OCCLUSAL HARMONY OF HAND ARTICULATED DIGITALLY MASTERED DEFINITIVE CASTS MOUNTED IN MAXIMAL INTERCUSPAL POSITION

A Thesis

by

SVEN ERIK BONE

Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Chair of Committee,	William W. Nagy
Committee Members,	Elias Kontogiorgos
	Peter Buschang
Head of Department,	Larry Bellinger

May 2015

Major Subject: Oral Biology

ABSTRACT

Digital acquisition of a patient's oral anatomy has the potential to improve the accuracy of dental restorations. The iTero intraoral scanner is emerging as a popular system in clinical practice, however the accuracy of the digitally mastered (DM) casts acquired with this system has not been evaluated.

In this study, 20 scans were acquired of a simulated patient producing 10 pairs digitally mastered (DM) definitive casts. The occlusal differences between DM casts and SP were evaluated by comparing the differences in areas of actual contact and near contact.

The DM casts were significantly different in both areas of actual contact and near contact compared to the simulated patient ($p < 0.001$). The null hypothesis of no detectable occlusal differences was rejected.

It is postulated final restorations fabricated on these DM casts may require adjustments upon delivery to attain occlusal harmony.

DEDICATION

To my mentors, family, friends, and loved-ones that have helped shape me and never stopped believing in me.

ACKNOWLEDGEMENTS

I would like to thank the Baylor College of Dentistry Graduate Prosthodontics, Texas A&M Health Science Center for providing me with excellent education and training in the specialty of prosthodontics.

A tremendous appreciation is owed to Dr. William Nagy and his boundless supply of patience, knowledge, and skillful instruction. Thank you to Dr. Frank Higginbottom for facilitating in the data acquisition phase. Thank you to Dr. Elias Kontogiorgos for helping with the statistical analysis and his friendship.

NOMENCLATURE

AC	Actual Contact
NC	Near Contact
DM	Digitally Mastered
SM	Simulated Patient
VPS	Vinylpolysiloxane
MIP	Maximum Intercuspation Position
EC	Experimental Casts

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Fixed prosthodontics [1] is concerned with the replacement and/or restoration of teeth, which are not readily removable by the patient, and often require fabrication in a dental laboratory. Restorations must be in harmony with the patient's stomatognathic system [2]. Materials, instruments, and clinical techniques have been developed to aid in the fabrication process. Accurate articulation and replication of the patient's dentition are integral to fabrication of these prostheses. Unfortunately, the clinical and laboratory processes can be described as an accumulation of errors, which can cause inaccuracies in the final restorations.

Traditionally, impressions and subsequent definitive casts are made to replicate the patient's dentition. The most commonly used materials employed in this procedure are vinylpolysiloxane (VPS) and type IV or V dental stone. Errors inherent in both materials and their manipulation are well documented and compound to produce misrepresentations of the patient's dentition [3-17].

To further replicate the patient's stomatognathic system the definitive casts are mounted on a dental articulator. This process involves making a facebow record to orientate the maxillary definitive cast to the transverse horizontal hinge axis and cranial base. The next step in the mounting process is to mount the mandibular cast. Definitive casts are usually mounted and articulated in the maximum intercuspation position (MIP) or centric occlusion. MIP is a tooth directed mandibular position and centric occlusion is a joint directed position [18]. Dimensionally accurate definitive casts must be a prerequisite to replicate the patient's tooth contacts on a dental articulator.

There are two methods used to articulate casts in MIP. One is by hand articulation; the other utilizes an interocclusal record. If the casts are stable when hand articulated; the hand articulation method is recommended and has been shown to be more accurate than when an interocclusal record is utilized [19]. Therefore, when mounting stone casts in MIP the elimination of an interocclusal record reduces error.

Emerging dental technologies have the potential to address the problem of compounding errors during the fabrication of dental restorations. The digital impression is a technology proposed to eliminate the elastomeric impression material, tray, and adhesive from the replication process. The digital impression is accomplished by an optical scanning or laser-scanning instrument. The instrument records the surface topography of the patient's hard and soft tissues. This data can then be utilized for analysis or computer aided manufacturing replicas of the patient's dentition [20]. The iTero by Cadent (Cadent Inc.; Carlstadt, N.J.) is a parallel confocal laser scanning instrument for digital impressions with the purpose of fabricating digitally mastered milled polyurethane definitive casts of the patient's dentition [20]. Therefore, this technology also eliminates the need for using dental stone.

