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Accuracy of the Indirect Method Evaluated by Mercury Micromeasurement

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School of Graduate Studies

ACCURACY OF THE INDIRECT METHOD EVALUATED BY MERCURY MICROMEASUREMENT

by

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A Thesis In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Dental Materials

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I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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CHAPTER I

PRESENTATION OF THE PROBLEM

Since Weston Price and W. D. Tracy began, about 1912 to use the indirect method for preparation of dental castings, many improvements in materials and technics have been made. The profession has long recognized the many advantages (1) of the indirect method, but only in recent years has this method produced castings the accuracy of which compared favorably with that of those produced from wax patterns formed directly on prepared teeth.

Improvements in the materials peculiar to the indirect method, namely gypsum die products and elastic impression materials, have in recent years been accelerated by the development of precise methods of evaluating their physical properties.

The development of a precise and quantitative method for determining the accuracy with which a casting or wax pattern may be adapted to the die for which it was made was necessary before a valid comparison could be made between the direct and indirect methods.

Doctor G. M. Hollenback presented a paper before the I.A.D.R., in March of 1959, in which he described a method for measuring the adaptation of dental castings by mercury displacement. The method is unique in that it gives a quantitative measurement of the space existing between a casting, or wax pattern and the die.

It was the object of this research project to investigate the accuracy of the indirect method for preparing dental castings by use of this test.

CHAPTER II

REVIEW OF THE LITERATURE

The materials and procedures differentiating the direct and indirect technics, have received considerable attention in recent years. A search of dental literature, however, will show that, while a few attempts have been made to measure the accuracy of castings some of which were made by the indirect method, a paucity of information relative to the accuracy of the indirect method per se exists.

The simplest and most extensively used method of evaluating the adaptation of dental castings in the past has been to try the casting back on the die or prepared tooth and to then determine by visual examination or by use of a sharp explorer whether or not the casting seems to fit (2). In a study made of the effect of water powder ratio on the accuracy of fit of gold castings, in 1956, an attempt was made to decrease the subjectivity of this type of evaluation (3). Castings were presented at random to a group of five examiners who were asked to grade each casting as either a good, doubtful, or bad fit.

Bjorndal and Sahs, in a study of the marginal adaptation of amalgam and gold inlay restorations, used a microphotographic technic (4). It will readily be seen that methods, such as those described above, can at best only given an indication of the marginal adaptation of castings.

Snyder and Shell, (1956) attempted to simplify the measurement of wax pattern and casting accuracy (5). Two tapered invar dies were prepared each being given approximately the same degree of taper. The first compared to a full shoulder crown preparation and the second to a plug preparation. Wax patterns were then prepared for the dies and allowed to reach a constant temperature. The wax patterns were then placed on the dies and again allowed to reach a constant temperature. The patterns were then measured for any possible change in dimensions by a micrometer. Castings were then made and the changes in dimension of the castings were determined by a measurement with a micrometer.

Charbeneau and Peyton, while evaluating some effects of cavity instrumentation on the adaptation of gold castings, seated class I inlays into preparations the walls of which had ten percent tapers (6). A seating force of 125 pounds was used to assure complete seating of the castings after which the teeth were sectioned and examined for adaptation. With full crown castings, they found it necessary to use a force of 400 pounds in order to bring about complete seating as might be determined by use of a sharp explorer.

Suffert and Mahler, at the University of Oregon, in an investigation concerned with the reproducibility of gold castings made by present day dental casting technics, made use of pyramidal indentations from which measurements could be made (2). Two special brass dies were constructed to approximate a one-surface restoration, and a full crown. Indentations were placed on the floor of the mold, which would correspond to the pulpal floor of the cavity preparation, and on the bottom and shoulders of the full crown mold, which would correspond to the pulpal floor and cervical shoulders, respectively, of the cavity preparation. Indentations were made in the die which could be reproduced in the wax pattern and subsequent gold castings. These indentations were made with a steel instrument shaped in the form of a pyramid. Ten measurements were taken of the distance between these pyramids on the wax pattern as well as the gold casting for each experimental run.

Armstrong and Simon (1951) demonstrated that the space between the inlay and the cavity wall could be photographed by use of radio calcium which penetrated the cement (7).

