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Comparison of Occlusal Plane Orientation Obtained Using Five Facebow Systems

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by

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Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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ABBREVIATIONS

FHP	Frankfort Horizontal Plane

ABSTRACT OF THE THESIS

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by

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Master of Science, Advanced Specialty Education Program in Prosthodontics
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PURPOSE: An in vitro investigation analyzing the sagittal and coronal orientation of the occlusal plane using five different facebow transfer systems.

MATERIALS AND METHODS: A phantom head containing a maxillary typodont (the control) was oriented so that Frankfort Horizontal Plane (FHP) corresponds with the horizon. The angle between the occlusal plane of the maxillary arch of the phantom head and the FHP was measured along the sagittal and coronal planes using a digital protractor. Fifteen Facebow records using each of 5 facebow transfer systems (the test groups) were made on the phantom head containing the maxillary typodont. Diagnostic casts of the maxillary typodont were fabricated and mounted onto each of the respective semi-adjustable arcon articulators using the facebow records. The same angles measured on the control were measured on the test groups. These angles were compared with the same angle measured on the maxillary arch of the phantom head (the control). The measurements were made by two operators. Intra-operator and inter-operator reliability testing was completed. The data was collected and evaluated for statistically significant differences: 1. Within the groups 2. Between the groups versus the control and 3. Between the groups.

RESULTS: Significant differences in the sagittal and coronal orientation of the occlusal plane were observed between the mounted casts obtained using the five different facebow transfer systems. The Denar system had the least significant difference in the coronal orientation of its occlusal plane versus that of the control. The Hanau and Panadent systems had the least significant difference in the sagittal orientation of their occlusal planes versus that of the control. Inter-group comparison of the test groups showed significant differences between the groups. The Kois system showed the greatest difference in the coronal plane orientation while the Denar system showed the greatest difference in the sagittal plane orientation.

CONCLUSIONS: Significant differences in the sagittal and coronal orientation of the occlusal plane were observed with the five facebow transfer systems versus the control. Inter-group comparisons revealed significant differences in the sagittal and coronal orientation of the occlusal plane. Further research is needed to evaluate the clinical implications of these results.

CHAPTER ONE

INTRODUCTION

The Glossary of Prosthodontic Terms defines a facebow as a caliper-like instrument used to record the spatial relationship of the maxillary arch to some anatomic reference point or points and then transfer this relationship to an articulator; it orients the dental cast in the same relationship to the opening axis of the articulator (GPT 8th Ed 2005). In 1953, Brandrup-Wognsen provided a short historical summary of the development of the facebow. At the end of the 19th century, the importance of mounting plaster casts in the articulator in a given positional relation to the condylar mechanism was realized to be significant in complete denture construction. Bonwill stated that the distance from the center of each condyle to the median incisal point of the lower teeth was 10 cm (Brandrup-Wognsen 1953). Using this measurement, he was able to mount his casts in the articulator. However, he did not mention what level below the condylar mechanisms the occlusal plane should be situated. He appeared to mount his casts with the occlusal plane in a horizontal position midway between the upper and lower part of the articulator, and found this satisfactory. In 1866, Balkwill demonstrated an apparatus that allowed him to measure "the angle formed by the occlusal plane of the teeth, and a plane passing through the lines extending from the condyles to the incisal line of the lower teeth" (Brandrup-Wognsen 1953). This angle varied from 22 degrees to 30 degrees. In the 1880's, Hayes developed the "Caliper", another apparatus for localizing the plaster casts on the articulator (Brandrup-Wognsen 1953). One of the major limitations of the device was that only the median incisal point was localized in relation to its distance from the two condyles. Furthermore, there was no control of the proper orientation of the occlusal plane.

Walker invented the "Clinometer" in the 1890s, whereby one could obtain a relatively good position of the lower cast in relation to the condylar mechanism (Brandrup-Wognsen 1953). However, the apparatus was exceedingly complex. Walker also used this instrument for measuring the inclination of the condylar path, but did not utilize the instrument as a facebow.

At the turn of the 19th century, Gysi constructed an instrument for registering the condylar path, which he also employed as a facebow. Around the same time, Snow constructed an instrument which became the prototype for all facebows. Brandrup-Wognsen stated that the "Snow's facebow – in spite of it's very simple construction – was of paramount importance to prosthetic dentistry" (1953). The instrument allowed positioning of the plaster casts on the articulator so that all points on the occlusal plane were given their correct positions in relation to the condyles. The instrument allowed correct anatomical positioning of the plaster casts onto the articulator.