The iTero technology then, proposes the potential to reduce the number of errors that accumulate in the fabrication of a dental restoration by eliminating the conventional impression and definitive cast fabrication steps. However, as previously mentioned, prerequisites to accurately replicating the patient's stomatognathic system are dimensionally accurate paired definitive casts properly mounted on a dental articulator. Therefore, if it can be shown that the digitally mastered definitive casts produced by iTero are dimensionally accurate then it follows that the subsequent final restorations will require less adjustments in the clinical setting to bring them into harmony with the patient's stomatognathic system. An approach for determining the accuracy of the digitally mastered definitive casts is to compare the areas of actual and near contact of the paired casts mounted in MIP on a dental articulator to those of a simulated patient.

Meng et al. investigated the accuracy of mounted casts, utilizing a protocol of optically scanned interocclusal records (scan records) to evaluate the differences between a simulated patient and definitive casts of type IV and V dental stone [3]. The protocol provided a method for analyzing the areas of near contact (NC) and actual contact (AC) of the posterior teeth in maximal intercuspation [3]. The sensitivity of this protocol has been shown to be within the range of 50μm [19].

The purpose of this in vitro study was to determine the occlusal harmony of digitally mastered definitive casts mounted in MIP compared with a simulated patient by comparing occlusal contacts areas. The null hypothesis was the digitally mastered definitive casts mounted in MIP would not differ significantly from the simulated patient in both areas of actual contact and near contact.

2. MATERIALS AND METHODS

This study was designed around a methodology similar to the investigation in Meng et al [3]. This was a valid approach to reveal occlusal differences between the simulated patient (SP) and the experimental casts (EC). The study was mapped and designed using a flow diagram (Fig. 1) with each step parsed into separate protocols. Starting with the simulated patient protocol and proceeding through the diagram to the end resulted in usable data for analysis. The specific for each protocol is described below.