A description of the mercury displacement test was first published in September, 1959 (8). This test, described later in this paper as the Mercury Micromeasurement test (under materials and methods used), apparently offers the only available method, to date, of measuring volumetrically the total space which may exist between a wax pattern or gold casting and the die.

Recently, Sahs and Wick, at the University of Iowa, have completed three phases of research into the accuracy of inlays by use of mercury micromeasurement (9). These included: (1) Standardization of procedures for making wax patterns of cavities prepared in metal dies, (2) testing and the establishment of controls for investing, burnout, and casting procedures, using eleven investment materials, (3) determination by mercury micromeasurement of the amount of space between each casting and the cavity walls. They reported that in measuring the accuracy of the inside fit of cast gold inlays, they tried placing various substances into the space between clinically acceptable inlays and their corresponding dies. The straight displacement method was used. The volume of material was computed from the microweight and specific gravity, which showed the accuracy of fit. Five materials that ran the gamut from high to low surface tension were tried: (1) mineral oil, (2) glycerin, (3) dibutyl phthalate, (4) zinc oxide and eugenol, and (5) mercury. The first three materials required a great deal of care to remove the oil around the margins and on the outside of the casting and die without withdrawing oil from marginal areas. Slow setting zinc oxide and eugenol, it was found, did not flow readily under the inlays. Mercury proved to be very desirable because its high specific gravity made it easy to measure small differences in castings.

CHAPTER III

TEST MATERIALS AND METHODS USED

It was evident early in the study that insufficient data was available in the literature regarding the accuracy and reliability of the mercury micromeasurement test. Accordingly, a typical three surface inlay preparation was carefully cut in a one and one-half dimension ivorine tooth. An upper first molar (Figure 1) was used. Throughout the project this served as the master die. A polished hexagonal aluminum base was prepared for the master die in order to facilitate impression taking and to provide an esthetic mounting for the die. The base, held simply by a single screw, was removed during the mercury displacement test to avoid the possibility of stray mercury attacking the aluminum.

The technic used for mercury micromeasurement as used in this project was as follows: A cornucopia of cellophane or light weight plastic was formed tightly around the die and was retained with a rubber band, dental floss, or by digital pressure, gingivally. A plaster index was constructed so as to cover the entire occlusal surface and upper portion of the proximal surfaces of the wax pattern. Sufficient mercury was then placed in the cornucopia to completely cover the occlusal surface of the master or stone die. The wax pattern was

