Relationship between craniocervical orientation and center of force of occlusion in adults

Curtis D. Westersund DDS\textsuperscript{a}, Jeffrey Scholten DC, DCCJP, BSc\textsuperscript{a} and Raymond J. Turner PhD\textsuperscript{b}

\textsuperscript{a}Private practice, Calgary, Canada; \textsuperscript{b}Department of Biological Sciences, University of Calgary, Calgary, Canada

\textbf{ABSTRACT}

\textbf{Objective}: Clinical observation and anecdotal reports suggest changes can occur to dental occlusion following intervention with the National Upper Cervical Chiropractic Association (NUCCA) procedure. This case controlled study discerned if occlusion changes are measurable using a dental force plate (T-Scan\textsuperscript{TM}) following an adjustment to the craniocervical junction (CCJ).

\textbf{Methods}: A degree of case control was established by active patients being assessed twice prior to and following intervention. Before–after intervention assessment included posture evaluation and dental occlusion (T-Scan\textsuperscript{TM}).

\textbf{Results}: Findings suggest that changes in posture and occlusion can be observed after the NUCCA chiropractic procedure. Not all patients demonstrated a more balanced contact pattern following the adjustment, indicating a need for further investigation.

\textbf{Discussion}: These findings may suggest interconnectivity between the CCJ and an individual's occlusal contacts and support the need for further integration between chiropractors and dentists seeking to co-manage temporomandibular joint disorders.

\textbf{Introduction}

The craniocervical junction (CCJ) consists of the kinematically complex connection between the skull and the first two cervical vertebrae, also referred to as the occipital-atlanto-axial (OAA) joint complex. The joints connecting these vertebrae create a functional unit that facilitates the majority of the movement of the CCJ. The temporomandibular joint (TMJ) is also a kinematically complex bilateral connection between the mandible and the temporal bones of the skull. If the CCJ is displaced from its normal neutral juxtaposition, and the positional neutral is no longer attainable by the head, this malposition is directly transferred to the temporal portion of the TMJ, creating a potential for a shift in occlusal contact.\cite{1}

The function of the TMJ is to help guide and stabilize the movement of the mandible relative to the maxilla, and the TMJ is the only joint in the body with a set terminal end point in flexure adduction: the occlusion of the maxillary and mandibular dentition. The occlusal terminal set point determines how and where the condyle is positioned within the articular fossa of the temporal bone. As head position influences the position of the temporal portion of the TMJ in space, the muscles of the head and neck complex must be considered to hold sway over the movement of the mandible through alteration in the position of the head. Any change to the occlusion will require a change in the activity of all of the muscles of mastication, including the muscles associated with the head and neck. The biomechanical interaction between the occlusal forces upon clenching and the position and balance of the CCJ may be more intimate than previously thought. Considered in the present study is whether the alteration to the CCJ affects occlusion and if it can be measured effectively.

Practitioners who utilize The National Upper Cervical Chiropractic Association (NUCCA) (\texttt{www.nucca.org}) procedures treat the CCJ as a functional unit in an attempt to restore all components of the complex to a more appropriate neutral and orthogonal orientation.\cite{2} This structural repositioning of the cranial component of the CCJ is translated directly to the cranial components of occlusion.

Recently, innovative integration of care between dentists treating temporomandibular joint dysfunction (TMD) and chiropractors focused on treating disorders of the CCJ has developed as clinicians seek novel and effective integrative
patient management strategies. This study uses the NUCCA procedure on established patients and a bite force plate (T-scan®, Tekscan Inc., South Boston, MA, USA) to evaluate the changes to the occlusion resulting from intervention at the CCJ. The authors posed the question of whether there is a relationship between craniocervical orientation and center of force of occlusion in adults that can be measured. The authors noted that there is no specific research in this area, and therefore, proposed this preliminary study.

Methods

Clinical assessment protocol

This protocol received ethics approval by the University of Calgary Conjoint Health Research Ethics Board (Ethics ID: 13-1372).

