Using State-of-the-Art Occlusion Technology to Simplify and Improve Functional Risk Assessment

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Abstract: Occlusal analysis is a valuable tool for alleviating a patient's pain emanating from temporomandibular disorders (TMDs) and enabling lasting dental function. Modern-day dental occlusion technology is expanding and includes innovative devices and methods such as joint vibration analysis, digital articulating paper, digital articulators, digital jaw tracking, intraoral scanning, and others that are on the cutting edge of dental science. These state-of-the-art techniques provide insights and data-driven results that can offer clinicians a more complete picture of a patient's temporomandibular joint and how it contributes to TMDs.

Occlusion is subject to scrutiny and disagreement perhaps like no other facet of dentistry. Historically, dentists typically have not assessed occlusion risk at the front end of treatment. Occlusal symptoms largely are dealt with after patients have developed pain or dysfunction for one reason or another. Possible explanations for this can be complex: a lack of emphasis in early training or dental school, difficulty in visualizing or predicting occlusal disease and relationships to the temporomandibular joint (TMJ), inadequate education or scarce widespread acceptance in the dental community, and difficulty applying occlusal tools or determining which patients would benefit most from occlusal interventions. Currently, modern occlusal analysis technology may be leveraged that not only can transform patient care and improve long-term dental health, but also enhance the dentist's professional satisfaction.

Occlusal analysis is a valuable tool that can be implemented when dentistry does not work as expected. If a restoration fails for no explicable reason, or a patient presents with increasing discomfort and jaw pain with no obvious contributors, the science of "how teeth touch" becomes the pathway to alleviating the patient's pain and enabling lasting dental function. Modern-day dental occlusion technology includes innovative tools such as joint vibration analysis (JVA), digital articulating paper, digital articulators, digital jaw tracking, intraoral scanning, and others that are on the cutting edge of dental science. Predictable success is more achievable when dentists who are motivated to use their skill in occlusion leverage the right tools in the most appropriate situations to improve their patients' quality of life.

Analysis of Temporomandibular Joint Disorders

Restorative dentistry allows dentists to simultaneously elevate a patient's oral health along with esthetics. This includes the somewhat complicated endeavor of evaluating and managing a patient's occlusion. Patients who display heavy wear on past restorations may also feel emotional distress related to physical discomfort, their past experiences with dentistry, and how they think they are viewed as a dental patient. Patients may present having lived with long-term discomfort and pain associated with occlusion-related diseases and TMJ dysfunction and a sense that their issues are undetectable or untreatable. However, an array of state-of-the-art occlusion tools is available to guide advanced patient care and improve outcomes.

Temporomandibular disorders (TMDs) are characterized by reduced jaw movement and hyperalgesia or clicking noises regionalized to the jaw joint, specifically the area

near the external part of the ear (Figure 1).[1] In evaluating the history and future outlook of TMD diagnosis, Ohrbach and Dworkin noted the importance of considering the biopsychosocial aspect of TMD disorders, particularly how patients make sense of and seek treatment for chronic pain.[1] They also identified TMD as having a population prevalence of 10% to 15% and explained that it is often quite difficult to associate a physical finding with the source of the pain. JVA is a tool used for the diagnosis of TMJs that has advanced in its efficacy and clinical reliability. JVA uses accelerometers and amplifiers to assess the motion and friction of joints and is based on the assumption that healthy biomechanical relationships demonstrate hardly any vibrations.[2]

Due to the variability of TMJ sounds, however, the validity of JVA has been called into question. A 2017 study by Sharma et al analyzed the reliability and diagnostic validity of JVA for bilateral disc displacement by comparing JVA output variables to magnetic resonance imaging (MRI) evaluation with a radiologist.[2] From a group of 36 participants with a mean age of 39.03 +/- 13.6 years (21 with normal joints versus 15 having disc displacement with reduction), the researchers recorded maximum unassisted openings and lateral deflections, as well as the vibrations of the condyles as the mouth opened and closed. These JVA tracings were compared to previously recorded MRI images by blinded clinical examiners. The researchers concluded that a JVA composite score could be used with "acceptable levels of sensitivity and specificity" to differentiate between normal and displaced discs.[2]

JVA may soon face competition from incoming dental ultrasonography (known as "ultrasound") technology, which was recently patented and given FDA market clearance as a class II medical device. Significant challenges of implementing ultrasound technology in the dental practice include dentists' unfamiliarity with reading an ultrasound image and the digital interface being made more amenable to diagnostic interpretation. Ultrasound technology is based on the principle of how fast sound waves travel through different densities.[3]