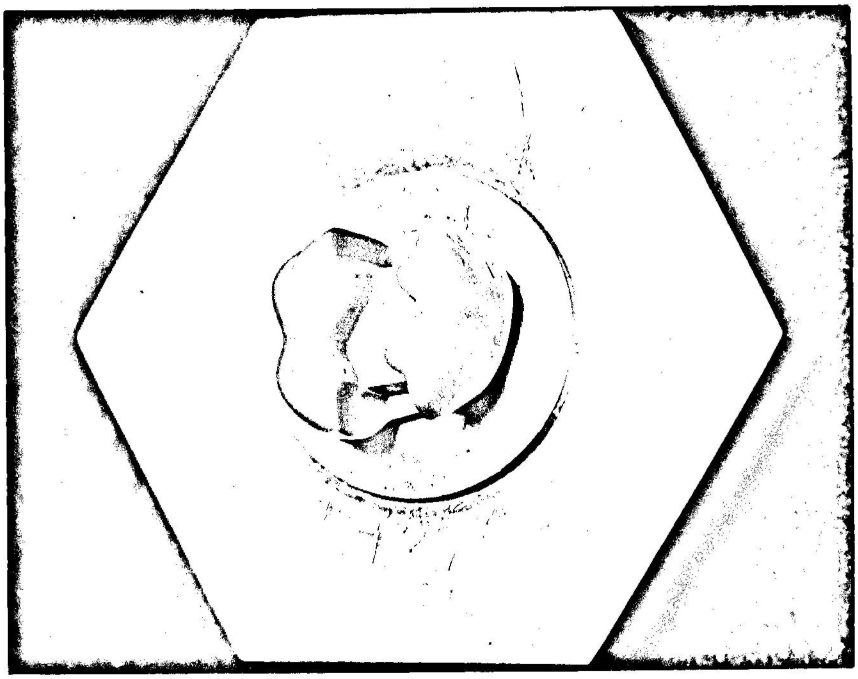

FIGURE 1

THE MASTER DIE

REPRESENTING A TYPICAL THREE-SURFACE INLAY PREPARATION CUT IN A ONE AND ONE-HALF DIMENSION IVORINE TOOTH carefully placed in the cavity and seated by applying evenly distributed force occlusally through the use of the prepared plaster index. Force for this purpose was supplied by a specially constructed lever arm with a sliding weight (Figure 2) calibrated so as to give increments of one-half pound. Two pounds pressure was found to be sufficient to seat wax patterns. The cornucopia and excess mercury was then separated from the tooth, and any remaining globules of mercury adhering to the external surfaces of the die or wax pattern were carefully removed with a fine sable brush. Since the die was essentially immersed in mercury at the time the wax pattern was seated, any space existing between the die and wax pattern, or casting, remained filled with mercury. To recover this entrapped mercury, the pattern was carefully removed over a porcelain dish after which any globules of mercury remaining on the cavity surfaces or wax pattern were brushed off and collected in the dish. It will be appreciated that the amount of mercury recovered will be in direct relationship to the adaptation of the wax pattern. The collected mercury was then weighed on a balance accurate to 0.0002 grams (0.2 mg.). If desired, the micromeasurement thus made could be converted to a volumetric reading through division by the density (13.456) of mercury.

A total of fifty-six wax patterns were formed in an effort to determine an accuracy which could be considered

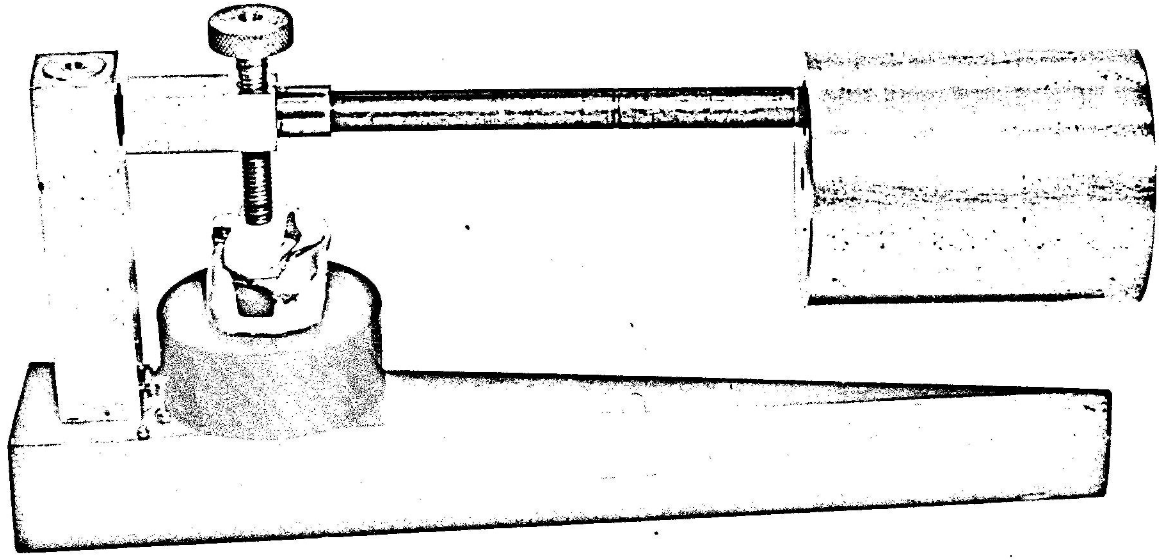

Figure 2

MERCURY MICROMEASUREMENT APPARATUS

THE SIMPLE LEVER-TYPE APPARATUS PERMITS VARYING PRESSURES TO BE PLACED ON A PLASTER INDEX WHICH DISTRIBUTES THE PRESSURE EVENLY TO THE WAX PATTERN AS IT DISPLACES THE MERCURY FROM THE CAVITY to constitute a well adapted pattern. Three technics were tried in the formation of the wax patterns, and the patterns were readapted by two swaging methods. Fifteen of the patterns were constructed using small increments of wax with digital pressure between additions. Another set of fifteen were formed by pressing a matrix filled with softened wax down over the die and maintaining digital pressure until the wax had cooled. The third set of patterns were prepared by first placing a matrix about the tooth then pouring the wax in a single increment, after which digital pressure was maintained until the wax had hardened.

