

**THE EFFECT OF EQUILBRATING MOUNTED DENTAL STONE CASTS IN
MAXIMUM INTERCUSPATION ON THE OCCLUSAL HARMONY OF AN
INDIRECT RESTORATION**

A Thesis

by

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ABSTRACT

The purpose of this study was to determine if equilibration of dental stone casts mounted in maximum intercuspation can improve occlusal harmony of a cast gold restoration. A dentoform mounted on an articulator with crown preparation on tooth #19 served as the simulated patient. Dental stone cast replicas were hand articulated in maximum intercuspation, mounted, and allocated for either equilibration or no equilibration. A crown was fabricated and adjusted on each cast set and returned to the dentoform. Vinylpolysiloxane interocclusal records were made and scanned for optical density with contact areas quantified as actual contact and near contact. Non-parametric tests were used to compare near and actual contact areas.

Results of this study showed crowns fabricated from non-equilibrated casts had less near and actual occlusal contact than crowns from equilibrated casts ($p < 0.001$). Crowns fabricated from equilibrated casts were nearer to that of the simulated patient. It is concluded from this study that cast equilibration improves occlusal harmony of an indirect restoration fabricated on casts mounted in maximum intercuspation.

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CHAPTER I

INTRODUCTION AND LITERARY REVIEW

The successful fabrication of an indirect dental restoration relies on the step-wise management of procedural and material inaccuracies. The selection and handling of materials used to produce dental stone casts have been identified as sources of distortion when replicating oral structures. It has been suggested that accurate articulation of definitive dental stone casts in maximal intercuspation (MI) is not possible due to stone expansion [1], and therefore, indirect restorations fabricated on these casts will frequently require occlusal adjustment at delivery. If these problems are not addressed in the laboratory phase prior to delivery, the need for chairside adjustment will result in increased chairtime and a potential change in occlusal morphology.

In a recent in vitro study by Meng et al [1], a cast equilibration technique was investigated as a way to improve the occlusal harmony of a cast crown upon delivery and thus minimize the need for clinical adjustment. The technique for mounting and adjusting definitive casts was based on the premise that distortion from stone expansion precludes the accurate intercuspation of casts, creating both an increased vertical dimension as well as an “artifact CO-MI discrepancy.” In their study, occlusal contacts on the casts were adjusted using the original vertical dimension of casts in MI as an endpoint to equilibration. By measuring areas of actual contact (AC) and near contact (NC) on the dentiform, occlusal harmony was quantitatively compared between crowns

made on equilibrated definitive casts versus crowns made on unequilibrated definitive casts [1].

MI is defined as the complete intercuspation of the opposing teeth independent of condylar position [2] MI has been advocated as both a treatment position and mounting position for dental casts [3-5]. Some clinicians recommend treating a patient in CR almost exclusively, making appropriate occlusal modifications in the patient such that MI will coincide with CO [6]. While CR is often regarded as a physiologic, optimal condylar position from which a new occlusal scheme may be developed, an MI occlusion may also be physiologic and well-tolerated despite a non-centric condylar position.[3] When $MI \neq CO$, a conformational approach, using MI as the treatment position, has been advocated so long as certain clinical criteria for functional stability are met [3-5, 7]. Parker has outlined this criteria clearly: 1) The jaw manipulates easily into CO, is comfortable neurologically, and is free of muscle engrams. 2) MI lies within 0.5 mm of CO 3) Temporomandibular joints and elevator muscles are asymptomatic and unrestricted. 4) There is no evidence of primary occlusal trauma, including mobility, fremitus, vertical bone defects, or excessive occlusal wear [3]. These criteria may aid in determining whether a patient's existing MI position is physiologically acceptable and whether it can be an appropriate treatment position.

Both MI and CR are considered repeatable positions. In MI, deflective tooth contacts serve as tactile references to reproduce the position [3, 4]. Some of these contacts may provide primary guidance from CO to MI, or may serve as guidance in

lateral excursions [4]. So long as these tactile references are preserved throughout the restorative procedure, MI may be an appropriate treatment position [3, 4, 7].

Several authors have described an acceptable physiologic range for an MI/CO discrepancy. Ramfjord found 0.3 to 0.5 forward of CO to be physiologic [8]. Celenza, using the RUM definition of CR, found MI to be 0.02 to 0.36 mm forward of CO [9]. Parker recommends a maximum MI/CO discrepancy of 0.5 mm forward as a criterion for approving MI as a treatment position [3]. It is also important to note that the definition of CR has not been a consistent from study to study.

Dimensional inaccuracy of stone dental casts will affect the ability to accurately relate them together; therefore, it is of value to explore each aspect of the fabrication process as it relates to introducing dimensional error.

Accurate impressioning is a critical aspect to generating accurate dental casts. Vinylpolysiloxane (VPS) is a popular and highly regarded impression material. It is noted for its ease of use, dimensional accuracy and stability, detail reproduction, and relative tear resistance [10, 11]. Pouring of VPS impressions can be done immediately since there is no byproduct of the polymerization reaction [10]. When used in an automatic mixing gun, a proper base to catalyst ratio and adequate mixing can be assured with minimal inclusion of air bubbles or outside contaminants [10].

The use of a custom tray has also shown to improve impression accuracy [12-14]. This may be due to its ability to withstand potential distortion upon seating and removal [13, 15, 16]. Also, a custom tray allows for a uniform thickness of impression material and minimizes inaccuracy associated with an excess bulk of material [17].