The introduction and development of the first facebows laid the path for further developments of the apparatus. One crucial development was to ascertain the level on the articulator at which the occlusal plane should be placed. Snow attempted to give the occlusal plane an individual position in the third dimension by fixing the bite-fork in the upper occlusion rim so that when placed in the patient's mouth, the handle of the fork was parallel with a plane extending from the bottom of the glenoid fossa and passing through the anterior nasal spine (Brandrup-Wognsen 1953). This approximately corresponds with a line drawn from the upper part of the tragus, to the lower edge of the nostril. This plane is known as Campers plane or the Bromell plane (Brandrup-Wognsen 1953). A similar orientation plane was introduced by Gysi and termed, the "protetische Ebene" (the prosthetic plane), which extends from the condylar area and runs at right angles to a line that connects the most prominent points of the chin and forehead (Brandrup-Wognsen 1953). A more recent orientation has been the Frankfort Horizontal Plane (Brandrup-Wognsen 1953), which is defined as a horizontal plane represented in profile by a line between the lowest point on the margin of the orbit to the highest point on the margin of the auditory meatus (GPT 8th Ed 2005).

Various posterior reference points have been advocated for use during facebow transfer (Gold 1983). These include:

1. Arbitrary points, selected by anatomical surface markings, and dependent upon average value measurements.

2. Arbitrary points related to mechanical devices fitted into the external auditory meati.

3. Kinematically located terminal hinge axis using skin points.

The kinematic method is generally considered to be the most accurate and has been the standard by which other "approximation" techniques have been evaluated (Schallhorn 1957, Lauritzen & Bodner 1961, Bosman 1974. From Gold 1983). Schallhorn stated that an arbitrary axis for facebow mountings on semi-adjustable articulators is justifiable since 95% of the subjects evaluated in that study had the kinematic center located within a radius of 5mm from the arbitrary center (Schallhorn 1975). Weinberg stated that this reasonable error in the transverse hinge axis location

(+/-5mm) results in negligible anteroposterior mandibular displacement (in the range of 0.2mm) when a 3mm centric relation record is removed and the articulator is closed (Weinberg 1961).

There have been controversies regarding the use of a facebow. Logan (1926) considered it indispensable, while Craddock (1952), Stansberry (1928), Symmons (1952) and others considered it useless or at the most, unnecessary (Christiansen 1959). Craddock (1952) stated that when a face-bow is not used, "the resulting errors in the occlusal relations of full dentures are so small as to be incapable of clinical detection".

Due to such controversies over the use of a facebow, Gold decided to investigate the reproducibility of the position of the maxillary cast on semi adjustable articulators with repeated facebow transfers using three different facebows. The results in cast positions rarely exceeded +/- 1.0 mm in any of the three planes of space. Although the results suggested a ranking in accuracy, all were considered clinically acceptable (Gold 1983).

Using four different facebow transfer systems, Goska evaluated the positions of the maxillary casts mounted on semi-adjustable articulators. He found great variability between subjects due to the differences in anatomic landmarks. He concluded that this prevents establishing clinical superiority of one facebow over another (Goska 1988).

Yanus also evaluated the reproducibility of facebow transfers made using two different facebows: The kinematic facebow versus an earbow. Three records were made with each facebow and the positions of selected points on the mounted maxillary casts. Their results showed that facebow transfers from both facebows were found to be reproducible on the same subject (1983).

Bailey and Nowlin (1981) investigated the possibility that the orbital indicator attachment for the Hanau spring-bow may not accurately establish the relationship of the Frankfort Horizontal plane to the plane of occlusion. A standardized cephalometric radiograph and facebow records using the orbitale as the third point of reference were made on 10 subjects. Maxillary casts were mounted on a Hanau 130-28 articulator. The angle between the horizontal plane of the articulator and the occlusal plane was compared to the angle between the Frankfort Horizontal plane and occlusal plane that was traced on the radiograph. These angles were found to differ by an average greater than 5 degrees, which suggests that the use of the third point of reference (orbitale) did not accurately establish the correct relationship of the Frankfort Horizontal Plane to the occlusal plane on the articulator.

Additional investigation is needed to evaluate the reproducibility of the occlusal plane orientation when a facebow record is made. A comparison of the sagittal and coronal orientation of the occlusal plane from facebow records made with different facebows is suggested. The purpose of this study was to evaluate the sagittal and coronal orientation of the occlusal plane on maxillary casts mounted using five different facebow transfer systems into their corresponding semi-adjustable arcon articulators. The casts from each facebow transfer system (test groups) will be compared to a phantom head with a maxillary typodont (control) on which the facebow records were made.

The null hypotheses tested were: 1. The mounted maxillary casts in each test group are not significantly different in the sagittal and coronal orientation of the maxillary occlusal plane compared to the control. 2. The mounted maxillary casts in each test group are not significantly different in the sagittal and coronal orientation of the maxillary occlusal plane compared to the other test groups.

