Comparison of specific jaw position measurements on a static and dynamic virtual patient.

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COMPARISON OF SPECIFIC JAW POSITION MEASUREMENTS ON A STATIC AND DYNAMIC VIRTUAL PATIENT

By

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B.A., University of Mississippi

A Thesis
Submitted to the faculty of the School of Dentistry at the University of Louisville in Partial Fulfilment of the Requirements for the Degree of

Master of Science
In Oral Biology

Department of Oral Biology
University of Louisville School of Dentistry
Louisville Kentucky

May 2024
COMPARISON OF SPECIFIC JAW POSITION MEASUREMENTS ON A STATIC AND DYNAMIC VIRTUAL PATIENT

By

Payton Lofton

A Thesis Approved on

May 3, 2024

by the following Thesis Committee:

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Gustavo Santaella

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Christiano de Oliveira Santos

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Kathleen Fischerer Name
ACKNOWLEDGEMENTS

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ABSTRACT

COMPARISON OF SPECIFIC JAW POSITION MEASUREMENTS ON A STATIC AND DYNAMIC VIRTUAL PATIENT

Payton M. Lofton

May 3, 2024

This study aimed to compared the differences in jaw position measurements in protrusive and open/close positions on a static virtual patient created using 3dMD System to those from a dynamic articulation of a virtual patient (MODJAW) as well as measurements between the Cadiax and MODJAW. Six fiducial surface markers were placed on a volunteer subject’s face and dynamic facial scans of protrusive and open/close jaw movement acquired and exported. A CBCT scan was also acquired. The mandible and maxilla were segmented and loaded into Vultus and aligned to the facial scan using the fiducial markers. Results were compared using a paired t-test (p<0.05). Cadiax recordings were taken separately.

There were no statistically significant differences between the static and dynamic techniques of virtual articulation. The average percentage difference between techniques for protrusive motions is high, possibly due to the influence of soft tissue flexibility and adaptability during motion.
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CHAPTER 1: INFORMATION & BACKGROUND

Accurate simulation of human mandibular movement is fundamental in diagnosis and treatment planning in dentistry. However, mandibular movement is very complex, so it is not easily and accurately recorded.¹ Often the path of the mandible in various excursions is simplified to rotation around one single axis.¹ Since this is not the true path of motion of human jaws, this representation can lead to completion of dental work with improper occlusion². Traditionally stone models on dental articulators have been used to visualize occlusion and fabricate diagnostic, therapeutic, and restorative appliances.² The occlusal anatomy of any restoration must accommodate the movement of the antagonist teeth without interfering with the movement of mandible³. Further, when determining occlusion for restorative appliances, horizontal forces on the prosthesis should be minimized. Traditional articulators do not properly anticipate these forces due to their simplification around one axis.⁴

Traditional articulators are mechanical devices that represent the temporomandibular joint and jaw members, to which maxillary and mandibular casts may be attached using a facebow record. Analog based articulators can be fixed, semi-adjustable or even fully adjustable. Fully adjustable articulators are complex devices allowing the clinical scenario to be most closely reproduced. They will accept three-dimensional dynamic registration. These instruments allow for orientation of the casts to the T.M.J. and replication of all mandibular movements. Instead of flat tracks and
planes that reproduce the condylar movements on semi-adjustable articulators, fully adjustable articulators have further components that can be adjusted and use curved condylar inserts that can more accurately reproduce the three-dimensional nature of the movement of the condyles. These articulators require more complex information and time to program them, as well as external recordings are needed. In general, practitioners mostly use average articulator values on semi-adjustable articulators on patient’s simplifying movements around one axis on traditional articulators. This can allow for more errors in prosthesis fabrication leading to more chair side adjustments taking more time.\textsuperscript{5}

Most recently fully adjustable “digital articulation” jaw tracking devices have been introduced into dentistry that provide virtual dynamic or 4D (i.e., motion) articulation of digital diagnostic records (dental casts) and potentially incorporating true maxillofacial skeletal components acquired using cone beam computed tomography (CBCT). The basic system of the virtual articulator generates an animation of the movements of the mandible based on the input data and calculates the points of occlusion which are shown on the screen.\textsuperscript{6} Virtual articulators can show the effects of soft tissue during muscular movements of chewing or eating that traditional articulators do not.\textsuperscript{6} Virtual articulators also reduce inaccuracies while making interocclusal registration with materials prone to deformation and accurate repositioning of the master cast into bite impression without leaving any space.\textsuperscript{3}

One such system of virtual articulation is MODJAW (MODJAW, Place Bellecor, Lyon, France). This system is used worldwide and shown to be reproducible. The repeatability of this system was found to be good to excellent when measuring both
sagittal condylar inclination and transversal condylar inclination relative to the real hinge axis. We used this system as a “proof of concept” comparing it to other articulation and virtual patient methods available at the University of Louisville School of Dentistry (ULSD).