The use of gypsum-based material is a major source of inaccuracy in fabricating dental casts [18-21]. Gypsum-based material displays linear expansion between 0.06% and 0.5% [22]. Classification of these materials is based on The American Dental Association's Specification No. 25 [23]. It indicates that measurements be made two hours from initial time of mixing [23]. It has been shown, however, that ADA type IV and V dental stones continue to expand for 72-120 hours [19]. Additionally, expansion of various dental stones within a similar classification are known to vary significantly [24].

The method by which opposing casts are articulated may impact the accuracy of the occlusal relationship [20, 21, 25-28]. Past studies have addressed various materials and techniques, including the use of an interocclusal record interposed between two casts [5, 20, 21, 25-31]. Common record materials used include plaster, wax, acrylic resin, ZOE, polyether, and rigid VPS. Some concerns regarding the use an interocclusal record include capturing detail or dimension in the record too accurately to properly accommodate a less accurate stone casts [20, 21, 26, 30, 31] and potential compressibility of the recording medium [27, 30]

Steele et al. described assessing the ease by which unmounted casts may be articulated by hand, and favors not using an interocclusal record so long as the casts demonstrate adequate occlusal stability [5]. Wall and Peregrina have shown that in an otherwise occlusally stable patient, hand articulation with no bite registration is the most accurate way to relate one cast with another [30, 31]. Use of a stabilization device

adhered to the casts when mounting has also been shown to improve accuracy of the final occlusal relationship [32].

The proven effectiveness of the dual-arch impression technique lends some credence to the concept of an accurate MI mounting, even with an interocclusal record. The key, however, is that the interocclusal record is not only similar to the casts, but *is* the impression that produces the casts [33-35].

The use of occlusal adjustment techniques to mounted casts has been discussed in the literature as means to compensate for inherent material and procedural inaccuracies. Davies et al. termed the cast adjustment procedures as “model grooming,” with the intention of making the casts’ occlusal contacts better reflect those found in the patients’s mouth [4]. Davis applies the practice into the use of casts produced on dual-arch impressions by adjusting posterior occlusal contacts on definitive casts until the most anterior teeth known to contact in the mouth contact on the casts. A casting could thus be fabricated at the proper vertical dimension [33]. Boyarsky and colleagues found that definitive cast occlusal adjustment procedures performed by laboratory technicians after mounting significantly decreased the adjustment time of single posterior full coverage restorations at delivery by student clinicians when compared to restorations fabricated on unadjusted definitive casts [36]. The problem of supraocclusion of an indirect restoration due to cast inaccuracy is common, and the practice of cast adjustment appears to offer an effective solution.

Evaluating the efficacy of cast equilibration requires an objective way to assess occlusal harmony. A method of measuring areas of actual and near occlusal contact has

been used in prior studies to quantify occlusion [1, 37-40], both to compare the effect of occlusal alterations [1, 37] as well as relating it to masticatory function [38, 39]. This method employs a rigid VPS material to record the occlusal relationship via a bite registration, an optical scanner to record light transmission through varying thicknesses of the bite registration, and imaging software to quantify these thickness areas by correlation to a grayscale (ranging from 1 to 256). A detectable range of 50 to 300 μm was reported, therefore, a convention of “actual contact” area and “near contact” area was also established. Actual contact was defined as areas of record thickness ranging from 0 to 50 μm , and near contact was defined as areas of record thickness from 50 to 300 μm [1, 37-39]. Using the described technique, it is possible to quantitatively compare an altered occlusion to a norm, thus evaluating occlusal harmony.

Meng et al. [1] demonstrated that definitive casts mounted in CR can be effectively equilibrated to improve occlusal harmony of an indirect restoration. While the results of their study indeed demonstrated an improvement in occlusal harmony for crowns fabricated using this technique, clinical application may be limited. The technique used in their study requires a patient with coincident MI-CO. Additionally, clinical time and skill would be required to make an accurate centric record. The comment is made that stone expansion will likely make mounting of casts in the MI position problematic and more difficult to adjust [1]. However, it remains to be seen if a cast equilibration procedure may overcome this mounting error to produce an indirect restoration with minimal occlusal inaccuracy. The purpose of this in vitro study was to quantitatively compare the occlusal contacts in a simulated patient after insertion of a

single molar crown fabricated from adjusted and unadjusted derived definitive casts mounted in maximal intercuspation. The null hypothesis is that there would be no differences in the occlusal contacts between crowns fabricated on adjusted and unadjusted casts.

CHAPTER 2

**THE EFFECT OF EQUILIBRATING DENTAL STONE CASTS MOUNTED IN
MAXIMUM INTERCUSPATION ON THE OCCLUSAL HARMONY OF AN
INDIRECT RESTORATION**

OVERVIEW

Distortion from stone expansion makes accurate mounting of definitive casts in maximum intercuspation (MI) difficult and leads to hyperocclusion of indirect dental restorations. The purpose of this in vitro study was to quantitatively compare the occlusal contacts in a simulated patient after insertion of a single molar crown fabricated from adjusted and unadjusted derived definitive casts mounted in maximal intercuspation.

A dentoform mounted on an articulator served as the standardized patient for this in vitro study. Eighteen cast pairs were made with type V dental stone and mounted in MI on a highly adjustable articulator. Cast sets were randomly allocated for adjustment (experimental group) and no adjustment (control group). Crowns were fabricated on each cast set and delivered to the standardized patient. The occlusion was quantitatively analyzed using vinylpolysiloxane interocclusal records scanned for optical densities at areas of actual contact (AC) and near contact (NC). Measured areas of actual and near contact represented the resulting occlusion upon crown insertion. Data was analyzed with non-parametric tests. Occlusal harmony was compared relative to areas of actual

contact and near contact resulting from crowns of the control group, crowns of the experimental group, and the simulated patient with no crown inserted.

