T-SCAN: OCCLUSION DEMYSTIFIED

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ABSTRACT

Knowledge about occlusion is critical to good clinical practice in dentistry. Among clinicians there has been an increasing interest on treatment planning focusing on the biomechanical elements associated with occlusion. All disciplines of dentistry require that the clinicians assess the articulation of the teeth/prosthesis with respect to simultaneous contacts, biting time and biting force. However, measuring dental occlusal forces has been an inexact science, often requiring complex and subjective decisions. Occlusal indicators are widely used to obtain information on tooth contacts during occlusion in the fitting of prosthetic devices. A wide range of indicators exist ranging from articulating ribbons through to the T-Scan pressure measurement system. These devices differ not only in their measurement characteristics but also in their material properties such as thickness and plasticity. The aim of this article is to provide an insight to various occlusal indicators available in the clinical world of prosthetics and T-SCAN in particular.

Keywords: Occlusal Indicators, Temporo Mandibular Disorders, T Scan System.

INTRODUCTION

Based on the glossary of Prosthodontics terms (2005), Occlusion is "the static relationship between the incising or occlusal surfaces of the maxillary or mandibular teeth or tooth analogues. The occlusion should be balanced and as stress free as possible"14. For proper functioning, occlusal contacts must be in synchronization with the stomatognathic system. The concept of occlusion is not restricted to morphological contact interactions between teeth. It embraces the dynamic morpho-functional interactions amongst all constituents of the masticatory system, including teeth, periodontal tissues, the neuromuscular system, the temporo-mandibular joint and the craniofacial bones24.

IMPORTANCE OF OCCLUSAL ANALYSIS

Uneven distributions of pressure on occluding teeth that often do not contact simultaneously result in occlusal trauma. This may be produced due to unusual occlusal contacts and excessive occlusal height of a restoration. It has been demonstrated that dental and periodontal tissues suffer from occlusal trauma and even dental implants may deteriorate under excursive overload and/or higher bite forces, eventually leading to bone loss and failure complications. Moreover, temporo-mandibular joints may be harmed especially in atypical protrusive interferences57 or by moving the mandible into a physiologically unsound position leading to muscle pain (myalgia). If premature or interfering contacts (such as excursive on the non-working side) points are not detected, they would lead to destructive forces through the masticatory system and could even result in parafuction such as clenching89. This may further lead to sore neck and facial muscles, and endanger nerves within the temporo-mandibular joint (TMJ), as has been seen in various temporo-mandibular disorders (TMDs)10. In contrast, a low occlusal height may result in disorders such as disuse osseous atrophy1112 and/or unstable centric occlusion13. Therefore, assessment of the occlusion is crucial to remedy these occlusal issues. Clinicians use various occlusal indicators to analyze occlusal contacts.

OVERVIEW OF CONVENTIONAL TECHNOLOGIES

Commonly used techniques are described below:

1. Articulating Paper Foils/Ribbon

Articulating paper/ribbon could be a carbon paper, inked paper/ribbon or a paper/ribbon treated with brightly colored dye/wax (Fig. 1). It is commonly used in clinical and laboratory settings to mark premature contacts in the occlusion. These are produced in various thicknesses, shapes and colors to facilitate use in the oral cavity (Fig. 2). Clinical implementation requires placement of the paper/ribbon

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between the teeth that are then closed onto the paper. This produces marks on the teeth representing either high force or premature contact\(^4\). Within the literature, large and dark marks are reported to represent heavy occlusal load, whereas, smaller and lighter marks are related to lesser occlusal loads. Moreover, presence of numerous similar-sized marks on neighboring teeth have been stated to be an indication of evenness in the occlusal contact intensity and time. The analysis of the marks created by articulating paper is dependent on the subjective interpretation by the clinician. However, there are no scientifically proven guidelines for the clinicians to follow. Opponents of this technology have claimed that the current literature does not provide sufficient evidence that articulating papers can measure occlusal load. Furthermore, clinical decisions based on the darkness of marks are reported to be an inaccurate method for evaluation of the density of contacts. Some other disadvantages of articulating papers include that they are susceptible to being destroyed by saliva, are usually thick, and have a relatively inflexible base material. These factors are believed to result in a high proportion of pseudocontact markings\(^5,6\). In general, articulating paper is restricted to measuring only the position and quantity of tooth contacts. However, their low cost and ease of application have made them the most commonly used qualitative indicators.

2. Silk strips

These are usually made up of natural silk that contains tube-shaped protein which has a very high color reservoir capacity\(^3\). They are available in average thickness of 80µ and are soft flexible indicator materials, which are reliable because of their texture and do not produce pseudo contact markings by adapting perfectly to cusps and fossae. For these reasons silk strips have been considered as the best material for indicating occlusal contacts by some researchers. However, when silk strips’ stain components are dried it is possible to lose their marking capability and they can also be modified by saliva\(^8\).