An ultrasound device emits high-frequency pulses that allow clinicians to safely and effectively visualize tissues. In dental research, ultrasound has been tested for purposes as wide ranging as the detection of carious and soft-tissue lesions, the diagnosis of TMDs, and assessment for implant dentistry.[3]

MRI is the current gold standard for visualization of inflammation in the TMJ but is limited by factors such as cost, time, the need for radiologist expertise, and the inability to use it with patients who have metallic elements in their bodies.[3] In a literature review, Marotti et al determined that ultrasonography for TMD diagnosis had an accuracy of "54%-100% for diagnosing disk displacement, 56%-93% for osteoarthrosis, and 72%-95% for joint effusion" with operator-dependent results.[3] The authors indicated that operator training was the most significant shortcoming. They also noted that studies have analyzed the use of ultrasound for TMD injection guidance, internal derangements detection, and assessment of increased capsular width. Greater frequencies may be necessary to improve the accuracy and sensitivity of ultrasound for dental purposes.[3] Overall, however, oral cavity soft-tissue imaging is increasingly becoming a "simpler" reality. Devices are being introduced that provide ultrasound probes designed for the oral environment, and new visualization systems are being used to guide new users in diagnostics.

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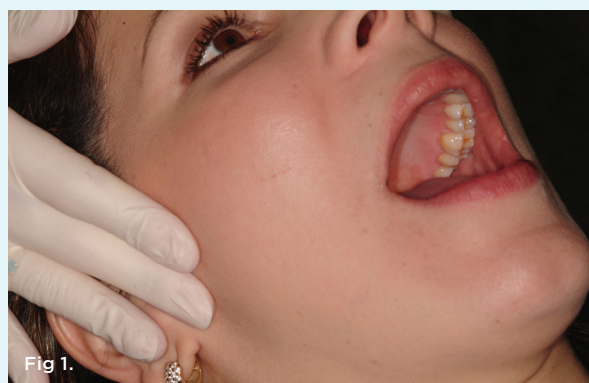

Fig 1.

Fig 2.

Fig 1. Palpating the patient for joint sounds indicating TMJ changes. **Fig 2.** Measuring the maximum opening distance to assess patient's jaw range of motion.

Digital Jaw Tracking for Visualization of TMJ Motion

While occlusal diagnosis has benefited from advances in imaging technology, a related area of occlusion technology is also improving: digital jaw tracking or jaw motion tracking (JMT). Applying information related to the movement of the mandible can simultaneously frustrate and delight dentists who seek to bring their patients into greater comfort through restorative dentistry. By bridging the initial occlusal diagnosis with the later application of occlusal analysis via an articulator, digital jaw tracking acts as the missing piece that enables dentists to translate more accurate information about the true hinge axis point location to a virtual articulator than what is usually possible with a traditional facebow (Figure 2).

In 2019 Kwon et al described a digital approach to jaw tracking using a 3D optical scanner and target tracking system, which merged cone-beam computed tomography (CBCT) data for clearer simulation of the TMJ and mandible.[4] The researchers scanned the oral cavity in maximum intercuspation with a structured-light 3D facial scanner. The data captured from this scan was then placed in alignment with CBCT STL data and dental cast scan data to provide a more realistic recreation of the patient's TMJ and mandible movement. With this data, they were then able to use a facial scanner again to track the movement of the mandible in real time. This technique was designed to use a target sticker placed on an anterior tooth's labial surface. Novel digital methods like this one can vastly improve hinge axis recording.

In their 2017 case report, Aslanidou et al used dynamic jaw tracking to fabricate an occlusal splint for a patient with a TMD.[5] JMT that could capture the range of mandibular movement was also combined with CBCT data in this case, as was information gained from an optical impression. The researchers used a JMT system that converts acoustic signals to spatial information. The combined system measures all mandibular movements, including chewing, left and right lateralization, and more. This occlusal analysis solution enables clinicians to analyze limitations of dysfunction in the movement of jaw and teeth and joint space changes.[5] Digital jaw tracking provides the guidance and insight necessary for clinicians to truly visualize a patient's anatomy in action.

Bringing Digital Articulator Technology to Occlusal Analysis

Occlusal analysis and restorative dentistry are highly dependent on mechanical articulators (Figure 3 and Figure 4). But as digital dentistry becomes more prolific and dental scanning and milling easier to use, a demand for digital articulation systems has grown. In a 2020 study, Yau and colleagues noted the need for improved virtual articulator mathematical modeling and verification of model accuracy.[6] To verify digital articulator accuracy, they developed an optical tracking method and analyzed their digital articulator system and

Fig 3.

Fig 4.