Results demonstrated that crowns made on unadjusted casts yielded an occlusion with significantly less AC and NC than both the non-adjusted group and the simulated patient with no crown group ($p < 0.001$). Crowns made on adjusted casts yielded NC and AC less than the simulated patient ($p = 0.011$, $p < 0.005$, respectively).

From this study it is concluded that occlusal harmony may be improved for a cast crown by using a cast equilibration procedure in the laboratory phase of fabrication. The clinical implication is that definitive casts may be mounted in MI, but will require occlusal adjustment in the laboratory phase to minimize chairside adjustment of an indirect crown upon insertion.

INTRODUCTION

The successful fabrication of an indirect dental restoration relies on the step-wise management of procedural and material inaccuracies. The selection and handling of materials used to produce dental stone casts have been identified as sources of distortion when replicating oral structures. It has been suggested that accurate articulation of definitive dental stone casts in maximal intercuspation (MI) is not possible due to stone expansion [1], and therefore, indirect restorations fabricated on these casts frequently require occlusal adjustment at delivery. If these problems are not addressed in the laboratory phase prior to delivery, the need for chairside adjustment will result in increased chairtime and a potential change in occlusal morphology.

In a recent in vitro study by Meng et al, a cast equilibration technique was investigated as a way to improve the occlusal harmony of a cast crown upon delivery and thus minimize the need for clinical adjustment. The technique for mounting and adjusting definitive casts was based on the premise that distortion from stone expansion precludes the accurate intercuspation of casts, creating both an increased vertical dimension as well as an “artifact CO-MI discrepancy.” In their study, occlusal contacts on the casts were adjusted using the original vertical dimension of casts in MI as an endpoint to equilibration. By measuring areas of actual contact (AC) and near contact (NC) on the dentiform, occlusal harmony was quantitatively compared between crowns made on equilibrated definitive casts versus crowns made on unequilibrated definitive casts[1].

Maximal intercuspation (MI) is defined as the complete intercuspation of the opposing teeth independent of condylar position [2]. MI has been advocated as both a treatment position and a mounting position for dental casts [3-5]. Some clinicians recommend treating a patient in CR almost exclusively, making appropriate occlusal modifications in the patient such that MI and centric occlusion will coincide [6]. While CR is often regarded as a physiologic, optimal condylar position from which a new occlusal scheme may be developed, an MI occlusion may also be physiologic and well-tolerated despite a non-centric condylar position[3].. When $MI \neq CO$, a conformative approach, using MI as the treatment position, has been advocated so long as certain clinical criteria for functional stability are met [3-5, 7]. Parker has outlined this criteria clearly: 1) The jaw manipulates easily into CO, is comfortable neurologically, and is free

of muscle engrams. 2) MI lies within 0.5 mm of CO 3) Temporomandibular joints and elevator muscles are asymptomatic and unrestricted 4) There is no evidence of primary occlusal trauma, including mobility, fremitus, vertical bone defects, or excessive occlusal wear [3]. These criteria may aid in determining whether a patient's existing MI position is physiologically acceptable and whether it can be an appropriate treatment position.

Both MI and CR are considered repeatable positions. In MI, deflective contacts serve as tactile references to reproduce the position [3, 4]. . Some of these contacts may provide primary guidance from CO to MI, or may serve as guidance in lateral excursions [4]. So long as these tactile references are preserved throughout the restorative procedure, MI may be an appropriate treatment position [3, 4, 7].

While Meng's [1] results indeed demonstrate an improvement in occlusal harmony for crowns fabricated using this technique, the clinical application of his method may be limited. The technique used in the study requires a centric mounting of casts and a patient with coincident MI-CO. Additionally, clinical time and skill would be required to make an accurate centric record. He also comments that stone expansion will likely preclude the ability to articulate the casts in maximal intercuspal position [1]. However, it remains to be seen if a cast equilibration procedure may overcome this mounting error to produce an indirect restoration with minimal occlusal inaccuracy.

Dimensional inaccuracy of stone dental casts may affect the ability to accurately relate them together. These factors have been studied extensively, including selection of impressioning material, use of custom trays, and full-arch vs quadrant style trays.

The use of gypsum-based material is a major source of inaccuracy in fabricating dental casts [18-21]. Gypsum-based material displays linear expansion between 0.06% and 0.5% [22]. Classification of these materials is based on The American Dental Association's Specification No. 25 [23]. It indicates that measurements be made two hours from initial time of mixing [23]. It has been shown, however, that ADA type IV and V dental stones continue to expand for 72-120 hours [19]. Additionally, expansion of various dental stones within a similar classification are known to vary significantly [24].

The use of occlusal adjustment techniques to mounted casts has been discussed in the literature as means to compensate for inherent material and procedural inaccuracies. Davies et al. termed the cast adjustment procedures as "model grooming," with the intention of making the casts' occlusal contacts better reflect those found in the patients's mouth [4]. Davis applies the practice to dental casts produced on dual-arch impressions. By adjusting posterior occlusal contacts on definitive casts until the most anterior teeth known to contact in the mouth contact on the casts, an indirect restoration could thus be fabricated at the proper vertical dimension [4]. Boyarsky and colleagues found that definitive cast occlusal adjustment procedures performed by laboratory technicians after dental casts were mounted in MI significantly decreased the adjustment time of single posterior full coverage restorations at delivery by student clinicians when compared to restorations fabricated on unadjusted definitive casts [36]. The problem of supraocclusion of an indirect restoration due to cast inaccuracy is common, and the practice of cast adjustment appears to offer an effective solution.