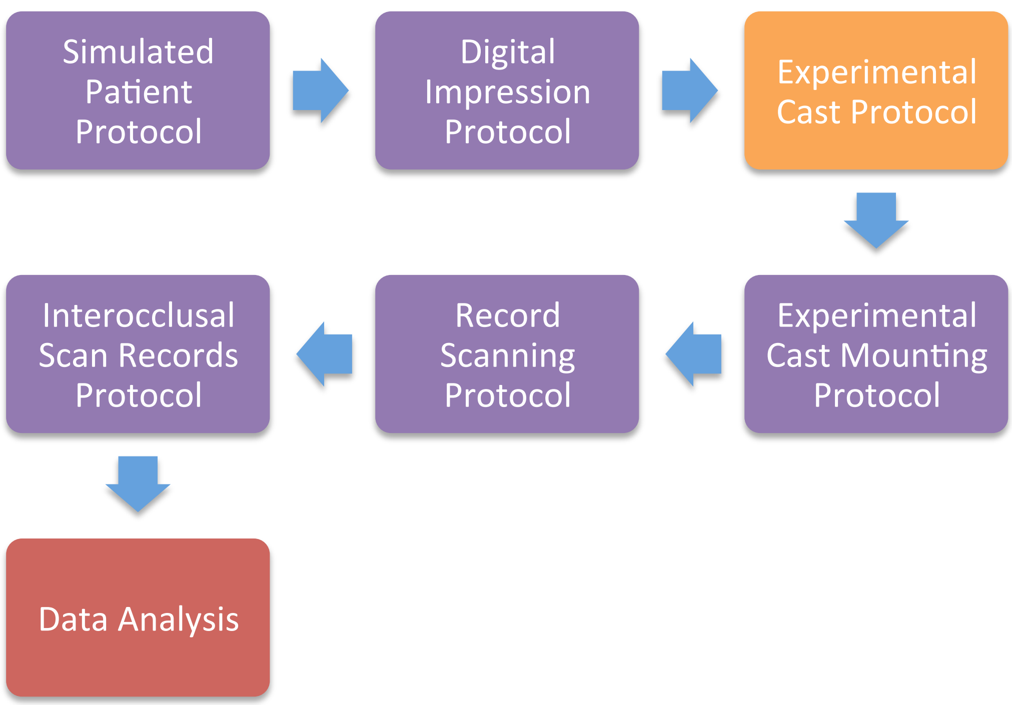

Figure 1. Flow Diagram Illustrating the Study Design

In the simulated patient (SP) protocol, a complete anatomic dentoform (M- 1560; Columbia Dentoform Corp, New York, NY) was arbitrarily mounted in a semi-adjustable articulator (SAM 3; SAM Präzisionstechnik GmbH, Munich, Germany) with centric locks in place in maximal intercuspal position (MIP) using Mounting Stone (WhipMix Corp., Louisville, KY) Type III dental stone and the Axiosplit mounting plates (SAM Präzisionstechnik GmbH, Munich, Germany) [3]. The MIP was attained by hand occluding and stabilizing the maxillary dentoform with the mandibular dentoform [3]. Mounting Stone on the mandibular dentoform and mounting plate then hand stabilized in MIP till the Mounting Stone was set [3] (Figure 2).

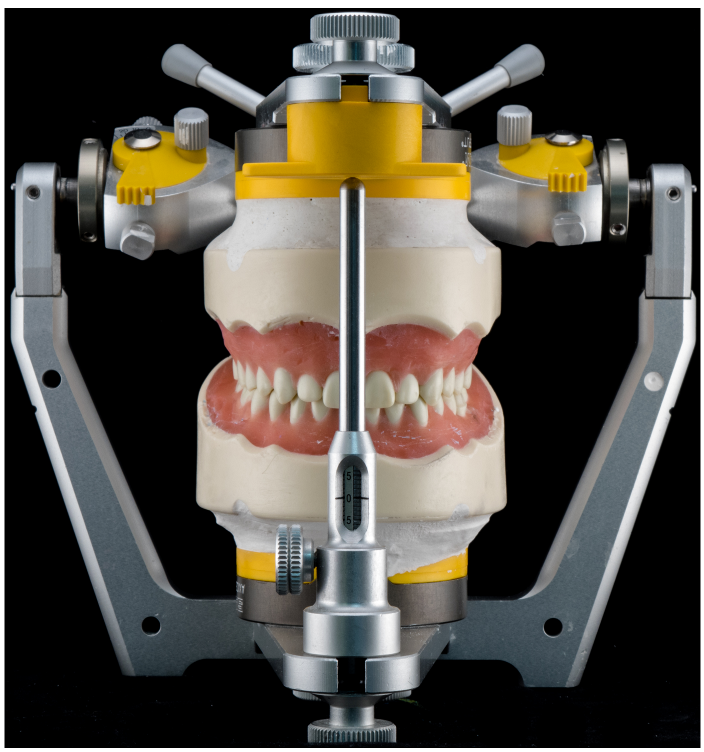

Figure 2. The Simulated Patient

In the digital impression protocol, twenty digital impressions of the SP were made resulting in ten per arch using the iTero system (Cadent Inc.; Carlstadt, NJ). Each impression captured all supra-gingival surfaces of all the teeth. Each impression was visualized and inspected for scanning errors. In the experimental cast (EC) protocol the digital impression files were sent electronically to Cadent for fabrication according to iTero protocol.

The experimental cast (EC) mounting protocol went as follows. When the 20 digitally mastered (DM) definitive casts returned from Cadent, each matching maxillary and mandibular DM casts were paired together and labeled (1-10) with a felt tipped permanent marker. A base was then added to each DM cast using Mounting Stone. The Mounting stone engaged undercuts in the DM casts to prevent separation. The bases were made by placing each DM cast in a base former (SAM Präzisionstechnik GmbH, Munich, Germany) filled with Mounting stone. A facebow record of the SP was recorded, using the SAM Anatomic Facebow and transfer Fork (SAM Präzisionstechnik GmbH, Munich, Germany). The recording material used was Aluwax arranged in a tripod format. This ensured that the maxillary DM casts and the SP maxilla had the same location and orientation with respect to the SP transverse horizontal axis. The maxillary DM casts were then placed in the facebow instrumentation and secured to the upper member of the articulator with a mounting plate and Mounting Stone. MIP was attained by hand occluding and stabilizing the mandibular DM cast with the matching DM maxillary cast [3]. Mounting Stone was added to the mandibular DM cast and mounting plate then hand stabilized in MIP till the Mounting Stone was set [3]. (Figure 3)

