School of Dentistry itself, amortized cost of purchased equipment over a five-year period with 10% added for maintenance and use in four other classes, and the cost of instructional personnel on the scale prevailing at the University of Southern California. The figures presented for the Conventional Laboratory assume the preparation of only one set of materials for group presentation and the purchase of only one slide projector and one 8mm silent motion picture projector.

It will be seen that the total cost of one semester of the automated Supervised Laboratory type of instruction would be $9,710 or $97.10 per student and of Machine Only Laboratory type instruction $6,560 or $65.60 per student. The cost of the Conventional Laboratory type of instruction would be $8,730 or $87.30 per student. The significantly lower cost for the Machine Only Laboratory type of instruction resulted from the virtual elimination of professional supervision in the laboratory. On the other hand, the Conventional type of laboratory instruction could be conducted with very low expenditure for equipment. The main administrative advantage for the two automated laboratories was in the saving of professional personnel--four instructors for the Supervised Machine Laboratory and twelve instructors for the Machine Only Laboratory--an important consideration given the increasing manpower shortage.

TABLE 14

RELATION BETWEEN LECTURE ACTIVITY AND TYPE OF INSTRUCTION
(Percentage of Distribution of Scores)*

	Co Le/ Co Lab (N=6)	Co Le/ Su Lab (N=10)	Co Le/ Ma Lab (N=9)	Ma Le/ Co Lab (N=8)	Ma Le/ Su Lab (N=11)	Ma Le/ Ma Lab (N=9)
Values of sound-slide machines						
Generally good	No response elicited	0	4.1	0	2.0	2.0
Generally bad		0	0	0	0	2.0
Self-pacing. Step-by-step		16.3	14.3	12.2	14.3	12.2
Repetition and review		0	0	4.1	2.0	0
Better visualization		2.0	0	4.1	4.1	2.0
Don't know. No response		2.0	0	0	0	0
Disadvantages of sound-slide machines						
Generally good	No response elicited	0	2.1	0	0	2.1
Generally bad		2.1	0	0	4.3	4.3
Equipment malfunction		4.3	10.6	4.3	8.5	0
Too slow. Tiring		10.6	0	2.1	8.5	2.1
Could not ask questions		0	4.3	0	4.3	6.4
Difficulties in reviewing		2.1	0	0	0	0
Don't know. No response		2.1	0	10.6	0	2.1

*Respondents could give more than one response.

TABLE 15

ESTIMATED COST PER SEMESTER FOR AUTOMATED AND CONVENTIONAL INSTRUCTION
(Materials and Equipment Amortized over Five Semesters)

	Supervised Machine Laboratory	Machine Only Laboratory	Conventional Laboratory
Production of Materials (for 100 sets)	$1,560	$1,560	$ 850 (one set)
Equipment Costs (for 100 students; 20% of total use)	2,150	2,150	80
Instructional Personnel	6,000	2,850	7,800
TOTAL	$9,710	$6,560	$8,730
COST PER STUDENT (100 students)	$ 97.10	$ 65.60	$ 87.30

CHAPTER IV

CONCLUSIONS, DISCUSSION, AND IMPLICATIONS

This chapter will present the specific conclusions that may be derived from the data, discuss the results of the study, and suggest implications of the study for the instruction of graduate dental students.

Conclusions

The following conclusions may be made from an analysis of the results of the study:

1. No significant differences were found in the acquisition of operative dental skills or learning of cognitive information among groups that received lecture and laboratory instruction under mixed conventional or machine conditions.

2. Those groups which received both lecture and laboratory instructions by machine only without supervision performed at a significantly lower level than other treatment groups.

3. There were no significant differences among the six treatment groups in the making of color, form and texture discriminations or in the identification of the instruments used and knowledge of their use in the cavity preparation.

4. There were no significant differences among the six treatment groups in either subsequent laboratory cavity preparations, written test performance, or final semester laboratory or lecture grades.

5. Interviews of the subjects showed that those subjects who received laboratory instruction by machine only without supervision felt that they needed more help from the instructor, but all other groups felt that the help was adequate. All groups felt that the lecture prepared them for the laboratory instruction. The value of the sound-slide teaching machines was felt to be in the step-by-step self-pacing feature. The disadvantages of the machines were associated with equipment malfunction and the fact that they were often too slow in relation to the subject's pacing needs.