Evaluating the efficacy of cast equilibration requires an objective way to assess occlusal harmony. A method of measuring areas of actual and near occlusal contact has been used in prior studies to quantify occlusion [1, 37-40], both to compare the effect of occlusal alterations [1, 37] as well as relating it to masticatory function [38, 39]. This method employs a rigid VPS material to record the occlusal relationship via a bite registration, an optical scanner to record light transmission through varying thicknesses of the bite registration, and imaging software to quantify these thickness areas by correlation to a grayscale (ranging from 1 to 256). A detectable range of 50 to 300 μm was reported, therefore, a convention of “actual contact” area and “near contact” area was also established. Actual contact was defined as areas of record thickness ranging from 0 to 50 μm , and near contact was defined as areas of record thickness from 50 to 300 μm [1, 37-39]. Using the described technique, it is possible to quantitatively compare an altered occlusion to a norm, thus evaluating occlusal harmony.

In the study by Meng et al. [1], occlusal harmony was compared upon insertion of test crowns, control crowns, and no crown to the simulated patient. His method of cast equilibration yielded crowns with actual contact and near contact significantly closer to that of the simulated patient compared to crowns fabricated on unequilibrated definitive casts.

The purpose of this study is to show that definitive casts can be mounted in MI and equilibrated to produce an occlusally harmonious crown. This would not only reduce chairtime and preserve occlusal anatomy of the restoration, but also allow a simpler

mounting protocol to be used. The null hypothesis is that there will be no difference between indirect restorations made from equilibrated casts versus non-equilibrated casts.

MATERIAL AND METHODS

This study used a dentoform as a simulated patient (M-1560; Columbia Dentoform Corp, New York, NY). The maxillary dentoform was arbitrarily mounted on a semi-adjustable dental articulator (SAM 3; SAM Prazionstechnik GmbH, Munich, Germany) The mandibular dentoform was hand-articulated and mounted in MI and equilibrated to optimize occlusal contacts according to the protocol established by Meng et al [1]. The mandibular left first molar had been prepared for a complete coverage cast gold crown (Figure 1).

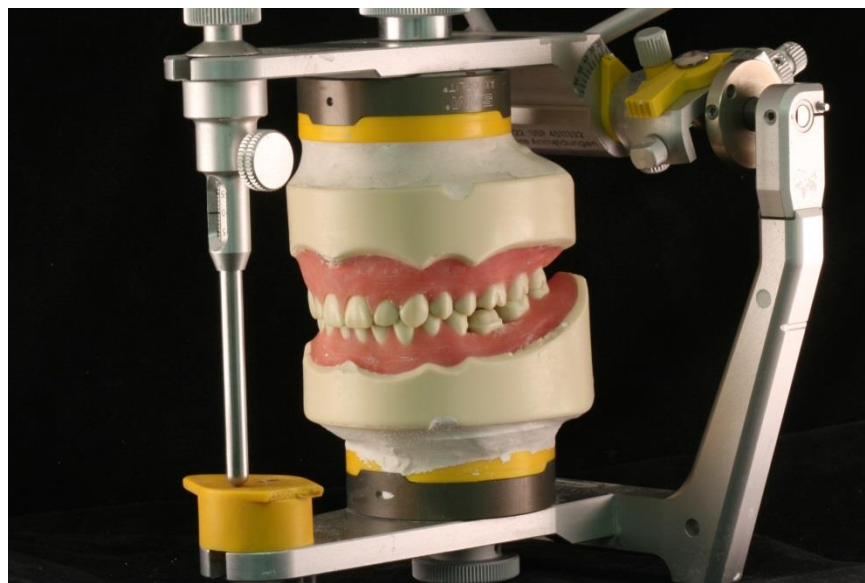


FIGURE 1. Simulated Patient. The simulated patient (SP) with prepared tooth #19.

18 maxillary and 18 die-indexed mandibular dental stone casts were generated according to the impression protocol by Meng et al. [1]. VPS impression material (Aquasil Ultra XLV and Aquasil Ultra Rigid; Dentsply Caulk, Milford, Del) was used for impressions and poured with a high-expansion type V stone (Die-Keen, Modern Materials; Heraeus Kulzer, Inc., South Bend, Ind. Maxillary and mandibular casts were randomly paired, and pairs were randomized and labeled 1 through 18.

Maxillary casts were mounted according to the mounting protocol by Meng et al. Each mandibular cast was hand articulated with its maxillary cast as deemed tactilely and visually satisfactory. Casts were stabilized with four pieces of wooden tongue blade and sticky wax (Sticky Wax; Kerr Corp., Orange, CA). The mandibular casts were then fixed to mounting plates (Axiosplit; SAM Prazisionstechnik GmbH) with mounting stone (Mounting Stone; Whip Mix Corp., Louisville, KY).

Cast pairs 1 through 9 were designated as the control group. Pairs 10 through 18 were designated as the experimental group. In the experimental group, occlusal adjustments were made with a hand instrument and articulating paper (Accufilm II; Parkell, Inc., Edgewood, NY). Equilibration was performed on the entire arch until all four posterior pairs of teeth on the left side matched the degree of “clinical contact” found on the simulated patient. Clinical contact was determined as the holding of 0.0005-inch shim stock (Shim Stock, Artus Corp., Englewood, NJ) between occluding teeth when the dentofrom or casts were passively occluded together on the articulator.