The adaptation of each of the above patterns was measured, using the mercury micromeasurement test, after which they were more closely adapted by use of a swager. They were then reevaluated. The patterns formed by the three technics just described, and listed in TABLE I, Page 18, were all swaged in a water swager. The remaining eleven patterns (TABLE II, Page 19) were formed by the single increment method and swaged in the mouldine swager.

Both swagers (Figure 3, A and B) were designed and constructed by Dr. Hollenback. The water swager is a cyllindrical aluminum flask with a screw type lid which is sealed with rubber "O" rings. A threaded plunger and a pressure gauge are fitted through the lid. This device is sealed to the extent that pressures in excess of one thousand

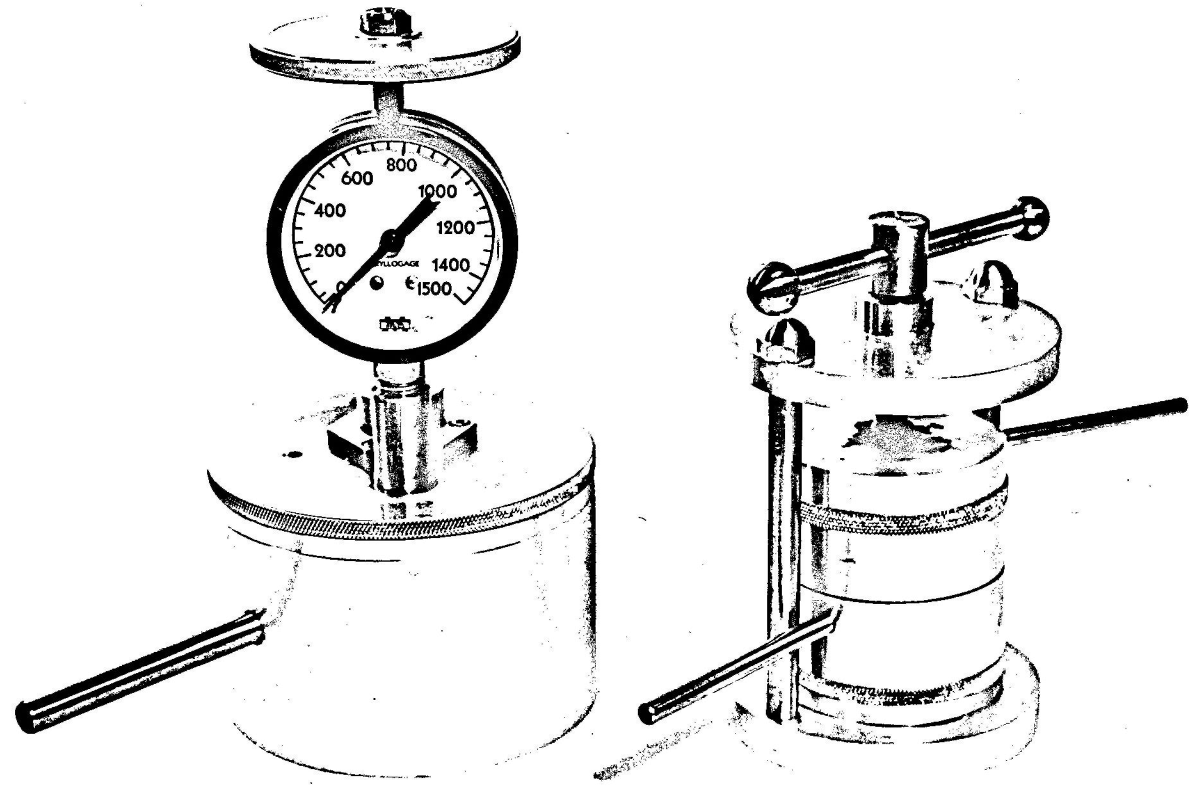

Figure 3

A. WATER SWAGER B. MOULDINE SWAGER

THE WATER SWAGER PERMITS SWAGING OF SEVERAL WAX PATTERNS SIMULTANEOUSLY UNDER CONTROLLED TEMPERATURES AND PRESSURES. THE MOULDINE SWAGER PERMITS RAPID SWAGING OF A SINGLE WAX PATTERN pounds per square inch can be maintained over a prolonged time. A number of trial runs were made swaging at different temperatures and pressures. Since high temperatures and pressures consistantly gave the best adaptation, most of the wax patterns reported were swaged with an initial water temperature of 140° F. and 1000 lbs p.s.i. However, this was not critical. The swager and its contents were allowed to bench cool to within five or ten degrees of room temperature. Before placing them in the water swager the master die with patterns in place was enveloped in mouldine swaging compound to distribute pressures evenly and to form a seal preventing water from getting under the wax patterns. When stone dies were used, especially in the mouldine swager, it was found necessary to surround the die and pattern with thin pollyethylene sheets to prevent forcing of the oil in the swaging compound through the pores of the stone to a position under the wax patterns.