6. The cost of a semester of instruction per student was estimated at $65.60 under the Machine Only Laboratory conditions and $97.10 under the Supervised Machine Laboratory conditions. Under normal Conventional Laboratory conditions the cost was estimated to be $87.30 per student.

Discussion

What does this study tell us about the teaching of perceptual-motor skills required in dental operative techniques and the cognitive knowledge of these techniques? How do students react to machine-mediated instruction of skills and content normally presented through close face-to-face personal instruction?

The Acquisition of Perceptual-Motor Laboratory Skills

Dental educators in general believe that the more direct personal attention a student can be given in the laboratory--reflected in a low student to teacher ratio--the more effective the instruction will be. Yet, this practice runs counter to the availability of professional personnel, and there is little direct evidence that this is, in fact, the most efficacious way to teach. The results of this study have presented some evidence challenging the accepted practices. In particular, the study has demonstrated the fact that some form of machine mediation of laboratory instruction can substitute for at least some of the supervisory professional personnel thought to be required without loss of instructional quality. Even the limited scope of this study, interpreted very conservatively, showed that the ratio of students to instructor could be increased from eight to twelve without loss of tested operative skills. And there was some supporting evidence that all professional supervision could be omitted without loss under certain conditions. These results are consistent with those in both the Barber (1964) and Vanek and others (1967) studies.

Although it was outside the range of investigation in this study, it may be suggested that these results were a function of the step-by-step procedures built into the machine-mediated program which led the student through the operation in the most instructionally acceptable order. The students who used the machines certainly recognized this factor, over two-thirds of them attributing this characteristic as a major value of the machine instruction. Often, under conventional instructional conditions, the students performed the operation on the tooth in an unsystematic way rather than in the approved step-by-step order. Another explanation of the results may be the fact that the students in the machine groups assumed more responsibility for solving the problems inherent in the operation rather than depending upon a readily available supervising dentist for the answers.

The supervising dentists often carried out much of the operation themselves while explaining what had to be done, thus depriving the students of this experience.

The significantly poorer performance by the group that received both the lecture and the laboratory instruction by machine without supervision bears closer scrutiny. These results appear to tell us that a student can receive "too much" machine instruction, and that such instruction needs to be balanced with some personal teacher contact, even if this contact is in the lecture situation alone. It is difficult to explain the large differences in performance between this machine-saturated group and the other groups. The students themselves, however, recognized the need for help, eight out of the nine students in the group stating they did not have adequate help from their laboratory instructor. Interestingly, in the other "machine only" laboratory group (which received the conventional lecture) only six out of the nine students felt they needed more help, and three of the nine felt they received adequate help. Perhaps the conventional face-to-face contact with the teacher in the lecture carried over into the laboratory situation. The fact that an identical pattern of inferior performance held also on the written test suggests strongly that some vital instructional (or possibly affective) element was missing from presentation (both lecture and laboratory) given only by machine.

The Learning of Cognitive Information

There is little new to add relative to the results in cognitive learning as measured by the Class II written test. As was the case with the Class II cavity preparation, the group that received both the lecture and the laboratory instruction under the machine conditions without supervision performed at a significantly lower level than did the other treatment groups. It would appear that the same factor that may have been operating to affect the motor skill performance were also operating to affect cognitive learning.

Transfer of Learning

The fact that none of the tests given to measure perceptual discrimination and identification skills or activities following the five-week experimental period showed any significant differences among the treatment groups, suggests that the nature of the lecture and laboratory instruction affected only those actions that were specifically taught. That is, the learning of the procedures for conducting the Class II cavity preparation and carrying out of these operations were the subject of the instruction in both the lecture and laboratory. The other activities measured, although related to the Class II cavity preparation, were not the subject of direct instruction.

The main conclusion to be drawn from these results is that the mode of instruction used during one sequence did not materially affect,

either positively or negatively, performance on subsequent activities. It is worth noting, however, that the laboratory performance of the group that received both lecture and laboratory instruction by machine without supervision (the lowest group on both the Class II cavity preparation and written test) continued to perform in the laboratory at a generally lower level than the other groups. Whether this was a result of the instruction received or lack of manual dental aptitude skills (not measured in the Dental Aptitude Test) cannot be determined. Although the group did not differ significantly from the other groups on any of the learner characteristics measures, it did fall in fifth or sixth rank on all these measures. The additional fact that it was lowest on final semester laboratory grade (although not significantly so) might further support the contention that the group was somewhat inferior in this manual skill.