Figure 3. Mounted Paired Digitally Mastered Casts

For the interocclusal scan records protocol, bilateral VPS (Blu-Mousse; Parkell, Inc) interocclusal records were made for each of the 10 matching pairs of mounted DM casts and the SP. All the teeth were lubricated with a separating medium (Super Sep; Kerr, Orange Calif). A bead of the VPS material was placed over the entire occlusal surfaces of the posterior teeth (1st premolar to 3rd molar), a 1kg load was applied, and the articulator was immediately closed while the VPS polymerized. Excess material was trimmed using an arbor band (Wells Dental, Comptche, CA) and lathe (Handler Manufacturing, Westfield, NJ). The trimming was performed to establish a uniform flat surface on the borders of each scan record approximately 3mm height to aid in placement into the scanner. The right and left interocclusal scan records corresponding to each of the 10 pairs of DM casts and SP were placed into separate labeled sealable plastic bags (Figure 4).

Figure 4. An Example of an Occlusal Scan Record

In the record scanning protocol a double-sided flatbed scanner (Expression 1680; Epson America, Long Beach, California) was used to produce a grayscale image of each scan record [3] (Figure 5). The trimmed interocclusal scan records were placed into a precut jig of foam-core to ensure complete closure of the scanner [3]. The uniform thickness of the trimmed scan records ensured a relatively constant distance from the light source to scan record [3]. All matching right and left scan records corresponding to the SP and paired DM casts were placed into the jig, one pair per scan, at the same location in the scanner and scanned in one sitting. The scans were taken at a resolution of 300 dots per inch (dpi) with 8-bits of information per pixel to form the grayscale image. This 8-bit image provided a stratified scale of 256 levels of pixel intensity ranging from pure black (value = 1) to pure white (value = 256) for each pixel in the image. The scans were analyzed with the computer software ImageTool Version 3.0 Software (University of Texas Health Sciences Center at San Antonio, San Antonio) [3]. A 557 bur measuring 18.94mm was also placed in each scan in order to calibrate the software. This provided an accurate relationship between the number of pixels in a known length. This ensured that the output of the software for an area arbitrarily outlined in the image was accurate. For each scan record image, the occlusal surfaces of the 1st premolar back to the 3rd molar were outlined in ImageTool and used for analysis.

Figure 5. Image of a Scan Record with a 557 Bur

The data analysis protocol went as follows. Since, the raw 8-bit image data from the scanner was composed of only the grayscale (GS) value and location for each pixel in the scan record image more information was needed to properly compare the scan records of the paired DM casts and the SP. The ImageTool software was used to generate two sets of data from the raw image data. One data set was in the form of a histogram generated by placing each pixel in the outlined area of interest into one of 256 rows based on its GS value. This therefore characterized the population of all the pixels in the scan record image based on pixel intensity. ImageTool also provided the area (mm^2) of the outlined occlusal surfaces, the second data set. This was then used to calculate the pixel density (pixels/mm^2) for each scan record image. The pixel density was calculated by dividing the total number of pixels in the outlined image of the occlusal surfaces by its area. Both data sets for each labeled right and left scan record images were imported into Microsoft Excel 2007 spreadsheet (Microsoft Corp, Redmond, WA) for further analysis. Meng et al. used a calibration step wedge stratified into known thicknesses to generate a quadratic regression equation, which related the pixel intensity (GS) as a function of scan record thickness (x) [3]. The thickest part of the step wedge provided the upper limit, which was given the GS value of 256 corresponding with pure white. The thickest undetectable part of the wedge provided the lower limit, which was given GS value of 1 corresponding with pure black [3]. The following regression equation thus described the relationship between GS values and record thickness in millimeters within these limits. Thus, another way to interpret pixel intensity was to relate it to the thickness of the scan record at any given pixel.

$$\text{Thickness (x)} = 0.0436 + 0.0002(GS) + 0.000003(GS)^2$$

When this equation was combined with the grayscale histogram data and calculated pixel density it was possible to calculate the amount of area for a certain thickness present in the scan record. Thus, the total area for a given thickness in the scan record was directly related to the number pixels of a given pixel intensity in the scan record image. This then established a measurable and reproducible method for determining how much area the paired DM casts and SP were in actual contact and near contact.