3. Foils

Foils are the thinnest indicator materials which give more accurate readings than paper and silk\(^9\). Their marking ability is decreased under reduced pressure and on glossy surfaces. Therefore, for the clinical use of foils, a greater pressure needs to be applied. (Fig. 3).

4. Impression materials

They have been used to register occlusal contacts due to their flow characteristics that permit biting without resistance\(^10\). The occlusal contacts can be distinguished when the material has been removed after setting. Occlusal-indicator type of silicon impression material, due to its elastic characteristics, has been used to mark the occlusal contacts. Silicone putty is used as an inter-occlusal recording material to assess occlusal contacts which appear as perforations in the silicone records are observed the location of tooth contacts.

5. Occlusal indicator wax

It follows a concept similar to impression materials, where the material is placed on the maxillary arch and the patient occludes in maximum intercuspation (MIC). (Fig. 4) There is resistance when biting into the wax. Then, the occlusal indicator wax is scrutinized in front of a light source. Each registration is positioned on the diagnostic cast to visualize and confirm the precise site of each contact. Inexactitude and manipulation issues are some disadvantages to clinically record and transfer information of the wax record\(^11\).
OVERVIEW OF QUANTITATIVE OCCLUSAL REGISTRATION TECHNOLOGIES

The sequence and density of the contacts can be differentiated with the quantitative methods of evaluating occlusal relationships. Photo-occlusion and the T-Scan system (Tekscan Inc., Boston, Mass.) are quantitative measures for determining occlusal relationships.

1. Photo-occlusion system

It consists of a thin photoplastic film layer which is positioned on the occlusal surface of the teeth in which the patient would bite for ten to twenty seconds. Then the film layer is inspected under a polariscope light to obtain the relative tooth contact intensity was measured. It has been proven that the photoelastic wafer enhances posterior contact intensity while diminishes the anterior ones. Therefore, some investigations have concluded that neither an inked marking material nor the photo-occlusion methods are highly reproducible\(^{22-24}\), as well as being considered a technique complicated to use.

2. T-Scan

The T-Scan System (Fig. 5) is a computerized device that consists of: 1) hand-held device with flat U-shaped pressure-measuring sensor, and 2) computer software. The latest type of this technology is marketed as the T-Scan III system, accompanied by a software version 8.0, Tekscan Inc. (South Boston, MA, USA). The pressure measuring sensor is a grid-based, mylar-encased recording sensor (High-definition Generation IV sensor, Tekscan Inc. S. Boston, MA, USA). The basic application of this sensor is occlusal registration. It is designed to obtain reliable measurements of occlusal biting forces on individual teeth by analyzing occlusal forces quantitatively.

It records the sequence of occlusal contacts in terms of time (as a film) and the associated force with each occlusal contact. The U shaped sensor foil is 60 µm thick, consists of an X-Y coordinate system with 1500 sensitive receptor points made of conductive ink, and is subject to elastic deformation. The T-Scan sensors are marketed in two sizes: the smaller sensor could accommodate an arch up to 58 mm wide and 51 mm deep whereas the larger sensor could accommodate an arch up to 66 mm wide and 56 mm deep\(^{25}\). The hand-held device that is the hardware for the system contains the U-shaped sensor, which fits into the patient's mouth between teeth’s occlusal surfaces. The T-Scan III connects to the USB port of a laptop or a Windows-based PC (Fig. 6). The system produces measurements at a consistent rate of 100Hz (Hertz= cycle per second). This sampling rate can be used to produce a frame-by-frame images in which each frame is spaced 0.01 seconds apart. The image frames when played together by the software produce a T-Scan movie, which produces a consistent data display. Similarly, the occlusion is scanned in time increments of 0.01 seconds to record the relative forces among the occlusal contacts, teeth with excessive forces, and occlusal contact timing sequences, which illustrates the exact order of tooth contacts and the associated forces.

![Figure 5: The T-Scan system consisting of the hand-held device and the computer software](image)

The system has vivid, full-color three-dimensional (3D) or two-dimensional (2D) graphics, which enable the clinician to see the patient's bite pattern. Proponents of this occlusal analysis system claim that the recorded data on occlusal force and contact timing provides much improved information to the clinicians as compared to the conventional methods requiring subjective judgments\(^{26,27}\). The common applications in dentistry claimed by the T-Scan III promoters include those crucial to natural dentition with occlusal disturbances, implant placement (fractional time delay on implant prostheses), orthodontics, temporomandibular disorders, myofacial pain, restorative dentistry and prosthetics (checking for high points and excessive contact locations), patient education (treatment acceptance, improve longevity, enhanced comfort, eliminate extra visits), occlusal diagnosis and equilibration. In essence, the T-Scan system is a diagnostic tool that assesses dental occlusion and finds utility in any field that requires diagnosis of the occlusion and/or occlusal balancing.

CLINICAL UTILITY OF T-SCAN IN TEMPOROMANDIBULAR DISORDERS (TMD)

Occlusal interferences often result in muscle dysfunction and consequently TMDs and MPDs. Occlusal adjustments to restore the muscle function back to normal requires careful assessment of the occlusion followed by adjustments.