Implications

The principal implication to be drawn from this study is that the machine mediation of dental operative laboratory and lecture activities is feasible under instructional conditions prevailing in the schools of dentistry. That some of the burden of guiding laboratory instruction and that the number of professional instructors needed the laboratory can be reduced appear to be indicated by the results f the study. There is no positive evidence, however, that the entire instructional function can be carried by machine mediation.

Where possible and where the personnel in dental schools are sympathetic to investigating innovative practices, further experimentation might be tried out with different patterns of machine mediation. Although the machines used in this study combined audio and slides supplemented by motion picture loops, a completely different combination of devices might be employed. Possibly the strength of the machine mediation was in its orderly step-by-step presentation of the procedures to be performed and the clear presentation of a realistic pictorial model to follow. If this is the case, the use of sound may be unnecessary, and adequate directions may be presented by means of printed captions or use of an accompanying workbook. Such modification of the machine would permit the use of small and inexpensive manually operated silent filmstrip or slide viewers that would have the added advantage of permitting easy review or repetition of the visuals. This could also decrease the cost of instruction under either the Supervised or Machine Only laboratory conditions significantly.

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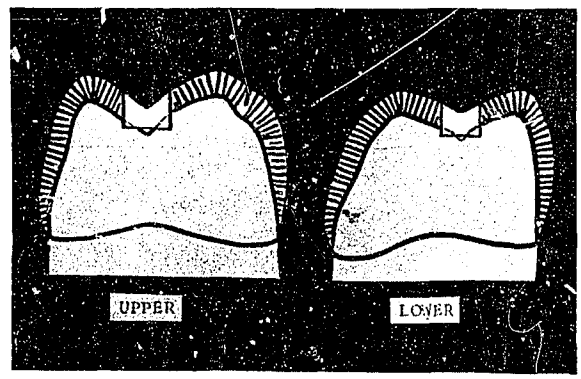
APPENDIX A

EXAMPLE OF PROGRAM SEQUENCE

Lesson No. 5: Class II Alloy Preparation on Mandibular Molar

EXPLANATION: The following script is selected from one of the lessons and presents the audio narration (recorded on tape for the machine groups or given by the instructor in the conventional lecture) and the accompanying color slides (presented by machine to the machine groups and projected on a screen to the conventional lecture group). The entire sequence was presented in the lecture sessions. However, the machine groups started with Frame No. 14 in the laboratory sessions.

Audio	Visual
7. These drawings show sagital section similarities of the Class II MO amalgams on lower and upper molars.	

1. The gingival walls are flat and far enough into the axial dentin to allow the tension to be placed in the dentin without undermining the enamel rods and a minimum of 1 millimeter in axial depth.

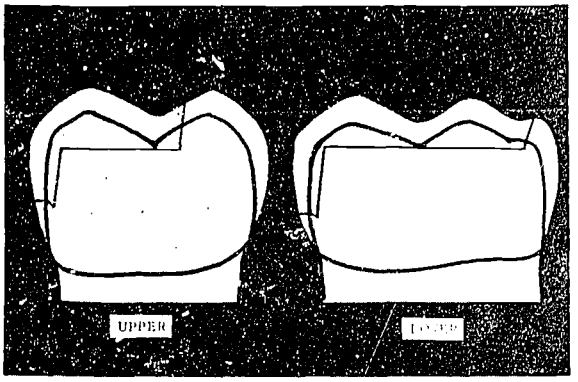
2. Gingival retention is identical in each case.

3. The walls form obtuse angles with the gingival wall for convenience in instrumentation.

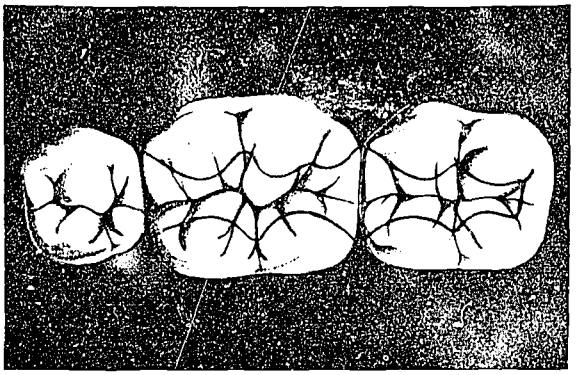
4. Pulpal walls just within dentin in line and point angle areas.