Fig 3. Gathering data using a dentofacial analyzer to mount upper model on an analog articulator. **Fig 4.** Mounting models on an analog articulator.

found that their device had sub-millimeter control.

A technique published by Kim et al in 2020 used the patient's CBCT data for occlusal plane reproduction alongside data gathered from a digital articulator.[7] They developed this technique because of the difficulty, patient discomfort, and time-consuming nature involved in a facebow transfer and stone cast mounting to a mechanical articulator. The researchers used an industrial scanner to scan a mechanical articulator, obtained CBCT data, and then imported the two sets of data together to assess a spatial relationship between the articulator and CBCT.[7]

A 2014 review article on a virtual articulator described the advantages of the technology, including optimized communication between technician and dentist, static and dynamic occlusion analysis, and 3D navigation, but also noted its limitations, such as poor cost-effectiveness and inadequate technical knowledge of the user.[8] These limitations result from the complexity of the technology, which requires navigation of scanners, sensors, and software, sometimes simultaneously.[8]

In their clinical study in 2020, Úry and colleagues tested the accuracy of virtual dentistry applied to the indirect

digital workflow.[9] Specifically, they examined the result of transferring analog dental casts to a virtual articulator, which involved indirect scanning 18 mounted maxillary and mandibular gypsum casts. The authors measured the matching analog and virtual contact points from an occlusal analysis and found the results indicated that the indirect digital method would be successful. Examples like this show the benefit of virtual articulators, which provide the integration necessary for dentists to fully digitize the occlusal diagnosis, analysis, and treatment process.

The Age of Digital Occlusal Contact Reporting

Digital occlusal contact reporting is another recent innovation that is transforming occlusal analysis. Occlusal analysis systems are now available that take what used to be done with paper, ink, and wax (Figure 5 and Figure 6) and transform the technique of marking and adjusting occlusal contacts into a precise estimation of applied force. A skilled clinician may require years of experience to develop the ability to adjust a patient's restoration precisely so that the patient experiences an exceptionally comfortable bite and touching of maxillary and mandibular teeth. This is a truly impactful dental treatment. With digital occlusal analysis, dentists can go one step further and gain an even clearer picture of the patient's bite.

Occlusal pressure surfaces can be identified through digital occlusal analysis systems. In their 2015 in vitro study of one such system, Cerna et al found a "good level of reliability."[10] The system provided relative bite force values, including the timing and distribution of the force. The study authors concluded that in comparing 18 sensors (including two different series of the same type of device), low validity was found in the system's ability to approximate "total occlusal force under laboratory conditions," but that the sensors had high reliability in the case of two consecutive measurements. The results of this study may indicate that occlusal analysis systems at that point in the technology's design lacked accuracy but provided consistent data, which would make them useful at the individual patient level for real-time assessment of the location and relative force of occlusal contacts.

More recently, a 2017 study of this occlusal analysis system for patients before and after orthognathic surgery also found high levels of reliability.[11] Agbaje et al tested how useful and consistent the occlusal analysis system was in recording information like maximum intercuspation and maximum bite force (preoperative and postoperative) for 40 patients in comparison to 30 patients with healthy occlusion.[11] The technology is based on a "pressure-sensitive bite transducer embedded in a dental arch-shaped recording sensor."[11] Two-dimensional and 3D image analyses of patient occlusal force distribution were gathered and the data analyzed to assess the technology's efficacy. The researchers concluded that the occlusal analysis system offered a comprehensive number of parameters for assessing occlusion and could even be used for faster detection of relapse. The landscape of occlusal contact analysis sensors and corresponding software continues to broaden to encompass complementary tools and even replacements for traditional articulating paper.

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Conclusion

Occlusion is the lynchpin of a healthy masticatory system and crucial to a patient's oral condition. Occlusal analysis and treatment tools are emerging like never before. The

Fig 5.

Fig 6.

Fig 5. Equilibration using traditional articulating paper to mark occlusal contacts. **Fig 6.** Marking the incisal edge position for anterior guidance with articulating paper.

state-of-the-art in occlusion technology provides insights and data-driven results through tools such as joint vibration analysis, digital articulating paper and occlusal analysis systems, digital articulators, digital jaw tracking, intraoral scanning, and more. Although dentists may feel overwhelmed by the number and complexity of systems available, especially when more established techniques are already functional or adequate, once they have overcome an initial learning curve they stand to gain a more thorough and clearer picture of a patient's TMJ and how it contributes to TMDs. Knowing the benefits and drawbacks of occlusion technology can give dentists more options for providing high-quality restorative dentistry and pain management to patients in need.

DISCLOSURE

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