The strategy of this experiment was to use the patients as their own control through collecting multiple measurements pre- and post-treatment; this allowed the acquisition of both a baseline and a trend. Because an individual’s muscular architecture, occlusal arrangement, and cervical alignment are unique, each subject was used as his/her own control so the comparisons could be made within each patient.

The study utilized 11 volunteer patients who presented to the chiropractic clinic as part of their regular supportive care and demonstrated CCJ misalignment the day of or the day before the study. No invited subject declined to participate. There was no selection bias as to age, gender, socioeconomic status, or health status. Each patient was assessed four times within 90 min. The initial baseline chiropractic and dental assessments were performed twice prior to the chiropractic intervention. Following the NUCCA adjustment, the assessments were performed in the same fashion twice more. Although all patients were treated by the NUCCA practitioner, the dentist was kept blind as to whether a patient was treated and the degree of measured improvement.

The total time for an assessment cycle was 22.5 min, equally divided into three 7.5-min steps: a rest period, a chiropractic assessment, and a dental assessment. Each step occurred in a separate room, keeping the practitioners blinded from each other’s findings. During Step 1, the participant was instructed to rest in a semi-reclined position. Following this rest time, and during Step 2, the subject attended a typical NUCCA assessment with their current chiropractor using standardized protocols. In Step 3, the patient was assessed by the dentist, where three separate bite force scans were taken. A second assessment cycle was immediately repeated exactly as described above. During the third assessment cycle, the only procedural alteration was that prior to the NUCCA assessment, the patient received a NUCCA adjustment; otherwise, the third and fourth round of assessments used the exact same methods as in the pre-treatments.

Chiropractic assessment

The NUCCA procedure involves the analysis of precisely taken radiographic images of the head and neck to determine an individualized vectored chiropractic intervention. The NUCCA practitioner utilizes an upper cervical low force hand adjustment to return the components of the CCJ toward a more neutral position. Pre- and post-intervention assessment procedures were consistent with the published standards of care of NUCCA [4] (supine leg check, paraspinal thermographic reading, and postural analysis). The supine leg length discrepancy was recorded utilizing NUCCA protocols.[5] Paraspinal thermography was performed in the cervical spine using the Titron instrument (Titron Industries Ltd., Kowloon, Hong Kong), which detects and compares radiant heat bilaterally, and the data were analyzed using MyoVision software (Seattle, WA, USA).[6,7] Head orientation data were collected by measuring the frontal and transverse plane positional angles and the anterior–posterior translation. Both postural position and head orientation data were evaluated by the Gravity Stress Analyzer (The Upper Cervical Store Inc., Campbell River, BC, Canada).[8] The Gravity Stress Analyzer utilizes calipers and an independent instrument, which contains protractors and inclinometers to obtain the measurements. Measurements were collected on the position of the head, shoulders, and hips of the subjects, and a total posture score was calculated by summing the degrees and centimeters of the deviations from neutral posture.

Dental assessment

The T-Scan® Occlusal Analysis System was used to assess the occlusal force as well as the ‘force to tooth’ distribution as the subject bit and clenched on the force plate, which was inserted into their mouth prior to each dental assessment. The force plate is an ultra-thin reusable sensor shaped to fit the dental arch; this device allows for a more accurate digital recording of the timing and force measurement of occlusal contact than the more traditional dental tools of paper, wax, or pastes (Figure 1).[9]

Patients provided three consecutive bites in order to obtain an appropriate representation of bite dynamics. Such parameters as full clench force, center of force, initial contact, force development, movement of center of force during bite, and individual tooth forces during bite were all collected with the T-Scan®. The authors chose to keep the threshold equal for each patient, because of looking for the presence of change vs. the quantity of change. The scan chosen was one where there was 100% force registered and
was most representative of the three trials accomplished on each patient at each stage. To simplify analysis, quadrant force distributions were collected at initial contact, at 'best bite', and at full force. The distribution of force between the left and right side was then used as a general evaluator of change.