5. Dove-tail walls form obtuse angles with the pulpal wall to preserve strength of the marginal ridge on lower, and the unfissured oblique ridge of the upper molar.

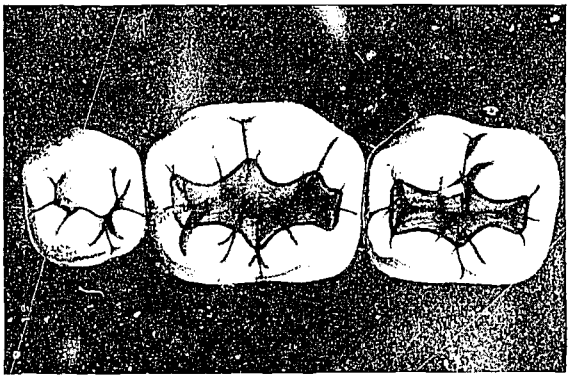
8. Part I deals with the pre-operative steps of design criteria. Utilizing the foregoing information and the knowledge gained to date, we will now design an outline form for Class II amalgam in the lower molar.



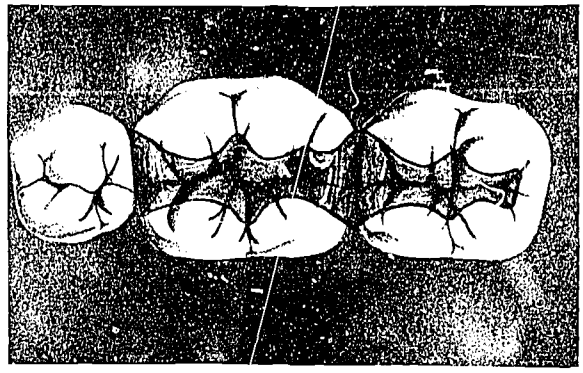
9. Study this slide for a moment and see if you agree with the outline form shown. What has been the rational for developing these particular outlines?



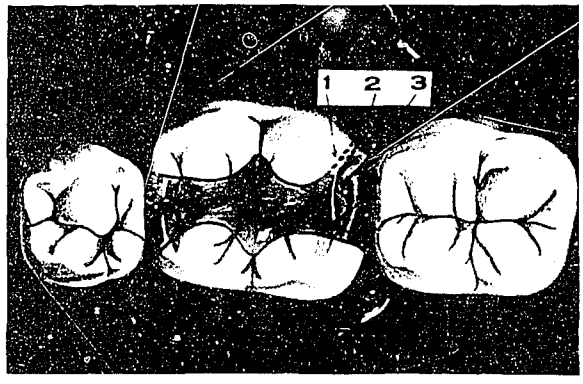
10. Develop the occlusal portion of the outline form first, as shown here in red. This preparation outline is determined by the caries, fissured grooves and other defects on the occlusal surface of the tooth. The prevention and convenience form requirements for this area determine the outline form.



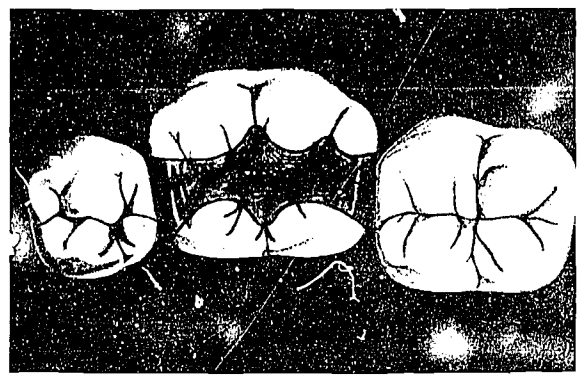
11. The blue depicts the proximal of the outline form and this portion is determined by the prevention and convenience form features for the proximal surface of the tooth. We must include the contact point and caries, and place the proximal margins in an accessible and relatively caries immune area without over-extension. A #15 Bin-Angle Chisle is used again as a rule of thumb guide for proximal extension, being 1 times the thickness of the instrument on the buccal and $1\frac{1}{2}$ times the thickness on the lingual. The light blue area represents the symmetrical connection between the rationally designed occlusal in red, and the properly designed proximal which are blue.