The crown preparation dies were sectioned from each of the pin indexed casts. The dies were trimmed, and a full contour wax pattern (Geo Wax; Renfert GmbH,

Hilsingen, Germany) was fabricated on each die. The wax patterns were sprued, invested (Cristobalite; Whipmix Corp., Louisville, KY), and cast in type IV dental alloy (Ney-Oro 60; DentsplyCeramco, Burlington, NJ) using the lost-wax technique. Each crown was fit to its die and adjusted on its respective casts to hold shim stock with intensity equal to that of adjacent teeth.

Each crown was delivered to the simulated patient. The crown was checked for complete seating visually with optical magnification and tactilely with an explorer. The crown was stabilized against proximal surfaces of the adjacent teeth with sticky wax (Sticky Wax; Kerr Corp., Louisville, KY) to prevent any slight rotation or dislodgement of the crown upon verification of occlusion (Figure 2).



FIGURE 2. Crown specimen inserted in SP, affixed with wax.

Each crown was subjectively evaluated as to whether or not it held shimstock upon closure. Next, the articulator was closed, and the incisal pin was dropped passively and set to the given vertical dimension. Bilateral VPS (Blu-Mousse; Parkell, Inc., Edgewood, NY) posterior interocclusal records were made with each crown in place. A weight of 1.35 kg was used to close the articulator with consistent force. Interocclusal records of the simulated patient with control crowns (from non-adjusted casts) inserted was designated as group SP_{con}. Interocclusal records of the simulated patient with experimental crowns (from adjusted casts) inserted was designated SP_{exp}. Nine additional interocclusal records were made of the simulated patient with no crown inserted. This group of interocclusal records was designated SP_{no}.

The periphery of each interocclusal record was trimmed to a thickness of 4±0.2 mm and scanned on a double-sided flatbed scanner (Expression 1680; Epson America, Long Beach, Calif.) according to the scanning protocol by Meng et al. [1] Computer software (ImageTool 3.0; University of Texas at San Antonio, San Antonio, Tex) was used to perform an optical density analysis of the transmitted light through perforations and near perforations of the bite registration material (Figure 3). Areas included were first premolars through third molars, excluding the area of the left mandibular first molar crown preparation (Figure 4).

The following equation relates thickness of Blu-Mousse to light transmission and was derived using the work of Meng et al [1]:

$$\text{Thickness} = 0.01470 + 0.0005474(\text{GS}) + 0.000002090(\text{GS})^2$$

This regression equation was generated from data which correlates the thickness of Blu-Mousse on a step wedge to the associated grayscale value (GS) when scanned on the above-mentioned scanner (see Figure 5). From this equation, areas of specific thickness could be defined as actual contact (AC) and near contact (NC). AC was defined as areas of thickness $\leq 50 \mu\text{m}$. AC was defined as areas of thickness between $50 \mu\text{m}$ and $250 \mu\text{m}$. Pixel densities for each record were quantified for AC and NC in mm^2 .

Group comparisons of AC and NC for each of the SP_{con} , SP_{exp} , and SP_{no} groups were performed using Krusal-Wallis ANOVA ($\alpha=0.05$). Mann-Whitney U tests ($\alpha=0.05$) were used for paired group comparison.

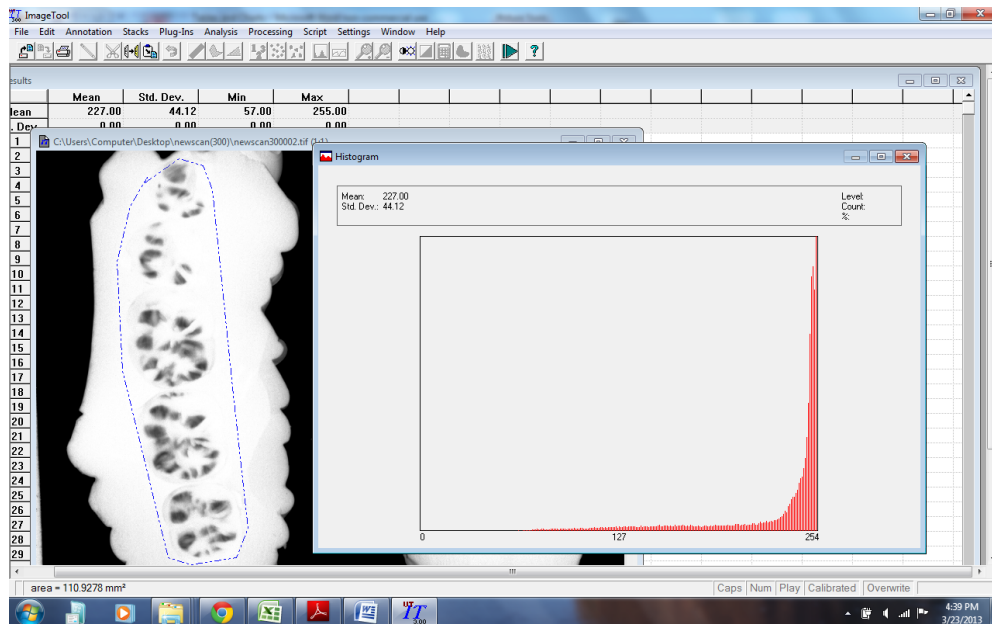


FIGURE 3. ImageTool software interface with histogram. ImageTool software interface showing area outlined on occlusal registration scan for analysis. The histogram contains optical density measurements on a 1-255 grayscale.