The mouldine swager (Figure 3B) was constructed late in the project. It was felt that cold wax would flow better and more completely under prolonged pressures than under a sudden impact such as is generally used in this type of swager. Accordingly, a press was constructed to apply such a force against the plunger. Eleven wax patterns were swaged in this instrument. Application of separating mediums to the dies was necessary in the use of both types of swagers to facilitate removal of wax patterns following swaging.

An effort was made to determine the distribution of residual mercury between the die and inlays as seen in the micromeasurement test. A three surface preparation similar to the one in the master die was cut in a clear plastic tooth (Figure 4). A wax pattern was formed and adapted to the cavity. Mercury was then displaced from the cavity after which a visual determination of the distribution of mercury could be made. Further comparison of the volume of entrapped mercury with the total surface area covered gave an approximate idea of the average thickness of the film of mercury. A wax pattern was then invested and cast in gold. Similar comparisons were made using the gold casting.

Comparison of the direct and indirect methods was made by measurement of the adaptation of a given pattern and casting on both the master die and a duplicate stone die. Three types of elastic impression materials were used. These included a hydrocolloid, a silicone, and a mercaptan rubber. Brands of materials selected, including the stone die material, were considered to be representative of the more dimensionally accurate materials in common usage today. Results are not necessarily representative of all materials in each classification. Selection was based on the results of a recent extensive study of gypsum die products and elastic impression materials in which the present author participated and which