12. This slide shows the effect of mal-alignment on cavity design. This molar is in buccal version and the distal is rotated some to the lingual. The occlusal portion is designed first, as shown in red. Secondly, the proximal is designed as shown in dark blue, so that the buccal proximal and lingual proximal margins are accessible to carving, polishing and cleaning. The light blue represents that portion which symmetrically joins the occlusal and proximal portions so desired. As a result of the mal-alignment, the distal contact point is brought well to the buccal. This causes our rationally designed distal buccal margin, #3 on the slide, to be very close to the distal buccal groove, #2 on the slide, so that there is danger that the enamel on the margin so placed, would fracture away, resulting in a failure. Thus the distal buccal groove is included as shown in yellow and a new outline form margin as shown by the dotted line, number 3, is established. This margin is over-extended to meet a resistance form requirement as a result of the mal-alignment.

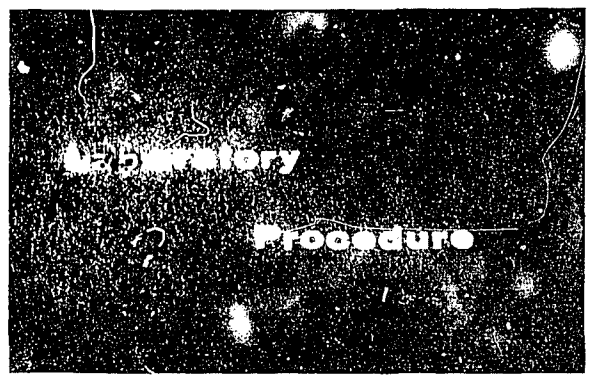


13. This mal-alignment is due entirely to buccal version, as might exist in a single tooth cross-bite case. Note here that the distal proximal outline is narrower, only because of its peculiar contact arrangement with the 2nd molar. The red is the occlusal portion; the dark blue is the proximal whose marginal position is established by our #15 instrument rule of thumb guide and uniform accessibility. The light blue, the symmetrical blending of the two portions. Note how following our basic rule results in a cavity outline that is designed for us. Let us now look at a movie of a preparation of a Class II amalgam on a mandibular first molar. Note how this movie generally follows the sequence as set forth as mid-preparation steps on the blue amalgam laboratory grey sheet. The movie sequence will be broken into individual steps as shown on the following slides, and in the laboratory you are to accomplish each of these steps as they are presented to you by the slides.

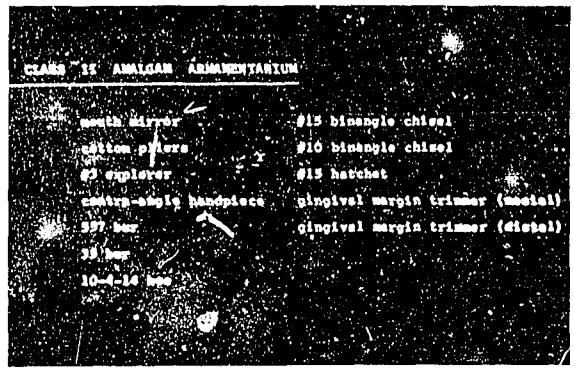


AT THIS POINT, YOU WILL TURN OFF THIS MACHINE, GO TO THE APPROPRIATE 8 MILLIMETER MOVIE, THEN RETURN TO YOUR VIDEOSONIC MACHINE TO CONTINUE THE LESSON.