We aimed to recreate a virtual patient using technology already present at ULSD using the 3dMD Facial Scanner (Atlanta, GA) and the Vultus software (Atlanta, GA). We compared these results to the MODJAW system.

Additionally, we compared the MODJAW measurements to The Cadiax system (Louisville, KY). This system is an analog pantographic system that records the jaw's lateral excursion and protrusive movements using a facebow-like apparatus producing 2D graphs in each plane – X, Y, and Z. It can be programmed to give settings for the traditional articulator to be more like patient’s occlusion via condylar anatomy and movement.
CHAPTER 2: METHODS

The MODJAW system was provided to Dr. Gerald Grant, University of Louisville School of Dentistry on consignment from the manufacturer for a limited 6-week period. Training was provided to the principal investigator (PI) and co-investigators (Co-I) via an online meeting. As this is a “proof of concept” project and the software was only available for a limited amount of time, the system was tested on 4 participants who were co-investigators. The process of creating a virtual patient began with taking an intraoral scan using the Trios system (3Shape A/S, Holmens Kanal 7, 1060 Copenhagen K, Denmark) (Figure 1). The resulting files were transferred over to the MODJAW system. A CBCT was acquired and then segmented into separate Maxilla and Mandible on Mimics 24.0 (Materialise NV, Leuven, Belgium, 1992–2015). MeshLab (Visual Computing Lab, ISTI - CNR, Pisa Italy) was used to align the segmented CBCT with the intraoral scan using a point meshing technique. Then the segmented and aligned CBCT was imported to the MODJAW system where it was merged with the MODJAW’s data creating a 4D virtual patient meshing an intraoral scan and motion tracking from MODJAW’s camera.

The MODJAW image capturing was then completed. This system required placing a tiara on the head that contains movement trackers and adhering a mandibular tracker on (Figure 2). We used composite to attach the mandibular tracker to the buccal surfaces of mandibular teeth (no etching and bonding). Excess resin was removed to not interfere
with occlusion. After placing the trackers, the reference points were identified (the cutaneous condylar, sub-nasal and five mandibular dental reference points). Movements of protrusion, right and left laterotrusion, maximum open/close, and chewing (wax) were recorded on each patient.

Prior to that the CBCT was taken with 7 fiducial markers placed on each participants face (Figure 3). After acquisition of the CBCT scans, the subjects were immediately moved to 3DMD (3dMD Inc., Atlanta, GA, USA) facial scanner so that the fiducial markers were in the same spots for proper alignment. This is for the process meshing a CBCT with the 3DMD scan to create a virtual patient with maxillofacial skeletal components on the Vultus software. The Maximum opening and protrusion were selected from 3dMD and imported into Vultus and manually aligned with fiducial markers.

After, measurements in the fully open and most protruded position were acquired from both systems. Results were compared using a paired t-test (p<0.05).

At an alternative time, the Cadiax system was also used to record measurements for each patient. The Cadiax required the facebow-like system to be correctly attached to the patient so that the system could do the readings (Figure 4). The Bennett angle and condylar guidance angles were determined for this system for a hanau articulator and compared to the measurements obtained using the MODJAW.
Figure 1: Trios intraoral scan being taken

Figure 2: MODJAW tiara and mandibular tracker adhered during recording

Figure 3: CBCT taken with fiducials

Figure 4: Cadiax during recording
CHAPTER 3: RESULTS AND DISCUSSION

For part one of the project, MODJAW worked as it was described, and we were able to obtain virtual patients with occlusion demonstrated.