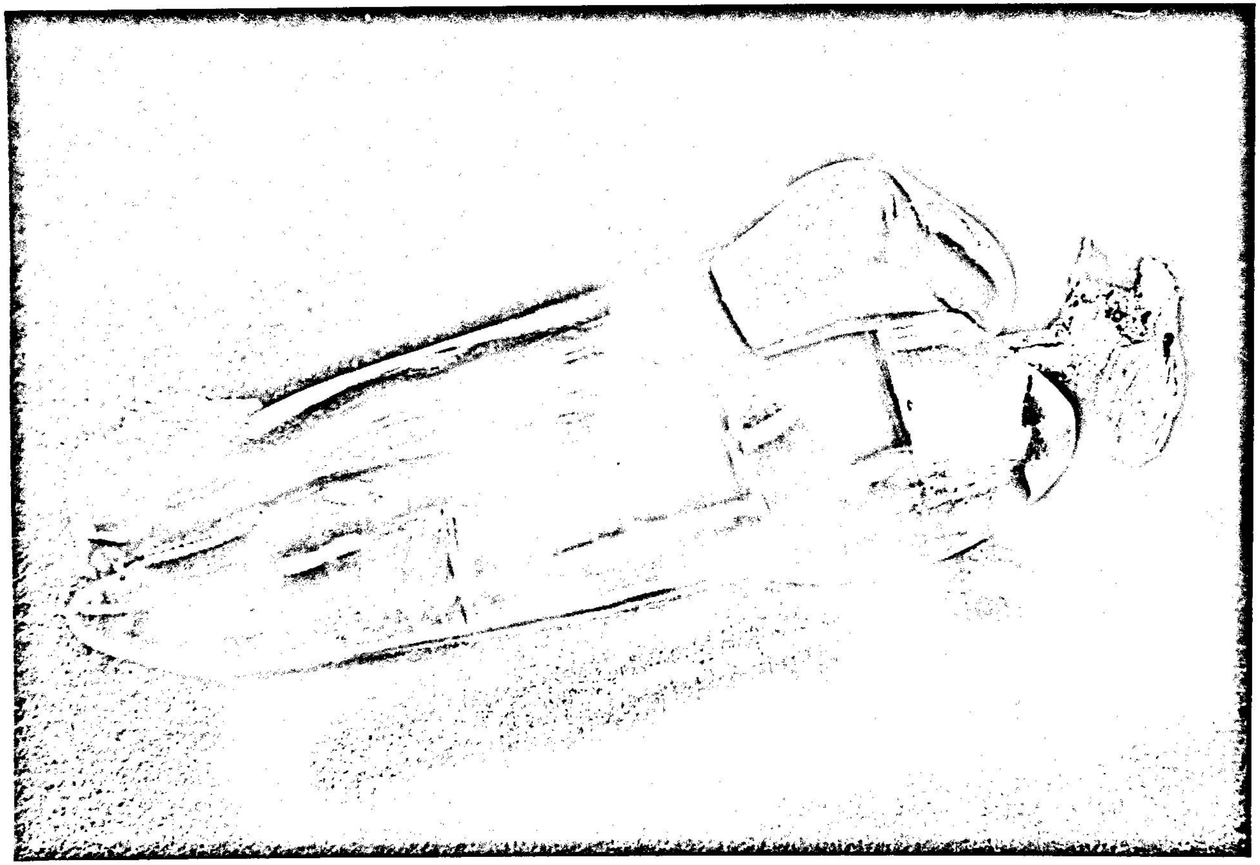

Figure 4

CLEAR PLASTIC TOOTH USED TO VISUALIZE THE DISTRIBUTION OF MERCURY IN MERCURY MICROMEASUREMENT is, as yet, unpublished.

The reliability of the mercury micromeasurement method for determining casting adaptation was determined by making ten consecutive measurements was made using a wax pattern to determine the reliability of the method for wax patterns.

The gold castings were protected from being attacked by mercury simply by oxidizing them. This technic of protecting the gold castings has been checked by comparison of the micro-weight of castings before and after mercury micromeasurement (9).

CHAPTER IV

RESULTS AND OBSERVATIONS

Mercury micromeasurement of the adaptation of wax patterns constructed by the addition of wax in small increments (TABLE I) showed these patterns to have an average of 1.57 cu. mm. of space between them and the master die. Following swaging the same patterns averaged only 0.58 cu. mm. It was noted that patterns formed by this method had the greatest tendency to adhere to the die. Accordingly, unless more separating medium was used, there was a greater tendancy for breakage of the patterns on removal.

The widest range of pattern adaptation was seen in the group formed by forcing wax softened in a matrix down over the die. As may be seen from TABLE I, micromeasurement of this group averaged 23.4 milligrams of mercury, or 1.73 cu. mm., before swaging and 7.7 milligrams, or 0.57 cu. mm., afterward. The line angles in these patterns were not always sharp before swaging, but the internal surfaces of the wax appeared smooth and shiny.