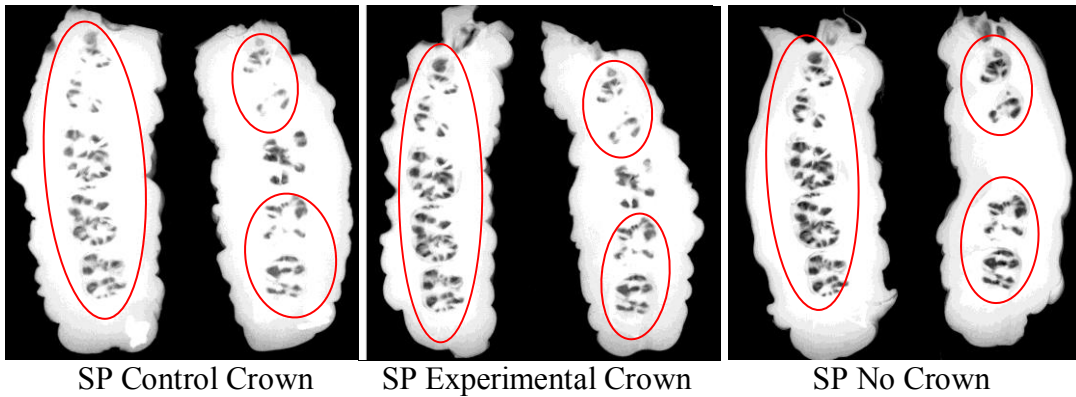


FIGURE 4. Sample specimen scans from each group. Red ovals comprise area of analysis for each specimen. Analysis excluded the occlusal area associated with the crown on tooth #19.

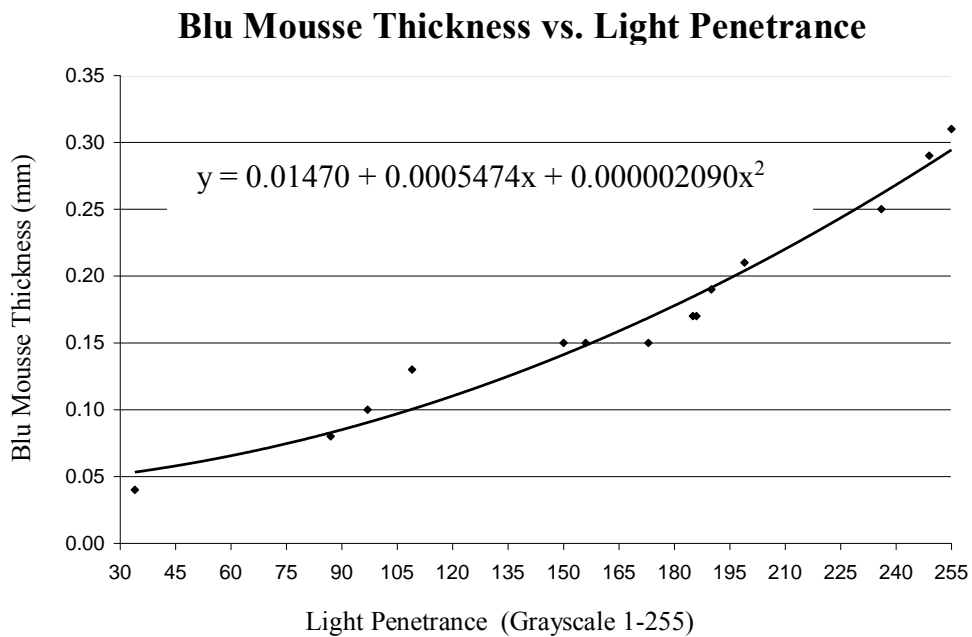


FIGURE 5. Blu mousse thickness vs. light penetrance. A regression curve from a calibration step wedge describes the relationship between thickness of Blu Mousse and light transmission (see Appendix).

RESULTS

AC values for SP_{con}, SP_{exp}, and SP_{no} were $0.45 \pm 0.43 \text{ mm}^2$, $7.43 \pm 1.64 \text{ mm}^2$, and $10.67 \pm 1.64 \text{ mm}^2$, respectively. AC for SP_{exp} was significantly greater than SP_{con}, but was significantly less than SP_{no} (Tables 1 and 2, Figure 6).

NC values for SP_{con}, SP_{exp}, and SP_{no} were $192.7 \pm 24.1 \text{ mm}^2$, $273.9 \pm 7.4 \text{ mm}^2$, and $286.7 \pm 8.3 \text{ mm}^2$, respectively. NC for SP_{exp} was significantly greater than SP_{con}, but was significantly less than SP_{no} (Tables 1 and 2, Figure 7).

When inserted in the SP, all crowns from both control and experimental groups held shimstock upon occluding.

TABLE 1. Descriptive group statistics. Descriptive statistical analysis for each group of interocclusal registrations.

	Descriptive Statistics					
	SPcon (mm ²)		SPexp (mm ²)		SPno (mm ²)	
	Mean	SD	Mean	SD	Mean	SD
Actual Contact (AC)	0.45	0.43	7.43	1.64	10.67	1.78
Near Contact (NC)	192.7	24.1	273.9	7.4	286.7	8.3

TABLE 2. Comparative group statistics. Comparative group statistical analysis performed with Kruskal-Wallis ANOVA and post hoc Mann-Whitney U tests ($\alpha=0.05$).

	Group Comparisons	Paired Group Comparison		
	SPcon/SPexp/SPno	SPcon/SPexp	SPcon/SPno	SPexp/SPno
	p value	p value	p value	p value
Actual Contact (AC)	<0.001	<0.001	<0.001	0.001
Near Contact (NC)	<0.001	<0.001	<0.001	0.011

DISCUSSION

This investigation sought to determine whether a more occlusally harmonious crown can be fabricated by using a cast equilibration procedure to sufficiently compensate for the inaccuracy induced by stone expansion and hand articulation in maximum intercuspation.