Comparing the MODJAW and 3dMD there were no significant differences \( p=0.2209 \) found in jaw maximal opening measurements between MODJAW \((34.25 \text{ mm} \pm 6.55)\) (Figure 5) and 3dMD \((31.47\text{ mm} \pm 6.80)\) (Figure 6) – the average percentage difference was 8.46%. While the average percentage difference in jaw protrusive measurements was 53.59%, no significant differences \( p=0.0898 \) were found between MODJAW \((5.25\text{ mm} \pm 1.50)\) and 3dMD \((9.093\text{ mm} \pm 3.749)\).
Fig 5: MODJAW maximum opening
Figure 6: 3dMD face scan stationary image chosen at maximum opening aligned with segmented CBCT scan and measured using the measurement tool on Vultus.
Figure 7: MODJAW Maximum protrusion

Figure 8: Maximum protrusion of 3dMD face scan aligned with the CBCT scan using Vultus.
<table>
<thead>
<tr>
<th></th>
<th>MODJAW</th>
<th>3dMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>7</td>
<td>9.81</td>
</tr>
<tr>
<td>S2</td>
<td>4</td>
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<td>S3</td>
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<td>13</td>
</tr>
<tr>
<td>S4</td>
<td>4</td>
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Table 1: Values for maximal protrusion

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<th>3dMD</th>
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</thead>
<tbody>
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</tr>
<tr>
<td>S2</td>
<td>39</td>
<td>27</td>
</tr>
<tr>
<td>S3</td>
<td>26</td>
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</tr>
<tr>
<td>S4</td>
<td>32</td>
<td>34.34</td>
</tr>
</tbody>
</table>

Table 2: Values for maximal open and closing

One of the drawbacks of the MODJAW system is the selection of the reference points. This allows for some
variance due to human error. Further the 3dMD allows for more error due to the
difference of hard and soft tissue movement of the fiducials. Additionally, manually
aligning via the Vultus software allows for variation.

The second part of the project, to verify the MODJAW readings with an already
used Cadiax system the complete assessment has been recorded for 4 subjects. It was
noted that the average difference between the two methods was 2.7° for the left condyle
and 5.7° for the right when subject 2 was excluded for the angle of movement of the
condyle from both the MODJAW and the Cadiax, this subject was determined to have an
internal derangement of the left articulation as both methods indicated that there was
minimal condylar translation on opening.
Figure 9: Cadiax recording data sheet for subject in a Hanau Modular Articulator
One subject (#2) was determined to have an internal derangement of the left articulation as both methods indicated that there was minimal condylar translation on opening.

A last goal for this project was to recreate motion on the 3dMD Vultus software to see if we could create a virtual patient with software we currently have at ULSD. It is in the parameters of the Vultus software to be able to include motion; however, after a
multitude of attempts and contacting the company we were unable to have our virtual patients move on this software.
CHAPTER 4: CONCLUSION

Between the MODJAW and 3dMD system there was no statistically significant differences between the static and dynamic techniques of virtual articulation. The average percentage difference between techniques for protrusive motions is high, possibly due to the influence of soft tissue flexibility and adaptability during motion.

The results from the MODJAW 4D system is comparable to the Cadiax Compact 2.0 system for most assessments. While some discrepancies exist between the average left and right condylar metrics, both methods identified a subject specific derangement. Further investigation is needed to correctly interpret results.

More research is suggested to recreate a virtual patient with dynamic occlusion using the 3dMD software.
REFERENCES


CURRICULUM VITAE
Payton M. Lofton

EDUCATION

University of Louisville School of Dentistry (ULSD) *(Louisville, KY) Aug 2020- May 2024*

   Doctor of Medicine in Dentistry Candidate

   Master of Science in Oral Biology Candidate *(MSOB)* Aug 2020- May 2024

University of Mississippi *(Oxford, MS) Aug 2016 – May 2020*

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CONFERENCE PRESENTATIONS

Presentation Title: *Comparison of Specific Jaw Position Measurements on a Static and Dynamic Virtual Patient*

27th Hinman Student Research Symposium October 2022 *(Memphis, TN)*

*KY AADOCR September 2022* *(Louisville, KY)*

*Research! Louisville October 2021 and September 2022*
LEADERSHIP, INVOLVEMENT, & SERVICE

Tau Sigma, Louisville Chapter

- Led an organization of 30 members, overseeing the execution of numerous events, information sessions, and fundraisers.

Secretary May 2021 – May 2022

- Took meeting minutes and helped organize numerous events, fundraisers, and information sessions.

ULSD Course Representative

Duties of the Course Representative include ensuring efficient clinic workflow and understanding within the course, conducting student polls, organizing exam dates and lab sessions, and communicating with the course director.

- Preclinical Occlusion and TMD Aug 2021-Dec 2021
- Ethical Issues in Dentistry Jan 2023-May 2023