The third group of patterns were prepared by pouring melted wax in a single increment into a matrix surrounding the cavity. As the wax cooled digital pressure was applied both from occlusal and proximal directions until the wax had

TABLE I

Mercury Micromeasurement of Wax Patterns Formed by Three Common Technics Before and After Readaptation in a Wager Swager

Micromeasurement in Milligrams of Mercury

	Small Melted Increments of Wax		Single Melted Increments of Wax		Wax Softened in Matrix	
	Before Swaging	After Swaging	Before Swaging	After Swaging	Before Swaging	After Swaging
	18.5	broken	16.9	8.1	27.3	5.0
	26.8	broken	24.1	broken	16.3	4.9
	19.5	6.9	52.7	11.0	19.6	6.1
	26.0	10.8	17.4	6.0	22.1	6.9
	28.7	9.9	23.8	9.5	24.8	broken
	28.0	15.8	22.2	5.6	13.6	10.8
	21.4	7.7	46.0	14.0	28.7	7.2
	16.0	broken	18.6	broken	14.4	5.8
	21.4	6.0	22.0	6.5	25.4	10.1
	34.4	5.9	23.4	8.1	17.7	5.5
	21.0	9.0	10.1	6.8	24.7	9.9
	24.2	3.1	22.4	6.8	15.6	5.8
	24.1	6.6	31.4	5.0	12.5	5.2
	12.7	5.8	10.3	5.5	13.1	4.7
	14.2	4.1	10.4	7.9	14.2	5.3
MEANS (mg.Hg)	21.2	7.9	23.4	7.7	19.3	6.4
MEANS (cu. mm. space)	1.57	.58	1.73	.57	1.43	.47

cooled. Micromeasurement of this group averaged 19.3 milligrams of mercury, or 1.43 cu. mm. before and 6.4 milligrams, or 0.47 cu. mm., after swaging. Patterns formed in this manner manifested sharp detail and appeared to have well condensed surfaces.

Eleven wax patterns were successfully swaged in the mouldine swager. The average space found under these patterns (TABLE II) was 0.66 cu. mm. When this type of swaging was used a greater tendency for distortion and breakage of the patterns was noted.

It was observed that the adaptation of wax patterns was effected by minute scratches in the walls of the cavity preparation. Difficulty was experienced in removing well adapted patterns and after removal small amounts of wax could be seen filling the scratches.

Since the die was cleaned before each micromeasurement, it was felt that the mercury would also find space in the scratches. Accordingly, the cavity walls were carefully polished. Following this a definite decrease in the amount of separating medium required to remove patterns was noted, and proportionately better adaptation was observed.

The method used to determine the distribution of residual mercury under inlays during mercury micromeasurement was not intended to give quantitatively accurate results. It did, however, serve to demonstrate that a relatively small amount

TABLE II

Mercury Micromeasurement of Wax Patterns* After Swaging in a Mouldine Swager

	mg. Hg.
	7.0
	12.8
	5.8
	5.2
	9.0
	8.1
	6.3
	9.8
	11.8
	10.3
	11.2
MEAN	8.8 mg. mercury (0.66 cu. mm.)

* All wax patterns were formed using the single increment method

of residual mercury may be spread over a large percentage of the surface on the cavity in a very thin film. Thus the average thickness of 1.5 cu. mm. of mercury spread over the entire 425 square millimeters of the cavity surfaces was about 1/300th of a millimeter. Complete coverage of the cavity surfaces was achieved under wax patterns but not under the casting.

In the comparison of the indirect with the direct method (TABLE III) the following results were obtained. The average difference in the amount of mercury entrapped under a wax pattern measured on the master die was 0.8 milligrams (.059 cu. mm. of space). In the same type of comparison using five stone duplicates made from a mercaptan rubber, the average difference was again 0.8 milligrams. Using five stone duplicates made from the hydrocolloid impression material, the average difference was found to be 0.6 milligrams (.045 cu. mm. of space). The total space under the patterns on the master die in the above experiments was 1.12 cu. mm., 0.95 cu. mm., and 1.08 cu. mm. respectively.

The standard error for the reliability of the mercury micromeasurement method (TABLE IV, Page 23), using gold castings, was found to be 0.4 percent, while that for micromeasurement using wax patterns was 0.6 percent.