To measure any occlusal differences between the paired DM casts and SP, actual contact (AC) and near contact (NC) areas were defined. A previous study has reported sensitivities of no less than 50 μm utilizing this protocol [20]. Studies utilizing this protocol considered actual contact to be 0 - 50 μm and near contact to be 50 μm to 250 μm [21, 22]. The regression equation was therefore used to solve for GS values at the upper limits of each contact category, thicknesses of 50μm and 250μm respectively. This yielded a range of GS values of 1 - 21 to be defined as AC and values 22 - 231 to be NC. Combining this with the histogram data and the pixel density for each scan record image it was possible to calculate the area for the contact criteria, AC and NC respectively. The area of AC was solved by the summation of all the pixels in rows 1 - 21 and dividing by the pixel density (pixels/mm^2). The area of NC was solved similarly with the exception of the population of pixels were from rows 22 - 231. It was therefore possible to compare the paired DM casts and SP for differences in area of AC and NC.

The AC and NC areas were calculated for both right and left sides of the record scan images for all 10 paired DM casts and SP. The full arch AC and NC areas were calculated by summing both right and left sides together for each pair and the SP. This yielded six populations (n=10) for the DM casts; AC right, left and full arch; NC right, left and full arch, respectively (tables 1 and 2). The difference in AC and NC areas between the DM casts and the SP yielded an additional six populations (n=10) (table 3). This data was imported into SPSS version 17.0 (SPSS Inc, Chicago, Ill) for statistical analysis. All populations were normally distributed. The occlusal differences between the DM casts and SP in AC and NC areas were evaluated using a one sample t-test (mean $\neq 0$, $\alpha = 0.05$) for the right, left and full arch respectively.

3. RESULTS

A visual examination of the DM casts subjectively showed less dental anatomic detail when compared to the dentition of the simulated patient (Figure 6). This loss of detail was captured and observed in the scan records (Figure 7). A side-by-side comparison between the images of the scan records for the paired DM casts and the simulated patient visually appeared to differ in the contact areas (Figure 8).

Figure 6. Side-by-side View of the Simulated Patient (Left) and a Digitally Mastered Cast (Right)

Figure 7. Side-by-side View of the scan record for the Simulated Patient (Left) and a Digitally Mastered Cast (Right)

Figure 8. Side-by-side Comparison of the Imaged Scan Records of the Simulated Patient (Left) and a Digitally Mastered Cast (Right)

All three means for the areas of AC were greater for the paired DM casts compared to the SP, right side, and the full arch (Table 1). Conversely, all the NC area means were less for the paired DM casts than what was measured for the SP, right side, left side, and the full arch (Table 2).

In order to quantify the differences between the 10 pairs of DM casts and the SP, each measurement for the areas of AC and NC were subtracted from those measured for the SP producing 6 normal distributions, Diff AC left side, Diff AC right side, Diff Full Arch, Diff NC left side, Diff NC right side, and Diff full arch (Table 3). The distributions for the differences in areas of AC between the paired DM casts and SP are shown in Table 3. These data showed quantifiable increases in areas of AC for the left sides, right sides and the full arches for the paired DM casts compared to the SP. One sample t-tests revealed these increases were significantly greater than zero ($p \leq 0.001$) (Table 4-6).

The distributions for the differences in areas of NC between the paired DM casts and SP are shown in Table 3. These data showed quantifiable decreases in areas of NC for the left sides, right sides and the full arches for the paired DM casts compared to the SP. One sample t-tests revealed these decreases were significantly less than zero ($p \leq 0.001$) (Table 4-6).

Table 1. Actual Contact (mm^2) of Digital Mastered Casts and the Simulated Patient for the Right, Left side and Full Arch

Variable	Mean (mm^2)	Standard Deviation	Minimum	Maximum
DM Casts Right Side	1.95	0.9	0.6	3.48
DM Casts Left Side	2.44	1.01	1.28	4.17
DM Casts Full Arch	4.4	1.48	2.85	6.8
SP Right Side	0.54			
SP Left Side	0.59			
SP Full Arch	1.13			

Table 2. Near Contact (mm^2) of Digital Mastered Casts and the Simulated Patient for the Right, Left side and Full Arch.