**Data analysis**

Utilizing MS Excel, the pre- and post-treatment postural analysis was averaged between the two assessments. In order to remove processing bias, the data were analyzed by the researcher with no knowledge of the patient’s dental and/or treatment history; this blinded data analysis was done by Dr. Raymond Turner and is presented in Figures 2–4. Data are plotted with the standard deviation of the measurements within the pre- and post-data. To determine the best bite force profiles (Figure 4), a representative profile was taken from the set of three recorded at each assessment; the values were then averaged for the pre- and post-trials, and standard deviations were calculated.

**Results**

**Posture analysis**

Head posture considering the left right view tilt angle (headfr), the transverse rotational angle (headtr), and
In the simplest level of analysis, the temporomandibular joint biomechanics can be evaluated by observing the bite force in different quadrants of the dental plane to determine the balance of the bite. The dental bite force of maximal occlusion is evaluated by the ratio of bite force of the left to right side of the bite and is plotted in Figure 4. Half of the patients showed a change in their maximal force left right balance (1, 3, 4, 6, 10, and 11; T-scans for these subjects are shown in supplementary material). The data show a trend of change with alignment of the CCJ.

Evaluating the pattern of the bite from initial contact through to maximum force can allow the clinician to see bite pattern changes. Examples of T-scan® maximal force occlusal patterns for two patients are shown in Figure 1. Subject #10 demonstrates a more balanced occlusal contact pattern after alignment of his/her CCJ. This might indicate that the occlusal pattern of subject #10 would help reduce stress translated to the CCJ while the occlusal pattern of subject #11 might show increased stress to the CCJ. Other patterns of subjects can be seen in the selected examples of the T-scan® bite patterns shown in the supplementary materials.

Discussion

This study investigated whether there is a change in occlusion that can be measured using a dental force plate following a NUCCA adjustment to the CCJ. Overall, consistent postural trends were observed within each set of pre- and post-treatment measurements. The T-scan® patients were not observed to always bite consistently; and thus it was more difficult to obtain trends; this is reflected in the size of the error bars for some patients. However,
bites were observed within each series that showed representative effects.

Traditional dental viewpoints saw the TMJ as the determinate force in the function of the mastication and parafunctional actions of the mandible. There is little attention given to the influence of the CCJ on the action of the mandible or the position of the TMJ within the mandibular fossa and the consequences that variations in the position of the CCJ would have on muscle and ligamentous tissue associated with the TMJ. Some dentists treating TMD are beginning to understand the interaction between the TMJ and the CCJ. Traditional dental treatments such as occlusal adjustments, dental orthotics, and reconstructive treatment options often do not provide consistent results in dealing with patient complaints.[10] The interconnection of the stomatognathic complex to the rest of the body needs to be recognized to understand the influences acting on the occlusal system. TMD is affected by malocclusion and posture; therefore, it is necessary to address all related physiologic issues with the patient if there is to be an effective method of treating problems with the biomechanics of the stomatognathic system.[11–16]

Posture

The NUCCA procedure analyzes the CCJ in the frontal and transverse planes to determine the appropriate correction vector to effectively and reproducibly reduce the imbalance. The intended effect of the NUCCA procedure is to return the joints of the CCJ to a normal neutral juxtaposition.[3]

Occlusion

Occlusion can be defined as intercuspation of mandibular and maxillary teeth. A complex interaction exists between the proprioceptive afferent neural inputs from mechanoreceptors within the periodontal ligament (PDL) and the efferent masticatory muscle activation. This trigeminal nerve sensory/motor loop guides the mandible on a learned path of closure into the approximation of mandibular and maxillary teeth during the final stages of occlusion. The importance of this neuromotor loop is to decrease the potential damage to tooth structures from excessive forces during mastication.[13,17–20] Involved in this interplay are the mechanoreceptors in the PDL, the muscles of mastication, the TMJ, and the innervation of all these components.[21] Within the PDL are mechanoreceptors that are myelinated nerves, which communicate with the Mesencephalic Nucleus of the Trigeminal Nerve within the Pons. The Mesencephalic Nucleus communicates with the Trigeminal Motor Nucleus to provide rapid response to afferent input from the PDL mechanoreceptors.[22]