TABLE III

EVALUATION OF THE INDIRECT METHOD BY MERCURY MICROMEASUREMENT

Materials Evaluated	Average Adaptation of Patterns in Master Die	Average Adaptation of Patterns in Stone Die	MEAN Difference between direct & indirect methods	Number of Experiments
Silicone Impression Material	15.0 mg. mercury	15.7 mg. mercury	0.8 mg. mercury	10
Mercaptan Impression Material	12.8 mg. mercury	13.7 mg. mercury	0.8 mg. mercury	5
Hydrocelloid Impression Material	14.5 mg. mercury	15.1 mg. mercury	0.6 mg. mercury	5

TABLE IV

RELIABILITY OF THE MERCURY MICROMEASUREMENT METHOD

	CASTING	WAX PATTERN
Number of Experimental Runs	10	10
MEAN Micromeasurement	36.9 mg. Hg.	15.7 mg. Hg.
Standard Deviation	± 0.4 mg. Hg. (1.08%)	± 0.3 mg. Hg. (1.9%)
Standard Error	0.4%	0.6%

CHAPTER V

DISCUSSION AND CONCLUSIONS

The adaptation of wax patterns by swaging under high temperatures and pressures, it was felt, should have given perfect adaptations. The fact that this was never achieved during the project was probably due to several factors. Removal of patterns after swaging without breakage or distortion was impossible unless a separating medium was used. Separating mediums took up space which was later filled with mercury. Although several types of lubricants were tried and some were found to function better in smaller amounts than others, no exhaustive attempt was made to find an ideal lubricant. There is a possibility that air may be entrapped under patterns in the swaging process. The effect of its initial compression and subsequent expansion when swaging pressures are released was not determined.

Results from the study of the three technics for forming wax patterns indicate that no one method gave significantly better adaptation than did the others.

A more complete study of the distribution of mercury under castings might well add to our present knowledge of the effect that variables in the casting process have on distortion of molds and subsequent castings.

The results of the comparison between the direct and indirect methods indicate that under ideal conditions the indirect method is very accurate. This can be graphically illustrated by the fact that the difference of eight-tenths milligrams, found in two of the materials used, represents the space occupied by a sphere of mercury the diameter of which is slightly less than that of the period at the end of this sentence.

We believe mercury micromeasurement to be a valid method for evaluating the total adaptation of wax patterns and gold castings. As such it should prove to be a useful tool in future investigations of many dental materials and technics.

CHAPTER VI

SUMMARY OF FINDINGS

1. No significant difference was found in the adaptation of wax patterns formed by three commonly used technics.
2. The volume of the space between a die and a well adapted wax pattern should be less than two cubic millimeters before swaging and less than one cubic millimeter after swaging, when the technics used in this study are followed.
3. Roughness of cavity walls adversely effects the adaptation of wax patterns.
4. The accuracy of the indirect method for preparing dental castings was found to be very good under controlled conditions.

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An Abstract of a Thesis
in Partial Fulfillment of the Requirements
for the Degree Master of Science
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Although the indirect method for preparing dental castings has been in use for over forty-five years, very little information has appeared in dental literature relative to its accuracy. The development of a precise and quantitative method for determining the adaptation of wax patterns or castings was necessary before such an evaluation could be considered valid. It was felt the Mercury Micromeasurement test, devised in 1958 by Hollenback, should meet these requirements. A description of the test had been published. However, at the time the project was begun, no data had appeared in the literature.

In order to establish a standard for accuracy of wax pattern adaptation, a total of fifty-six wax patterns were formed for a master die using three different waxing technics. The tooth used as a master die was a one and one-half dimension, ivorine, maxillary first molar with a typical M.O.D. preparation cut in it. After mercury micromeasurement the wax patterns were readapted by use of two types of swagers and reevaluated.

A three-surface preparation similar to the one in the master die was cut in a clear plastic tooth in order to visually ascertain the approximate distribution of mercury left under seated wax patterns and castings.

The accuracy of the indirect method was determined by comparison of the adaptation of given wax patterns in

The following is a brief summary of the more significant findings of this study:

1. No clinically significant difference was found in the adaptation of wax patterns formed by three commonly used technics.
2. The volume of the space between a die and a well adapted wax pattern should be less than two cubic millimeters before swaging and less than one cubic millimeter after swaging, when the technics used in this study are followed. Measurements on normal sized teeth, it will be recognized, should be less than two-thirds of the amounts found in these measurements.
3. Roughness of cavity walls adversely effects the adaptation of wax patterns.
4. The accuracy of the indirect method for preparing dental castings was found to be very good under controlled conditions.