AC and NC values of the SP with no crown inserted represent a baseline for contacts upon occluding. AC of control crowns is near zero, which appropriately reflects the result of a crowns which are expected be high in occlusion. The relatively high standard deviation of NC for the control crown group reflects the occlusal variability associated with hand articulating derived casts in MI.

The AC and NC found on crowns fabricated on equilibrated casts were less than the SP with no crown, but still show marked improvement of occlusal harmony compared to the control crowns. While the cast equilibration procedure did not

completely eliminate the occlusal discrepancy of a crown fabricated on derived casts, it can be said that it certainly diminished the discrepancy.

Reliability for the record scan and analysis method can be inferred from the values the SP_{no} group, since this group was not affected by stone expansion or mounting error. The limited range of variation as supported by relatively small standard deviation, especially in NC, reflects an acceptable degree of reliability for the scanning method used (Figures 6 and 7).

Actual Contact with Crowns Inserted in Simulated Patient

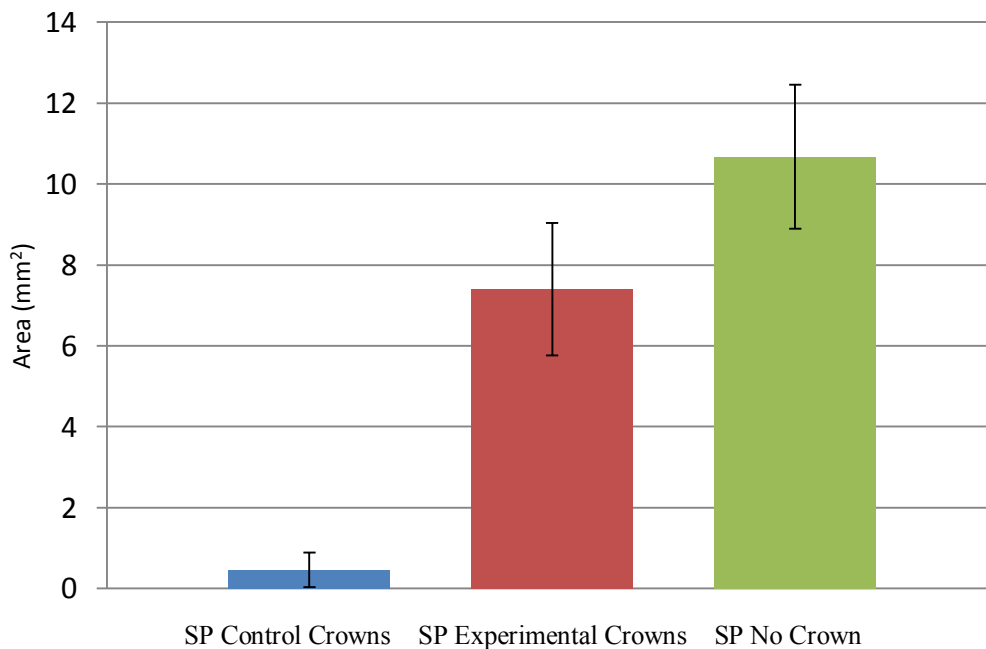


FIGURE 6. Actual contact with crowns inserted in simulated patient. Pair-wise comparison showed significant difference between control and experimental groups ($p < 0.001$) and between experimental and no crown groups ($p = 0.001$)

Near Contact with Crowns Inserted in Simulated Patient

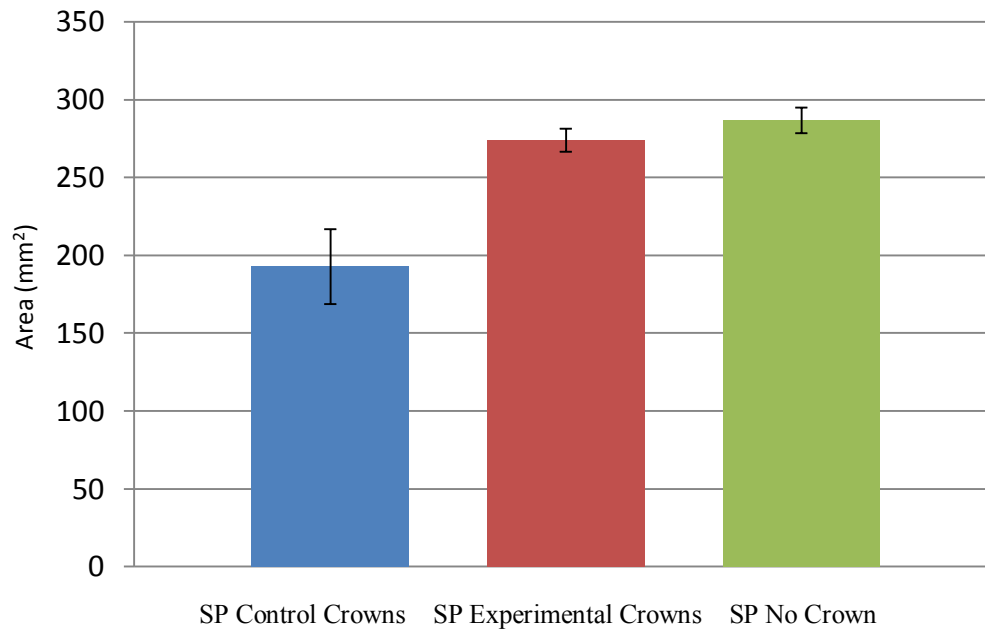


FIGURE 7. Near contact with crowns inserted in simulated patient. Pair-wise comparison showed significant difference between the control and experimental groups ($p < 0.001$) and experimental and no crown groups ($p = 0.011$).