The dental force plate utilized was a T-Scan® sensor that is 98 microns thick. The sensitivity of the T-scan® system can be increased to allow the recording of light occlusal forces or decreased to allow the measurements of heavy occlusal forces. Studies of the proprioceptive sensitivity within the PDL show a range of occlusal change awareness at 20–70 μm.[13] The T-scan® allows for the evaluation of these subtleties in the force of occlusion on individual teeth and allows for the visualization of these differences.

Typically, the scan of the bite that displays the most force is chosen as it presents the most data for occlusal force comparisons.[23] This approach was useful for addressing the fundamental question of this study: that there is often a change in the force of occlusion when head and neck position are altered.

Overall trends and clinical utility

Dentists are aware of the importance of their patients’ head position when attempting to record, check, or adjust a patient’s occlusion because occlusal contact forces and patterns are affected by head posture. The sense of which teeth touch first changes with the way the head is postured. This can be demonstrated by having a patient tap their teeth together while upright and looking straight ahead, and then having them tap their teeth together extending or flexing their head. Small changes in occlusal contacts are registered by the neuromotor loop via the sensory feedback from the proprioceptive receptors in the PDL; this results in an alteration of motor nucleus stimulation of the masticatory muscles and gives an immediate accommodative response to the changes in the occlusion.

Since changes in the position of the CCJ directly alter head posture, OAA alignment inconsistency has the potential to alter occlusal contacts, creating adaptation in the action of the muscles of mastication. This study showed that there were changes to both posture and head and neck position in all of the subjects of the study, and there were clinically measurable changes to the occlusal contact pattern in 6 of the 11 patients.

Some patients demonstrated a more balanced occlusal pattern when their CCJ was out of alignment; an extreme of this is shown in Figure 4 with Subject 11. This finding suggests that the integration between chiropractors who intervene at the level of the CCJ and dentists attempting to balance occlusion is important; the relationship between the CCJ and TMJ needs to be considered simultaneously so that changes to the CCJ reduces and does not amplify structural stress in the TMJ. The difference in occlusion pattern response to the adjustments as seen in Figure 4 (and supplementary material) demonstrates that not all
patients respond the same way. It is possible that the occlusal imbalance can provide stress to the CCJ (descending issue), and/or the misalignment of the CCJ can cause stress to the occlusal complex (ascending issue).

More investigation into this relationship is needed to define appropriate protocols for the integration between chiropractic and dental interventions.

Conclusion

In the present study, a link is shown between the alterations of a subject’s CCJ alignment and the generation of occlusal forces into a maximum bite. It is possible that a change in biomechanics of the bite is linked to head and neck postural parameters, and this relationship should be considered during treatment by both chiropractors and dentists focusing on the CCJ and TMJ, respectively.

Contributors

CDW conceived of the need for the research with JS and participated in project design. He performed the Dentistry measurements, participated in data analysis and writing of the manuscript. He also provided Clinical resources for the work. JS, conceived of the need for the research with CDW and participated in project design. He performed the chiropractic measurements and adjustments, participated in data analysis and writing of the manuscript. He also provided Clinical resources for the work. RJT, participated in project and experimental design, ethics applications, data processing, statistical analysis, and participated in the writing of the manuscript.

Acknowledgments

We would like to acknowledge Dr. Chuck Woodfield, Connor Westersund, and Kira Scholten for their time and contributions to this study, which were significant.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Curtis D. Westersund http://orcid.org/0000-0002-5118-1767
Jeffrey Scholten http://orcid.org/0000-0001-8009-9125
Raymond J. Turner http://orcid.org/0000-0002-9263-0776