CHAPTER TWO

MATERIALS AND METHODS

A phantom head (P-6/3 Standard Mannequin System, Frasaco USA, Greenville, NC) containing a maxillary typodont was oriented so that Frankfort Horizontal Plane (FHP) of the phantom head corresponded with the horizon. This was done by first marking the approximate position of the supraorbital rim on the phantom head. The infraorbital rim was then marked at a point 32mm below the supraorbital rim, based on a study by Weaver et al (2010) that evaluated dimensions of the orbit. A line was drawn from the infraorbital rim to the superior aspect of the external auditory meatus of the head (this was done on the right and left sides of the phantom head). A digital protractor (Pro 360 Digital Protractor, M-D Building Products, Inc. Oklahoma City, OK) was calibrated so that horizon equaled 0.0 degrees. The phantom head was oriented so that the drawn lines were parallel to the horizon. The infraorbital foramina (IF) were also marked on the phantom head. The foramina were marked at a point that was 8.5mm inferior to approximate position of the infraorbital rim and 28mm lateral to the facial midline. These values were the averages obtained from a study by Aziz et al (2000) who investigated the anatomic location of the IF on skulls. The maxillary typodont was modified by adding wax to the teeth to create a level occlusal plane. The typodont was then attached to the phantom head. A glass slab was held against the teeth of the maxillary typodont and served as a platform for the occlusal plane. A digital protractor (Pro 360 Digital Protractor, M-D Building Products, Inc. Oklahoma City, OK) was placed against the glass slab and was used to measure the angle between the occlusal plane of the maxillary arch of the phantom head, and the FHP. This angle was measured and recorded along the sagittal (AP) and coronal (LAT) planes. The measurements were repeated and recorded two more times. Fifteen facebow records were made using five face-bow systems (Whip Mix Indirect Mounting Face-Bow (Whip Mix Corporation, Louisville, KY), Hanau™ Spring-Bow (Whip Mix Corporation, Louisville, KY), Denar® Slidematic with Quick Lock Toggle (Whip Mix Corporation, Louisville, KY), Panadent Pana-Mount ™ Face-Bow (Panadent Corp, Grand Terrace, CA) and Kois Dento-Facial Analyzer System (Panadent Corp, Grand Terrace, CA). A total of seventy-five facebow records were made on the phantom head . The maxillary typodont was then duplicated by making an impression with vinyl polysiloxane impression material (CAPSIL, GC America, Alsip IL). This process was repeated to obtain two molds of the maxillary typodont. Type III dental stone (Microstone, Whip Mix Corporation, Louisville, KY) was used to fabricate seventy-five diagnostic casts. The casts were mounted with a Specialized Stone (Mounting Stone, Whip Mix Corporation, Louisville, KY) onto the respective semi-adjustable arcon articulators using the corresponding facebow systems. The angle between the occlusal plane and the FHP was measured and recorded in the same manner as previously described. The difference between the occlusal plane orientation of the mounted maxillary casts and the occlusal plane orientation of the phantom head was evaluated. All measurements were made by two calibrated operators to reduce the risk of operator bias when making the measurements.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics (Version 20; IBM Corporation 1989, 2011.). Descriptive statistics are given as mean and standard deviation for quantitative variables. Intra-operator and inter-operator reliability when making measurements were evaluated to ensure the two operators were calibrated. An Intraclass Correlation Coefficient Reliability test was carried out on the measurements made along the sagittal and coronal planes by both operators to check the reliability of the measurements made. The Pearson Correlation Coefficient was used to verify the calibration of the two operators.

The sagittal and coronal orientation of the occlusal plane of the control and of the mounted maxillary casts were compared and evaluated for statistically significant differences using the One-Sample T-test. The mounted maxillary casts in each face-bow system group were also compared with each other for statistically significant differences using one way ANOVA test. Alpha was set at 0.05 significance level.

CHAPTER THREE

RESULTS

The Intraclass Correlation Coefficient Reliability test of the measurements made along the sagittal (AP) and coronal (LAT) planes by both operators showed high correlation of the measurements made by each operator in the sagittal and coronal orientation of the occlusal plane for each of the test groups. The Pearson Correlation Coefficients showed a high correlation between the measurements along the sagittal and coronal planes made by both operators.

Intraclass Correlation Coefficient Reliability of coronal plane measurements made by Operator 1 (TM) had an overall Intraclass correlation of 0.971 (95% Confidence Interval, $P<0.001$). The lowest correlation was seen in the Whip Mix system (0.803 (95% Confidence Interval, $P<0.001$)), followed by Pana-Mount, Kois and Hanau. The highest correlation was seen in the Denar system (0.994 (95% Confidence Interval, $P<0.001$)).

Intra-class Correlation Coefficient Reliability of sagittal plane measurements made by Operator 1 had an overall Intraclass correlation of 0.999 (95% Confidence Interval, $p<0.001$). The lowest correlation was seen in the Denar®® system (0.965 (95% Confidence Interval, $P<0.001$)), followed by Kois and Hanau. The highest correlation was seen in both the Pana-Mount and Whip-Mix systems (0.99 for both (95% Confidence Interval, $P<0.001$)).