The concern existed that the cast equilibration procedure may overcompensate and produce a crown in infraocclusion upon delivery. By reproducing the SP's "clinical" contacts on the mounted casts (as determined by the holding of shimstock between antagonistic pairs of teeth), an equilibration endpoint was established. While adjustments were made to both sides of the arch, the endpoint criteria was only applied to the ipsilateral side of the arch which involved the crown. By not incorporating cross-arch occlusal criteria and by using shimstock (rather than articulating paper), the goal of preventing overadjustment was achieved. The fact that every experimental crown held shimstock upon insertion shows that, within the limitations of this study, the

equilibration technique did not produce crowns that were in infraocclusion upon delivery.

Meng et al. [1] stated that the accurate mounting of stone casts in MI may be challenging, if not impossible. Three reasons may include: 1) The inability to make a compatible interocclusal record from natural teeth to a dental stone casts. Articulating casts with an MI interocclusal record has been shown to create more error than articulating with no record at all [20, 21, 26, 30, 31]. 2) The errant tripodding of stabilizing occlusal contacts due to expansion distortion of stone casts [1]. 3) The dynamic nature of periodontal ligament (PDL) compression and bone flexure [40].

Meng et al. presented a method to resolve the stone expansion/ erroneous mounting quandary. They started with a patient with MI=CO and used a centric record at an increased vertical dimension to preserve the condyle centric relationship between the arches when mounting. They equilibrated the mounted casts until the the incisal pin reached the MI vertical dimension of the mounted casts. Their occlusal comparison methods were similar to those used in the current study. The mounting and cast equilibration technique also yielded crowns with values for AC and NC closer to that of the simulated patient than crowns that were made on non-adjusted casts.

However, the clinical impracticalities of implementing their technique are several: 1) Many patients do not have coincident MI/CO; therefore, that technique, which assumes MI=CO, may not be applicable to the broader population of patients. 2) Obtaining an accurate centric record and hinge axis location may vary by practitioner 3) It would require additional chair time and (more importantly) skill to obtain the centric

record. Due to these limitations, the technique used for mounting in that study may not be appropriate in many clinical situations.

The technique of MI mounting used in this study did not require an interocclusal record to mount casts. Additionally, it showed that the distortion suspected to be from stone expansion and the resulting error in MI mounting can be managed with a cast equilibration procedure. The findings support the hypothesis and are in agreement with previous studies regarding the efficacy of a cast equilibration procedure to minimize occlusal disharmony at insertion of an indirect restoration [1, 4, 35, 36].

To implement this technique into clinical practice, an accurate “mapping” of occlusal contacts must be communicated to the laboratory technician. The authors have found that vinylpolysiloxane interocclusal registration in MI used as an occlusal map (rather than as an aid to articulation) adequately communicates natural occlusal contacts. Casts can be equilibrated to reproduce the areas of “show-through” seen in the record. The interocclusal record is overlaid on the mounted casts. A red pencil can transfer the contact areas (show-through) to the casts. The record is then removed. Black articulating paper is used to disclose occlusal contacts on the casts and adjusted until it reflects the previously marked red contacts.

This study has limitations in that the SP lacked a PDL. Maximum intercuspation places active forces on teeth and may change tooth position by virtue of PDL compression and bone flexure, causing increasing intercuspation with increasing force [40]. When comparing mounted stone casts to the natural dentition, the periodontium create disparity in two ways. First, a cast is derived from an impression of teeth which

are passively situated and unloaded. Therefore, tooth position of the cast may be different than the tooth position of corresponding natural teeth in MI. Second, the casts mounted in MI will not reflect the dynamic, physiologic MI of natural teeth as there is no periodontium to allow the increasing intercuspation with increasing force. These differences between a natural dentition in MI and dental stone casts in MI lend further credence to the need for a cast adjustment procedure to reconcile occlusal disparities.

Another limitation was the scanner used in this study has a threshold for record thickness at 50 μm . 50 μm may stretch the literal definition of actual contact, however, it was necessary in order to accommodate the film thickness of the VPS occlusal registration material.

While this study may validate the use of MI as a mounting position, it is still important to emphasize that the decision to use MI as a treatment position is a clinical decision based on clinical criteria. The mounting of casts in MI is only appropriate once this decision is made.

Despite the fundamental differences between mounted casts and the patient they aim to replicate, crowns have long been fabricated on casts and successfully inserted into mouths. The goal is to optimize the occlusal harmony of a crown in the laboratory phase such that clinical adjustment is minimal. Within the limitations of this study, the hand articulation of casts in MI with subsequent cast equilibration has been shown to produce a more occlusally harmonious crown than if no equilibration had been performed.

Future studies include performing a similar study with a live patient model. This would allow the effects of PDL compression and other stomatognathic variables to be studied as well.

CHAPTER III

CONCLUSIONS

Within the limits of this study, it is concluded that when gypsum casts are mounted in MI, the resulting crown will be in hyperocclusion upon insertion in the simulated patient. Additionally, when gypsum definitive casts mounted in MI have been equilibrated prior to crown fabrication, the resulting restoration will approach occlusal harmony with the original dentition upon insertion.

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APPENDIX

Data from stepwedge measurements by Meng et al. From this data a regression curve was generated which related Blu Mousse thickness to grayscale values when scanned by the double-sided flatbed scanner. The regression equation generated was different than that published by Meng et al.

Thickness (mm)	Grayscale value
0.00	0
0.04	34
0.08	87
0.10	97
0.13	109
0.15	150
0.15	156
0.15	173
0.17	185
0.17	186
0.19	190
0.21	199
0.25	236
0.29	249
0.31	255