Variable	Mean (mm^2)	Standard Deviation	Minimum	Maximum
DM Casts Right Side	218.05	14.38	196.55	235.83
DM Casts Left Side	166.15	20.65	143.29	198.12
DM Casts Full Arch	384.2	20.14	354.82	429.91
SP Right Side	245.64			
SP Left Side	214.66			
SP Full Arch	460.3			

Table 3. Difference in Actual Contact (mm^2) and Near Contact (mm^2) between Digital Mastered Casts and the Simulated Patient for the Left, Right side and Full Arch

Variable	Mean (mm^2)	Standard Deviation	Minimum	Maximum
Diff. AC Left Side	1.85	1.01	0.69	3.58
Diff. AC Right Side	1.42	0.9	0.06	2.94
Diff. AC Full Arch	3.27	1.48	1.72	5.67
Diff. NC Left Side	-48.51	20.65	-71.37	-16.54
Diff. NC Right Side	-27.59	14.38	-49.1	-9.82
Diff. NC Full Arch	-76.1	20.14	-105.48	-30.39

Table 4. One-Sample Test Full Arch Differences in Actual Contact (mm^2) and Near Contact (mm^2)

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
AC (DM - SP)	6.988	9	< 0.001	3.265354	2.20823	4.32248
NC (DM - SP)	-11.950	9	< 0.001	-76.09892	-90.50471	-61.69313

Table 5. One-Sample T-Test for Right Side Differences in Actual Contact (mm^2) and Near Contact (mm^2)

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
AC (DM - SP)	4.979	9	< 0.001	1.416661	.77300	2.06033
NC (DM - SP)	-6.069	9	< 0.001	-27.593528	-37.87840	-17.30866

Table 6. One-Sample T-Test for Left Side Differences in Actual Contact (mm^2) and Near Contact (mm^2)

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
AC (DM - SP)	5.763	9	< 0.001	1.848694	1.12302	2.57437
NC (DM - SP)	-7.427	9	< 0.001	-48.505394	-63.28010	-33.73068

4. DISCUSSION

The aim of this study was to determine the occlusal harmony of the iTero DM definitive casts by comparing actual and near contact areas of the paired casts mounted in MIP with those of a simulated patient. The null hypothesis was that the paired DM casts mounted in MIP would not differ significantly from the simulated patient in both areas of AC and NC. This is a critical step in ascertaining whether or not this novel approach can lead to restorations, which require minimal clinical adjustment to achieve occlusal harmony. If the DM casts intercuspate in a similar manner to the SP, then it could be concluded that the MIP of the DM casts and SP are reproducible. Thus, an indirect restoration fabricated on the DM casts would display identical contacts when delivered to the SP. This has always been a problem when fabricating an indirect restoration on dental stone cast that requires no clinical adjustments and attaining occlusal harmony in our patients. A technique that generates definitive casts that accurately intercuspate in the exact manner as a patient is a key step toward attaining this clinical goal.

The iTero system was chosen as it offers the potential to eliminate errors inherent in the use of vinylpolysiloxane impression material and dental stone in the fabrication of a definitive cast. This digital alternative for recording the information regarding the patient's dentition bypasses the impression material shrinkage associated with the use of vinylpolysiloxane [3]. It also bypasses the stone expansion error associated with dental stone by computer aided milling of polyurethane, thus transforming the patient's digital information into a physical model. However, novel approaches that replace conventional techniques often introduce new errors yet to be identified and described.

This study found significant occlusal differences between the paired DM casts and the SP. The results showed that the areas of AC significantly increased and the areas of NC significantly decreased between the DM casts and the SP. Therefore, these data demonstrated that the iTero system as a whole did not accurately reproduce the complex anatomy of the SP's dentition for the paired DM casts to intercuspate in a manner identical to the SP. A subjective visual inspection of the DM definitive casts also gave an impression that the casts had less anatomic detail compared to the SP. This loss in detail did impact how the paired DM casts intercuspated when mounted in MIP, and final restorations fabricated on the paired DM casts may not be in occlusal harmony upon delivery in the SP due to mounting errors directly related to the differences between the intercuspation of the paired cast and the SP.