Intraclass Correlation Coefficient Reliability of coronal plane measurements made by Operator 2 (MS) had an overall Intra-class correlation of 0.979 (95% Confidence Interval, $P<0.001$). The lowest correlation was seen in the Whip Mix system (0.862 (95% Confidence Interval, $P<0.001$)), followed by Pana-Mount, Kois and Hanau. The highest correlation was seen in the Denar®® system (0.992 (95% Confidence Interval, $P<0.001$)).

Intraclass Correlation Coefficient Reliability of sagittal plane measurements made by Operator 2 had an overall Intraclass correlation of 0.999 (95% Confidence Interval, $p<0.001$). The lowest correlation was seen in the Denar®® system (0.955 (95% Confidence Interval, $P<0.001$)), followed by Whip Mix, Hanau and Kois. The highest correlation was seen in the Pana-Mount system (0.991 (95% Confidence Interval, $P<0.001$)).

Since all measurements made by each operator showed high Intraclass correlation, the averages of all coronal plane and all sagittal plane measurements by Operator 1 and Operator 2 were formulated and compared to each other. Using the Pearson Correlation Coefficient, mean coronal plane measurements of Operator 1 and Operator 2 had a correlation of 0.92 ($P<0.001$) and mean sagittal plane measurements of Operator 1 and Operator 2 had a correlation of 0.998 ($P<0.001$). This showed the positive and significant correlation of measurements made by both operators.

Comparison of the mean difference of the test groups to the control were made by formulating the average of measurements by both operators for each group and then using the one-way analysis of variance (ANOVA) test. In the coronal plane, significant differences were observed in four of the five groups (Table 1). The mean difference was most significant in the Kois system (P=0.000), followed by the Hanau (P=0.001), Whip Mix (P=0.001) and Pana-Mount (P=0.024) systems. No significant difference from the control was observed in the Denar system (P=0.114).

Table 1. Test Group comparison to Control – Coronal orientation.

Group	Control Value = 2.2 degrees				95% Confidence Interval of the Difference	
	Mean (degrees)	Std. Deviation	P-Value	Mean Difference (degrees)	Lower	Upper
Kois	.8178	.43976	.000	-1.38222	-1.6258	-1.1387
Whip Mix	1.7667	.39345	.001	-.43333	-.6512	-.2154
Hanau	1.6500	.51397	.001	-.55000	-.8346	-.2654
Pana-Mount	1.9156	.43568	.024	-.28444	-.5257	-.0432
Denar	1.8922	.70710	.114	-.30778	-.6994	.0838

Comparing the mean difference of the test groups to the control in the sagittal plane, significant differences were observed in three of the five groups (Table 2). The mean difference was most significant in the Denar system (P=0.000) and the Kois system (P=0.000) with the mean difference compared to the control being greater in the Denar system. Significant differences were also observed in the Whip Mix system (P=0.01). No significant differences from the control were observed in the Hanau system (P=0.406) and Pana-Mount system (P=0.849).

Table 2. Test Group comparison to Control – Sagittal orientation.

Group	Control Value = 7.9 degrees				95% Confidence Interval of the Difference	
	Mean (degrees)	Std. Deviation	P-Value	Mean Difference (degrees)	Lower	Upper
Denar	1.7944	.44049	.000	-6.10556	-6.3495	-5.8616
Kois	5.9411	.42575	.000	-1.95889	-2.1947	-1.7231
Whip Mix	8.9044	.91345	.001	1.00444	.4986	1.5103
Hanau	7.7956	.47248	.406	-.10444	-.3661	.1572
Pana-Mount	7.8733	.53318	.849	-.02667	-.3219	.2686

Inter-group comparison was then done comparing the average of measurements by both operators for each group using the repeated-measures analysis of variance (ANOVA) test. Comparison between the mean coronal plane measurements of the test groups showed significant differences between the groups (95% Confidence Interval, P<0.001)(Table I). The greatest difference was observed in the Kois system which had a significantly lower mean coronal plane measurement (0.8178 degrees, 95% Confidence Interval, P<0.001) than the other groups (Figure 1). This implies that coronal inclination of the occlusal plane of the mounted casts in the Kois system was significantly lower than the coronal inclination of the occlusal plane of the mounted casts in the other test groups. The means of the other test groups had smaller differences with overlapping regions indicating the absence of significant differences in those areas.