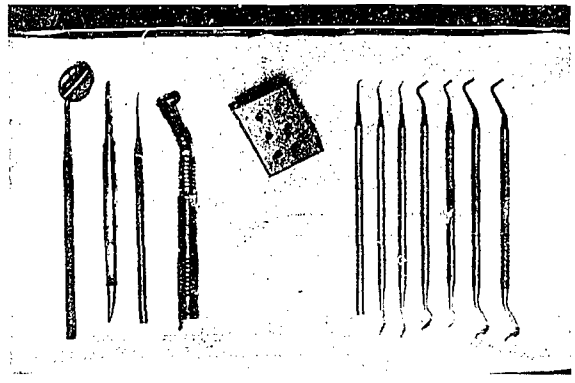
14. The following slides will depict the preparation of a Class II MO amalgam on a lower first molar. In the laboratory, you may prepare either a MO or a DO alloy on a lower first or second molar with an adjacent mounted tooth. Remember to rationally design your cavity outline applying the foregoing design outline criteria.



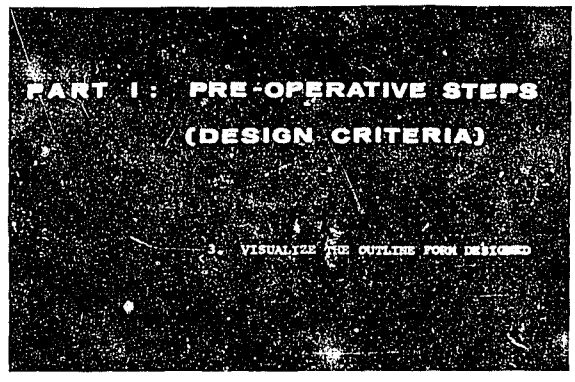
15. Note that the armamentarium utilized in preparing the Class II restoration on the mandibular molar is essentially the same we have previously used. If you note carefully on the following slides you will see that they are photographed with the 10-4-14 and bin-angle chisle you have been using. In the mouth, hatchets #10 and #15 have been designed to replace the hoes and chisles and are used because they give greater ease in instrumentation in the lower arch in the mouth. It would be wise to utilize the hatchets for your lower preparation in the lab to become familiar with their very slightly different feel.



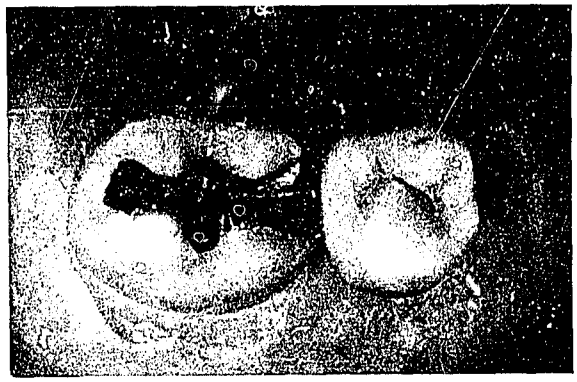
16. At your laboratory position, you should have eliminated all extraneous materials, have your engine set up, and your armamentarium as shown, sharpened and ready to go. You will also have selected and mounted the tooth on which will be operated, and accurately drawn this tooth and its contacting surface on your amalgam grade sheet.



17. It is extremely important to design the various margins of the outline form according to the rules presented and on the completion of so doing, to be able to visualize the entire outline form.



18. The ideal outline for this tooth is as seen here in red. The width of our isthmus is approximately $\frac{1}{4}$ the width of the occlusal table, unless greater width is dictated by caries or fissured grooves or excessive proximal dimensions. The margins must be placed sufficiently far up on their respective cusps to include all caries and fissure grooves and be on smooth, sound enamel surfaces. The buccal margins of the occlusal portion follows the line of the central groove and presents a symmetrical curve into the buccal proximal embrasure. The marginal ridge wall, or dove-tail wall is established parallel to and far enough up on the marginal ridge so it circumscribes all contiguous fissures, grooves and caries. It is normally about $\frac{1}{2}$ the distance from the adjacent pit to the crest of the marginal ridge. The lingual margin of the occlusal portion follows the line of the central groove and meets the proximal surface in a direction parallel to the enamel rods in that area. A reverse curve if it is indicated, generally is used where this margin meets the proximal in lower teeth.