There are two general possibilities where the error in the DM casts could have occurred. The first was in the data acquisition phase, while the SP was scanned. It is well known that unprepared teeth are scanned at a lower resolution than teeth prepared for a restoration, a default state of the iTero scanner. This lack of data could have introduced errors that affected the downstream cast fabrication process. However, the scanned screen images subjectively appeared to possess more anatomic detail than the fabricated DM casts. The second possibility for error introduction was the output phase, when the DM casts were fabricated. This involves the subtractive manufacturing of the DM casts from raw pucks of polyurethane. The process and theory that determines the precision and accuracy of the removal of excess polyurethane during the machining process is complex and beyond the scope of this study. However, the subjective differences observed in anatomic detail between scanned images of the SP and the DM casts point to the errors being weighted on the output phase. A more probable assertion is that a combination of errors accumulated in both phases, which yielded the intercuspation difference observed in this study.

The study data possessed sufficient specificity and sensitivity to quantifiably detect the differences in contact areas between the experimental DM casts and the SP, because an equilibrated dentoform was used for the SP. This ensured that all teeth had equal and simultaneous occlusal contacts when the articulator was closed; therefore maximum intercuspation was coincident with the centric occlusion position of the SP. This eliminated the need for an interocclusal record to mount the paired DM casts on the research articulator and minimized the mounting errors that would have increased the variability in the scan record image data. Therefore, changes in occlusal contact areas were justifiably attributed to distortions in tooth anatomy in the DM casts rather than errors that occurred in the mounting protocol. Meng et al established that the method of fabricating and scanning the interocclusal records and analyzing the scan record images had a high level of reliability [3], thus supporting the validity of the experimental method by limiting the number of scan records for the SP and paired DM casts to just one per side for a total of 20 (DM casts) plus 2 (SP). Thus, these results showed that the experimental method was sensitive enough to detect differences between the DM cast and the SP and specifically how they differed in areas of occlusal contacts.

This study identified contacts and near contact and the use of a flat bed scanner to scan VPS interocclusal records did not identify where the significant differences between the DM cast and SP were located. This was because the data produced by this method is one dimensional in nature and partially a product of the software used, ImageTool. This method analyzed a scan record image by simply ranking the pixels based on their 8-bit (2^8 =256) levels of intensity and summing them together depending on their assigned category, AC, NC or neither. If, however, each pixel location in the image was also collected, location maps of AC and NC as well as maps showing the differences could be generated. This approach could solve this particular limitation of knowing where the occlusal differences are located.

This study was an important to step in the investigation for determining if the iTero system can serve as a platform for fabricating restorations that will be in occlusal harmony in a patient upon delivery. The results show that there are indeed inherent occlusal errors with the DM casts compared to the SP. These results also suggest that areas of NC in the SP became actual contacts in the DM casts, suggesting the DM casts contact before the SP in the arc of closure. Therefore, it can be deduced that the vertical dimension of occlusion for the DM casts increased, resulting in a mounting error. It is reasonable to assume then that the mountings errors directly related to the anatomical differences between the DM casts and the SP will be transferred to the final restoration. The results of this study then predicts that final restorations fabricated on the DM casts would be in hyperocclusion upon delivery to the SP. To compensate for mounting errors Meng et al demonstrated that equilibrating the definitive casts is an appropriate laboratory procedure for conventionally frabricated definitive cast [2]. It remains to be seen if it is possible to equilibrate the MIP mounted DM casts to better fit the occlusal patterns seen in the SP. Further results regarding the clinical acceptability of final restorations fabricated on the DM cast should investigate possible changes in vertical dimension of occlusion of the SP with and without restorations fabricated on the DM casts. This would validate or invalidate the postulates proposed from this study. A clinical trial should be conducted to determine if these occlusal differences detected in this invitro study are indeed significant in our patients.

In summary, the DM casts from iTero were found to differ from the SP in areas of occlusal contact. It is postulated that differences between the DM casts and the SP are the result of anatomic errors generated primarily during cast fabrication and result in a mounting errors compared to the SP. The experimental method was sensitive and specific enough to detect these changes in AC and NC areas but it could not answer specifically where on the DM casts the changes occurred or characterize how the anatomy of the teeth of the DM casts differed from the SP. The results imply that the anatomic errors in the DM casts could transfer to final restorations requiring further clinical adjusts to be in harmony with the patient's stomatognathic system. These postulates, however requires further investigation.