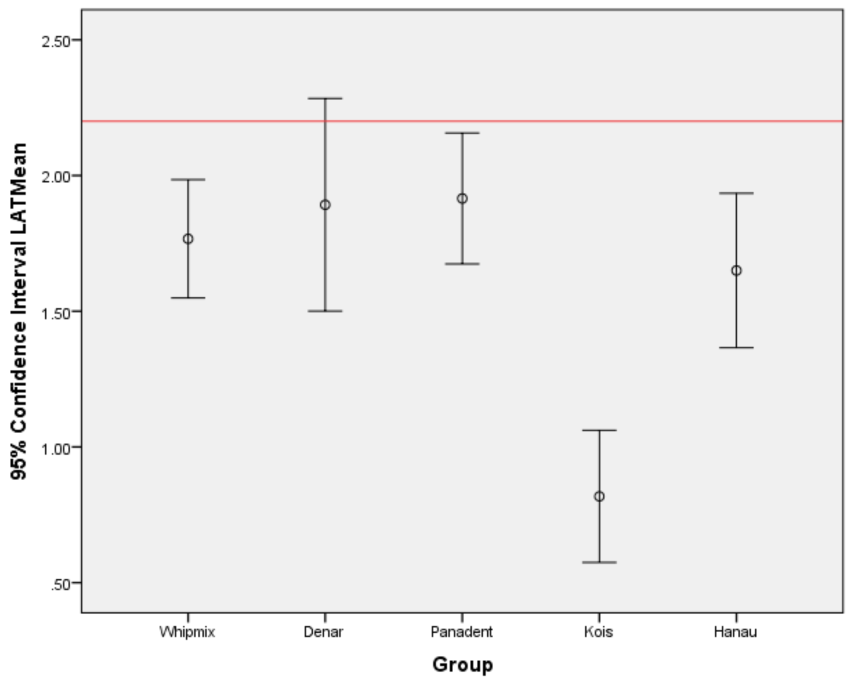

Figure 1. Inter-Group comparison – Coronal orientation.

Comparison between the mean sagittal plane measurements of the test groups showed significant differences between the groups (95% Confidence Interval, P<0.001)(Table 2). The greatest difference was observed in the Denar system which had a significantly lower mean sagittal plane measurement (1.79 degrees, 95% Confidence Interval, P<0.001) than the other groups (Figure 2). This implies that sagittal inclination of the occlusal plane of the mounted casts in the Denar system was significantly lower (flatter) than the coronal inclination of the occlusal plane of the mounted casts in the other test groups. The means of the other test groups had greater differences compared to the coronal plane measurements. The Pana-Mount and Hanau systems had similar means with overlapping regions indicating the absence of significant differences in those areas.

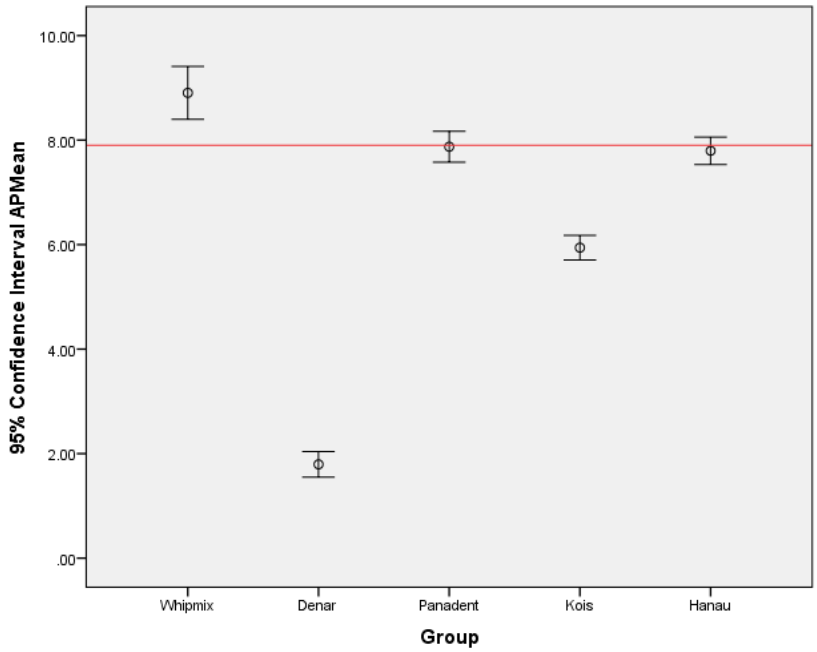

Figure 2. Inter-Group comparison – Sagittal orientation.

When comparing standard deviation of the test groups in the coronal plane, the Denar system had the largest standard deviation, followed by the Hanau, Kois and Pana-Mount systems. The Whip Mix system had the lowest standard deviation in the coronal plane. When comparing standard deviation of the test groups in the sagittal plane, the Whip Mix system had the largest standard deviation, followed by the Pana-Mount, Hanau and Denar systems. The Kois system had the lowest standard deviation in the sagittal plane.