References

[1] Maeda N, Sakaguchi K, Mehta NR, et al. Effects of experimental leg length discrepancies on body posture and dental occlusion. Cranio. 2011;29:194–203.
[2] Eriksen K. Upper cervical subluxation complex: a review of the chiropractic and medical literature. Philadelphia, PA: Lippincott, Williams & Wilkins; 2004.
[3] Thomas M, editor. NUCCA: protocols and perspectives, a textbook for the National Upper Cervical Chiropractic Association. Monroe, MI: National Upper Cervical Chiropractic Research Association; 2002.
[4] Bakris G, Dickholtz M, Meyer PM, et al. Atlas vertebra realignment and achievement of arterial pressure goal in hypertensive patients: a pilot study. J Hum Hypertens. 2007;21:347–52.
[5] Woodfield HC, Gerstman BB, Olaisen RH, et al. Interexaminer reliability of supine leg checks for discriminating leg-length inequality. J Manipulative Physiol Ther. 2011;34:239–246.
[6] Owens EF Jr., Hart JF, Donofrio JJ, et al. Paraspinal skin temperature patterns: an interexaminer and intraexaminer reliability study. J Manipulative Physiol Ther. 2004;27:155–159.
[7] McCoy M, Campbell I, Stone P, et al. Intra-examiner and inter-examiner reproducibility of paraspinal thermography. PLoS ONE. 2011;6:e16535. doi:10.1371/journal.pone.0016535
[8] Anderson RT, Winkler M. The gravity stress analyzer for measuring spinal posture. J Can Chiropr Assoc. 1983;27:55–58.
[9] Qadeer S, Kerstein R, Kim RJ, et al. Relationship between articulation paper mark size and percentage of force measured with computerized occlusal analysis. J Adv Prosthodont. 2012;4:7–12.
[10] Klasser G, Greene C. The changing field of temporomandibular disorders: what dentists need to know. J Can Dent Assoc. 2009;75:49–53.
[11] Kibana Y, Ishijima T, Hirai T. Occlusal support and head posture. J Oral Rehabil. 2002;29:58–63.
[12] Ohmure H, Miyawaki S, Nagata J, et al. Influence of forward head posture on condylar position. J Oral Rehabil. 2008;35:795–800.
[13] Reveredo A, Shetty S, Babu S, et al. Evaluation of active tactile perception of single tooth implant prosthesis. Int J Oral Implantol Clin Res. 2013;4:1–6.
[14] Ruscheweyh R, Becker T, Born Y, et al. Effects of stress and relaxation on pain perception in subjects with pain-free occlusional disharmony compared with healthy controls. Oral Dis. 2014;400–407. doi:0000-0002-5118-1767
[15] Yin C, Lee Y, Lee YJ. Neurological influences of the temporomandibular joint. J Bodyw Mov Ther. 2007;11:285–294.
[16] Yurchenko M, Hubalkova H, Klepacki I, et al. The neuromuscular approach towards interdisciplinary cooperation in medicine. Int Dent J. 2014;64:12–19.
[17] Cao Y, Li K, Fu K, et al. Central sensitization and MAPKs are involved in occlusal interference-induced facial pain in rats. J Pain. 2013;14:793–807.
[18] Duane E. Fundamental neuroscience for basic and clinical applications. Philadelphia, PA: Elsevier Health Sciences; 2012.
[19] Mori M, Nariyama M, Abo T, et al. Role of occlusion in masseter muscle acetylcholine receptor clustering. J Dent Res. 2013;92:352–357.
[20] German O, Ramirez-Yanez G, Mehta L, et al. The effect of dental occlusal disturbances on the curvature of the vertebral spine in rats. Cranio. 2015;33:217–27.
[21] Haines D. Neuroanatomy: an atlas of structures, sections and systems. 8th ed. Philadelphia, PA: Lippincott, Williams & Wilkins; 2012.

[22] Baker R, Llinás R. Electrotonic coupling between neurones in the rat mesencephalic nucleus. J Physiol. 1971;212:45–63.

[23] Garcia G, Cartagena G, Sequeros G. Evaluation of occlusal contacts in maximum intercuspation using the T-Scan system. J Oral Rehabil. 1997;24:899–903.