5. CONCLUSION

Within the limits of this study, it was concluded that the maxillary and mandibular DM definitive casts from iTero mounted in maximum intercuspation position differed significantly in areas of occlusal contact and near contact compared to a simulated patient. Therefore, the null hypothesis was rejected.

REFERENCES

1. Prosthodontics, T.A.o., *The Glossary of Prosthodontic Terms.* J Prosthet Dent, 2005. **94**(1): p. 10-92.
2. Dawson, P., *Functional Occlusion: From TMJ to Smile Design.* 2007, St. Louis, MO: Mosby, Inc.
3. Meng, J.C., et al., *The effect of equilibrating mounted dental stone casts on the occlusal harmony of cast metal complete crowns.* J Prosthet Dent, 2010. **104**(2): p. 122-32.
4. Breeding, L.C., D.L. Dixon, and K.E. Kinderknecht, *Accuracy of three interocclusal recording materials used to mount a working cast.* J Prosthet Dent, 1994. **71**(3): p. 265-70.
5. Butta, R., et al., *Type IV gypsum compatibility with five addition-reaction silicone impression materials.* J Prosthet Dent, 2005. **93**(6): p. 540-4.
6. Adabo, G.L., et al., *Effect of disinfectant agents on dimensional stability of elastomeric impression materials.* J Prosthet Dent, 1999. **81**(5): p. 621-4.
7. Cho, G.C. and W.W. Chee, *Distortion of disposable plastic stock trays when used with putty vinyl polysiloxane impression materials.* J Prosthet Dent, 2004. **92**(4): p. 354-8.
8. Eames, W.B., et al., *Elastomeric impression materials: effect of bulk on accuracy.* J Prosthet Dent, 1979. **41**(3): p. 304-7.

9. Heshmati, R.H., et al., *Delayed linear expansion of improved dental stone.* J Prosthet Dent, 2002. **88**(1): p. 26-31.

10. Langenwalter, E.M., S.A. Aquilino, and K.A. Turner, *The dimensional stability of elastomeric impression materials following disinfection.* J Prosthet Dent, 1990. **63**(3): p. 270-6.

11. Martinez, L.J. and J.A. von Fraunhofer, *The effects of custom tray material on the accuracy of master casts.* J Prosthodont, 1998. **7**(2): p. 106-10.

12. Matyas, J., et al., *Effects of disinfectants on dimensional accuracy of impression materials.* J Prosthet Dent, 1990. **64**(1): p. 25-31.

13. Millstein, P., A. Maya, and C. Segura, *Determining the accuracy of stock and custom tray impression/casts.* J Oral Rehabil, 1998. **25**(8): p. 645-8.

14. Millstein, P.L., *Determining the accuracy of gypsum casts made from type IV dental stone.* J Oral Rehabil, 1992. **19**(3): p. 239-43.

15. Sweeney, W.T. and D.F. Taylor, *Dimensional changes in dental stone and plaster.* J Dent Res, 1950. **29**(6): p. 749-55.

16. Thongthammachat, S., et al., *Dimensional accuracy of dental casts: influence of tray material, impression material, and time.* J Prosthodont, 2002. **11**(2): p. 98-108.

17. Valderhaug, J. and F. Floystrand, *Dimensional stability of elastomeric impression materials in custom-made and stock trays.* J Prosthet Dent, 1984. **52**(4): p. 514-7.

18. Parker, M.W., *The significance of occlusion in restorative dentistry.* Dent Clin North Am, 1993. **37**(3): p. 341-51.

19. Sakaguchi, R.L., G.C. Anderson, and R. DeLong, *Digital imaging of occlusal contacts in the intercuspal position.* J Prosthodont, 1994. **3**(4): p. 193-7.

20. Garg, A.K., *Cadent iTero's digital system for dental impressions: the end of trays and putty?* Dent Implantol Update, 2008. **19**(1): p. 1-4.

21. Owens, S., et al., *Masticatory performance and areas of occlusal contact and near contact in subjects with normal occlusion and malocclusion.* Am J Orthod Dentofacial Orthop, 2002. **121**(6): p. 602-9.

22. Parkinson, C.E., et al., *A new method of evaluating posterior occlusion and its relation to posttreatment occlusal changes.* Am J Orthod Dentofacial Orthop, 2001. **120**(5): p. 503-12.