The occlusal plane orientation of the test groups to that of the control showed significant differences in four of the five test groups in the coronal plane. The only group without a significant difference compared to the control was the Denar system. In the sagittal plane, significant differences were observed in three of the five test groups compared to the control. The Pana-Mount and Hanau systems did not show a significant difference compared to the control. The mean differences of each group compared to the control inversely correlated with the level of significance of the difference between the test group and the control. In the sagittal plane measurements the Pana-Mount system showed the smallest mean difference compared to the control (0.026 degrees), which had the lowest significance (P=0.849). The Denar system showed the largest mean difference compared to the control (6.105 degrees), which had the highest significance (P=0.000). The Kois system had an equally significant difference compared to the control (P=0.000) though the mean difference compared to the control (1.958 degrees) was smaller than the Denar system's. In the coronal plane measurements the Pana-Mount system showed the smallest mean difference compared to the control (0.284 degrees), but it was the Denar system which had the lowest significance (P=0.024). The Kois system showed the largest mean difference compared to the control (1.382 degrees), which had the highest significance (P=0.000).

CHAPTER FOUR

DISCUSSION

The first null hypothesis was rejected, as significant differences in the sagittal and coronal orientation of the occlusal plane in the test groups were observed, but not in all test groups. Significant differences were not observed in the Denar system in the coronal plane, nor in the Hanau and Pana-Mount systems in the sagittal plane. Inter-group comparisons revealed significant differences in the sagittal and coronal orientation of the occlusal plane.

Two operators were used to collect the data for this study to reduce the risk of operator bias during data collection. The highly positive Intraclass Correlation Coefficient Reliability for both operators validated the consistency of the measurements made by each operator. The Pearson Correlation Coefficient validated the highly positive and significant correlation of measurements made by both operators when compared to each other. This confirmed the calibration of both operators for the data collection of this study.

The ranking of the intraclass correlation of the test groups in the coronal plane were identical for both operators. The ranking of the intraclass correlation of the test groups in the sagittal plane were very similar – the groups with the lowest and highest correlation were the same for both operators. This further validates the consistency of the data collected by both operators.

The occlusal plane orientation along the coronal plane for all test groups showed a reduced cant in comparison to the control. The facebow system that most accurately replicated the cant of the control was the Denar system. The largest deviation from the cant of the control was observed with the Kois system, which produced a significantly reduced cant along the coronal plane in comparison to the control.

The occlusal plane orientation for all test groups showed variations in the sagittal inclination of the occlusal plane in comparison to the control. The facebow system that most accurately replicated the control was the Pana-Mount. The Denar system produced a decreased sagittal inclination of the occlusal plane when compared with the control group . The Whip Mix system was the only test group that showed a significantly steeper sagittal inclination of the occlusal plane compared to the control.

Standard deviations within the test groups showed variations in ranking in both coronal and sagittal planes. The Whip Mix system displayed the lowest standard deviation in the coronal plane. The Denar system showed the highest standard deviation in the coronal plane. In the sagittal plane, the Kois system showed the lowest standard deviation. The Whip Mix system showed the highest standard deviation in the sagittal plane. The Whip Mix system therefore showed both the lowest standard deviation in the coronal plane and the highest standard deviation in the sagittal plane.

O'Malley et al.[13] compared the steepness of occlusal plane in three different articulators: Whip Mix, Denar and Dentatus. They observed that Whip Mix was closest to the gold standard (cephalogram) and flattened the occlusal plane by only 2°. The results of the Denar and Dentatus differed significantly from those of the cephalogram as they flattened the occlusal plane by 5° and 6.5° respectively. These results for Whip Mix differed from those in the present study, where Whip Mix demonstrated a significantly different, steeper occlusal plane from the control.

Abdullah et al.[14] compared the steepness of the occlusal plane on Whip Mix and Hanau-H2. They found that the steepness of the occlusal plane of the cast when mounted on Whip Mix was significantly greater than the cast mounted on Hanau-H2. These findings are in agreement with the present study, where the steepness of the occlusal plane was greater for Whip Mix than Hanau. However, Abdullah et al.'s study did not include comparison to a control.

Paul et al.[15] compared the sagittal orientation of the occlusal plane on a Dentatus semi-adjustable articulator system and a customized orthognathic articulator system. There was a statistically significant difference between the two systems; the orthognathic system showed small random errors, the Dentatus showed systematic errors of up to 28 degrees. In comparison, the present study showed a smaller variation in sagittal occlusal plane orientation of the mounted casts.

Nazir et al.[16] evaluated the sagittal inclination of mounted maxillary casts on two semi-adjustable articulator/face-bow systems (Hanau and Girrbach) in comparison to the occlusal cant on lateral cephalograms. Sagittal inclination of the cast with the Hanau articulator was closer to the cephalometric occlusal cant. The steepness of sagittal inclination was greater on the Girrbach semi-adjustable articulator. In the present study Hanau did not have any significant difference in sagittal orientation of the occlusal plane compared to the control.