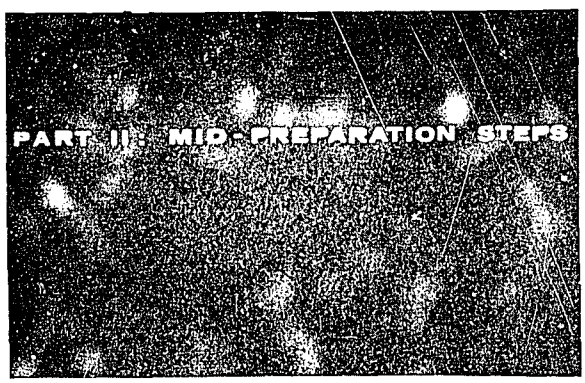
19. The buccal proximal margin is established as a straight line on the tooth surface in the buccal embrasure in a relatively non-carious area without over-extension. It must present uniform accessibility along its entire length, and generally, will form an acute angle with the long axis of the tooth. The gingival termination would be 1 millimeter above the cervical line of our own mounted teeth.

20. The lingual proximal margin is established as a straight line on the tooth surface in the lingual embrasure in a relatively accessible area without over-extension. It must present uniform accessibility along its entire length and its gingival termination will be 1 millimeter above the cervical line. Generally, but not always, this margin will be parallel to the long axis of the tooth.

21. This slide gives us a view of the proximal outline form. We note that the buccal gingival marginal junction customarily forms an acute angle while the lingual wall normally meets the gingival in the long axis of the tooth. This is opposite the maxillary molar. The acute angle when needed on the buccal, is due to the buccal bulk of tooth structure near the gingiva on lower teeth. The gingival margin is again a straight line joining the terminal points of the buccal and lingual proximal margin and located 1 millimeter above the cervical line on our mounted teeth.

22. We are now familiar with the mid-preparation steps which are:

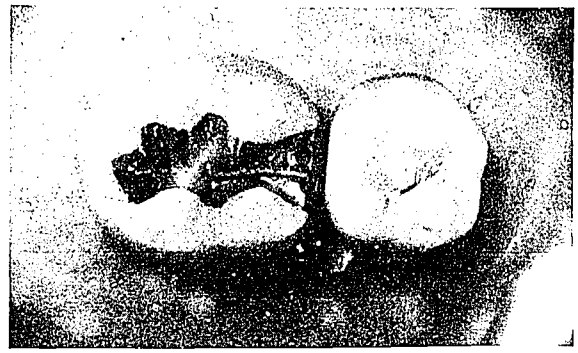
    1. Occlusal cuts
    2. Initial Proximal Cuts
    3. Proximal instrumentation
        a. Finishing the margins
        b. Boxing the preparation
        c. The retentive feature
    4. Cavo-finish stage



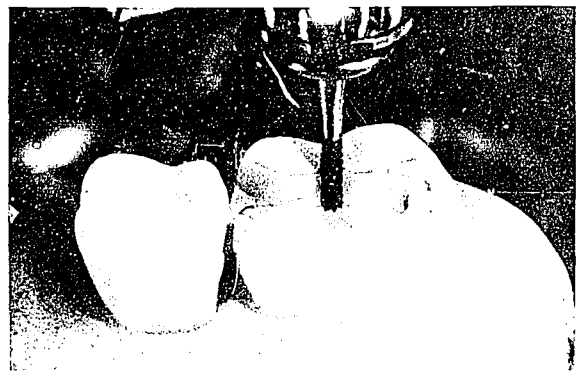
23. The first of the mid-preparation steps, the occlusal cuts, will now be discussed. During the laboratory phase, go now and observe the movie section on the occlusal cuts.

AT THIS POINT, YOU WILL TURN OFF THIS MACHINE, VIEW THE APP - PRIATE 8 MILLIMETER MOVIE, AND RETURN TO YOUR VIDEOSONIC MACHINE TO CONTINUE THE LESSON.

24. Our first penetration into the tooth will be exactly $1\frac{1}{2}$ millimeters, and we will start in one of the occlusal pits; remember, at no time do we increase this original penetration depth while roughing out the occlusal outline for portion of the preparation.



25. Here we see the occlusal cut extended to just barely shy of the marginal limits. The bur in place reminds us that we must pay particular attention to the proper direction of these walls to the pulpal floor. Look carefully at your model as you develop this portion of your preparation.



26. Except for the final cavo-finish and sharpening the internal line angles, this is the occlusal portion of your preparation. We must be sure our line angles are just barely into dentin. Note how excellently this slide shows the difference in appearance of enamel and dentin. It is not always this dramatic. You must learn how to discern enamel from dentin on the basis of color, sheen--the enamel being glassier, and the feel through instrumentation.