Ramasamy et al.[17] compared the variations in the inclination of occlusal plane of casts mounted on a Girrbach articulator using a facebow with a fixed value and customized nasion indicator. They evaluated 22 patients and found that variation in occlusal plane was very minimal and close to the cephalometric value when using the customized nasion indicator compared to fixed value nasion indicator on the Girrbach articulator. In comparison to the present study, Ramasamy et al. report higher standard deviations in the angle of the occlusal plane to Frankfort Horizontal. This could be attributed to anatomic variations in the patients.

Galanis et al.[18] compared the accuracy and reliability of the Pana-Mount Pana-Mount to the Kois Dento-Facial Analyzer System for locating and trasferring the hinge axis to articulator. 14 patients were evaluated. The Pana-Mount facebow was found to be more accurate as compared to the Kois Dento-Facial Analyzer for reliability and accuracy and may serve better when occlusal function is a primary concern. The simplicity of the use of Kois Dento-Facial Analyzer did not improve the accuracy of mounting the maxillary cast onto the articulator. In the present study, significant differences were noted in the sagittal and coronal orientation of the occlusal plane between the Kois Dentofacial Analyzer system and the control.

Literature supports that accurate transfer of orientation of the occlusal plane can significantly affect esthetics and function. It also has implications in the field of orthognathic surgery.

The effect of the occlusal plane on function was evaluated by Okane et al.,[19] who investigated the effect of anteroposterior inclination of the occlusal plane on muscle activity during clenching and biting force. He reported that biting force and efficiency of biting force exertion was the greatest when the occlusal plane was made parallel to the ala-tragus line. Muscle activity during clenching at various given forces was least when the occlusal plane was made parallel to the ala-tragus line.

Ogawa et al.[20] compared the inclination of the occlusal plane with occlusal guidance as a contributing factor to masticatory movement. The contribution of the inclination of the occlusal plane to masticatory movement was greater than that of occlusal guidance throughout the closing phase except near the intercuspal range.

O'Malley et al.[13] discussed the implications of inaccurate occlusal plane orientation in the field of orthognathic surgery. During model surgery, planning errors may occur if the articulator incorrectly reproduces the occlusal plane. For every 1° that the occlusal plane is flattened on the articulator compared with reality, the upper incisors look 1° more proclined and lower incisors 1° more retroclined on the articulator. The relevance of correct replication of the angle on the articulator has consequences on maxillary movements and mandibular autorotation.

The effect of the occlusal plane on esthetics was discussed by Pitchford[21], who stated that failure to accurately transfer the occlusal plane can result in complete dentures with an occlusal plane in which the maxillary posterior teeth seem to hang below the anterior teeth. It could also cause unnatural axial inclinations of the maxillary anterior teeth in both complete dentures and in fixed partial dentures.

Kattadiyil et al.[22] assessed the esthetic preferences of dental professionals and nondentists using three viewing angles of the anteroposterior orientation of the maxillary occlusal plane. They reported that the viewing angle impacted the esthetic preference for the maxillary occlusal plane.

Batwa et al.[23] determined the influence of the occlusal plane angle on smile attractiveness as perceived by a group of adult orthodontic patients and dentists. Changing the occlusal plane angle does affect relative smile attractiveness.

Stade[24] reported that inaccurate occlusal plane transfer could cause the maxillary cast to exhibit unnatural cants when viewed in reference to the horizontal plane. This distortion of the cast may not be recognized by the dental laboratory technician who develops the preliminary anterior esthetics and occlusal plane using the horizontal reference plane, i.e., his bench surface. The error may not be discernible until the prosthesis is placed in the mouth and it is evidenced by an incorrect cant to the incisal and occlusal planes. This inaccurate transfer of the orientation of the occlusal plane could potentially be misleading when restorations are being waxed up or fabricated in the laboratory. This could be overcome by try-in of provisional restorations which could be corrected as needed. However, the goal should be accurate transfer of occlusal plane orientation to maximize precision and minimize clinical chair-time for restoration placement.

CHAPTER FIVE

CONCLUSIONS

Within the limitations of the present study, the following conclusions were drawn:

1. Variations in the orientation of the occlusal plane were observed in the test groups.
2. Compared to the control group, four out of the five test groups displayed significant differences in the coronal orientation of the occlusal plane. These groups were the Kois, Whip Mix, Hanau and Pana-Mount systems. The Denar system did not display significant differences in the coronal orientation of the occlusal plane compared to the control group.
3. Compared to the control group, three out of the five test groups displayed significant differences in the sagittal orientation of the occlusal plane. These groups were the Denar, Kois and Whip Mix. The Pana-Mount and Hanau systems did not display significant differences in the coronal orientation of the occlusal plane compared to the control group.
4. Among the test groups, inter-group comparison showed significant differences with the coronal and sagittal plane orientations. The Kois system showed the greatest difference, having a decreased coronal plane orientation. The Denar system showed the greatest difference, having a decreased sagittal plane orientation.