APPENDIX B

FRESHMAN OPERATIVE DENTISTRY
ORIENTATION AND AMALGAM RESTORATION INSTRUCTIONS

LECTURE SCHEDULE

FRESHMAN ORIENTATION LECTURES
(given prior to experiment)

1. History and Philosophy of Dentistry.
2. Numbering of teeth.
3. Nomenclature of tooth surfaces.
4. Classification, identification, and uses of dental instruments and burs.
5. Terminology and definition.
6. Lecture on Class I amalgam.

LECTURE #1: "Governing Criteria of the Class II Alloy Preparation." Series of 79 slides; 8mm films.

Definition of a cavity. Basic steps in cavity preparation, factor of cavity design, outline form, retention form, resistance form, convenience form, prevention form, etc.

LABORATORY SCHEDULE

REQUIRED STUDENT FAMILIARIZATION

1. Memorize the terminology and associate it mentally for identification; the walls, internal line angles, and internal point angles of the Class II amalgam cavity preparations. Pgs. 12E and 12F Syllabus.
2. Instrument and bur explanation and classification. Pgs. 39B, 39D, 39E, 39F, 39G, 39H of Syllabus.
3. Mounting of extracted teeth for clinical (laboratory) preparation. (Hand out.)
4. The Basics of Cavity Preparation with Emphasis on Tooth Morphology. (Hand out.)

LABORATORY #1

1. Care and maintenance of engine and handpiece.
2. Basics of Cavity Preparation with Emphasis on Tooth Morphology.
3. Home work: Class I amalgam in lower molar.
   --Drawing on grade sheet and prep required at beginning of next laboratory period for instructor evaluation.
   --Guides to use: Pgs. 40-43 Syllabus.

Typodont tooth model
Notes from Class I lectures given in orientation lecture.

LECTURE #2: "Design Criteria and the Mechanics of Accomplishing the Ideal Class II Alloy Preparation." (Maxillary Molar as tooth operated)

80 slides; 8mm films

Design criteria, guides and visualization mechanics, gross cavity reduction, finalizing the box form, finalizing the occlusal.

LABORATORY #2

1. Submit Class I alloy prep done outside class the previous week.
2. Prepare in laboratory a Class II MO amalgam preparation on maxillary molar, mounted with an adjacent removable bicuspid.
3. Instructor critique of preparation.
4. Thoroughly study Grading Criteria Section for Class II Amalgam, pgs. 81-85 Syllabus. Critically evaluate your preparation and compare to typodont.
5. Prepare Class II amalgam max. molar with adjacent stationary tooth as homework and submit at beginning of next laboratory period.

LECTURE #3: "The Class II Alloy Preparations on a Maxillary Bicuspid."

65 slides; 8mm films

Typical outline form, altered outline because of position in arch, rotation, extent of decay, comparison of similarities and modification max. bi vs. molar.

LABORATORY #3

1. Prepare MO or DO amalgam on maxillary bicuspid, mounted with adjacent stationary tooth.
2. Student to critique own preparation utilizing typodont model and pgs. 81-85 of Syllabus.
3. Instructor critique of preparation.

LECTURE #4: "The Class II Alloy Preparation on Mandibular Bicuspid."

75 slides; 8mm films

Typical outline form of first and sec. bicuspid and variation due to tooth morphology, altered outline because of arch rotation or extent of decay, proximal and occlusal portion relations, importance and cuspal plane, comparison to maxillary bicuspid.

LABORATORY #4

1. Prepare an MO or DO amalgam preparation on lower bicuspid mounted with adjacent stationary tooth.
2. Instructor evaluation and critique.
3. Each student critique constructively another student in same group and compare with instructor's critique provided.

LECTURE #5: "The Class II Alloy Preparation on a Mandibular Molar."

58 slides; 8mm films

Comparison of lower molar and upper molar preps, alteration to develop M.O.D. prep, effect of altered arch position rotation, etc. Comparison with lower bicuspid.

LABORATORY #5

1. Written critiques and preps returned.
2. Amalgam MO or DO preparation on lower molar mounted with adjacent stationary tooth.
3. Instructor critique of work.