REFERENCES

Abdullah M A, Sherfudhin H. A comparative study of facebow transfer on Hanau and Whip Mix articulators. Saudi Dent J 1994;6:8-12.

Aziz SR et al. Anatomic characteristics of the infraorbital foramen: a cadaver study. J Oral Maxillofac Surg. 2000 Sep;58(9):992-6.

Bailey JO, Nowlin TP. Accuracy of the Frankfort plane transfer of the Hanau articulator. J Dent Res 1981;60(special issue): Abstract 885;531

Batwa W, Hunt NP, Petrie A, Gill D. Effect of occlusal plane on smile attractiveness. Angle Orthod. 2012 Mar;82(2):218-23.

Brandrup-Wognsen T. The face-bow, its significance and application. J Prosthet Dent. 1953 Sep;3(5):618-630.

Christiansen RL. Rationale of the face-bow in maxillary cast mounting. J Prosthet Dent. 1959 May-June;9(3): 388-398.

Craddock FW, Symmons HF. Evaluation of the Face-bow. J Pros Dent (2); 633-642, 1952.

Galanis A, Ali M, Belles D, Koeppen RG. A comparison of facebow and dentofacial analyzer mountings. Tex Dent J. 2013 Oct;130(10):1047-53.

Gold BR. An investigation of the reproducibility of face-bow transfers. J Oral Rehab. 1983; 10: 495-503.

Goska JR, Christensen LV. Comparison of cast positions by using four face-bows. J Prosthet Dent. 1988 Jan;59(1):42-44.

Kattadiyil MT, Goodacre CJ, Naylor WP, Maveli TC. Esthetic smile preferences and the orientation of the maxillary occlusal plane. J Prosthet Dent. 2012 Dec;108(6):354-61.

Logan JG. Indispensability of the Face-Bow and the effect of a short radius Full and Partial Denture Construction. D. Digest. 32: 537-42. 1926.

Nazir N, Sujesh M, Kumar R, Sreenivas P. Accuracy of two face-bow/semi-adjustable articulator systems in transferring the maxillary occlusal cant. Indian J Dent Res. 2012 Jul-Aug;23(4):437-42.

O'Malley AM, Milosevic A. Comparison of three facebow/semi-adjustable articulator systems for planning orthognathic surgery. Br J Oral Maxillofac Surg 2000;38:185-90.

Ogawa T, Koyano K, Umemoto G. Inclination of the occlusal plane and occlusal guidance as contributing factors in mastication. J Dent. 1998 Nov;26(8):641-7.

Okane H, Yamashina T, Nagasawa T, Tsuru H. The effect of anteroposterior inclination of the occlusal plane on biting force. J Prosthet Dent. 1979 Nov;42(5):497-501.

Paul PE, Barbenel JC, Walker FS, Khambay BS, Moos KF, Ayoub AF. Evaluation of an improved orthognathic articulator system: 1. Accuracy of cast orientation. Int J Oral Maxillofac Surg. 2012 Feb;41(2):150-4.

Pitchford JH. A re-evaluation of the axis-orbital plane and the use of orbitale in a facebow transfer record. J Prosthet Dent. 1991 Sep;66(3):349-55.

Ramasamy M, Karthigeyan S, Giri TC, Rajendran V, Shetty A, Deivanai M. Evaluation of the inclination of maxillary occlusal plane on mounted casts using a fixed value and customized nasion indicator in artex articulator: Facebow system - An in-vivo comparative study. J Pharm Bioallied Sci. 2013 Jun;5(Suppl 1):S54-9.

Schallhorn RG. A study of the arbitrary center and the kinematic center of rotation for face-bow mountings. J Prosthet Dent. 1957 Mar;7(2):162-169.

Stade EH, Hanson JG, Baker CL. Esthetic considerations in the use of face-bows. J Prosthet Dent. 1982 Sep;48(3):253-6.

The glossary of prosthodontic terms. J Prosthet Dent. 2005 Jul;94(1):10-92.

Weaver AA, Loftis KL, Tan JC, Duma SM, Stitzel JD. CT based three-dimensional measurement of orbit and eye anthropometry. Invest Ophthalmol Vis Sci. 2010 Oct;51(10):4892-7.

Weinberg LA. An evaluation of the face-bow mounting. J Prosthet Dent. 1961 Jan-Feb;11(1):32-42.

Yanus M. Comparison of a universal mounting jig to a face-bow. J Prosthet Dent. 1983 May;49(5): 623-627.