- MPDs are highly correlated to higher disclusion time of the posterior teeth. Conventional occlusal indicators have inconsequential utility in assessing contact timings.
Various authors have demonstrated that the T-Scan system allows for assessment of the disclusion time and aids in occlusal adjustments to reduce this time. For instance, Kerstein [27] reduced the posterior disclusion time to less than 0.5 seconds per excursion and the patients returned to normal muscle function within 1 month of treatment, without the use of any splints. The occlusal adjustments included removal of all posterior interferences (lateral and protrusive) by enameloplasty to develop a complete anterior guidance.

- In 1994, Mizui et al. [28] showed that the T-Scan system can be used accurately distinguish between the occlusion of affected subjects when compared to subjects with normal occlusion.
- In another recent study, Ciavarella [29] demonstrated the diagnostic utility of the T-Scan system for temporomandibular joint intracapsular disease, where the occlusal forces were considerably different from healthy subjects.

These reports provides evidence on the use of T-Scan system in temporomandibular disorders, which is purported to be one of the most reliable methods of analyzing occlusion. The conventional static occlusal indicators such as articulating paper and waxes only reveal the contact size and location, whereas the T-Scan has an additional ability of quantifying occlusal contact timings and forces.

Various authors support that occlusal contacts may play an important role in the pathogenesis of the conditions; however, the relationships are not fully understood. It has been reported that excursive masticatory muscle (temporalis and masseter) hyperactivity due to prolonged excursive tooth contact durations are a potential reason for the muscular symptoms in cases of TMDs. The assessment of the influence of the occlusion and neuro-musculature on the TMJ requires examination of the dynamic functional contacts in the masticatory cycle, which is not aptly examined by static occlusal indicators. Thus, the T-Scan system presents a superior alternative to conventional occlusal registration methods due to its ability to record dynamic tooth contact relationships. Additionally, T-Scan can display the relative occlusal force variance from the first point of contact to maximum intercuspation (MIC), in real time.

An important aspect of the T-Scan system that should be considered is that the contact timing and the force analysis can be studied on the software, however, additional occlusal markers such as articulating papers are required to mark the contact points when occlusal adjustments are being made. The new feature of synchronization of T-Scan data with electromyography is also able to demonstrate the abnormal dysfunction of the musculature via the center of force patterns and the disclusion timing. Therefore, the T-Scan is able to provide a definitive diagnosis of the occlusal force balance and masticatory muscular function.

**LIMITATIONS OF THE T-SCAN SYSTEM**

It has been shown that thinner occlusal registration materials provide more consistent records of the contact points. To fulfill the technological demands, the T-Scan sensors are made as thin as possible (0.1mm). However, these sensors are still relatively thicker as compared to occlusal indicators like articulating silk. This may significantly alter the functional occlusion, and even affect the activity of the masticatory muscles. Alteration of occlusion is shown to occur with all occlusal registration products, and clinicians should be aware of these limitations when functional adjustments are planned in the occlusion.

Furthermore, the sensors may be damaged when forces are concentrated over a small area, such as, a sharp tooth cusp. This is due to increased intensity of otherwise relatively low bite forces which become focused onto a small area and produce high pressure. This may also lead to inaccurate recording of the occlusal contact and/or artifacts in the produced images. The T-Scan system is able to reproduce occlusal interferences only exceeding 0.6mm in dimension. Also, the two different modes of the system (force and time analysis modes) may reproduce different occlusal contact data. Time mode has been shown to register the maximum number of contacts, while the force mode has been shown to present the least variability. However, these differences are small.

**CONCLUSION**

- Compared to conventional occlusal indicators, the T-Scan system clearly has more clinical utility in diagnosing and treating cases of temporomandibular disorders when caused due to occlusal disturbances.
- T-Scan system demonstrates sufficient sensitivity and specificity as a diagnostic tool and presents higher reliability in intra-oral conditions with presence of saliva. This technology reduces the subjective interpretation of occlusal analysis data and also provides registration of dynamic occlusal information.
- There is a need to conduct randomized controlled trials to quantify the benefits of T-Scan over traditional methods. Patient-centered approach to studies will also aid in understanding their perceived TMJ improvement after the treatment conducted using T-Scan system.

**SUMMARY**

Articulating paper mark size now is understood to be non descriptive of occlusal loads. Many different sized marks can represent the same load, and equal sized marks do not represent equal loads. Therefore, choosing paper marks to adjust occlusion, based on their relative size, is tantamount to “guessing.” It is important that practicing dentists worldwide realize that articulating paper mark size is subject to interpretation and a highly unreliable method to use in the assessment of applied occlusal loads. Computerized occlusal analysis completely removes the operator’s subjectivity from the clinical decision-making process when observing paper markings of various sizes and configurations. When using this technology, mark size, mark color depth, “donut”- shaped halo contacts, and other color and size mark appearance characteristics are ignored as “force indicators,” and used only as “contact locators.” The operator’s subjective paper mark misperceptions are replaced with accurate knowledge of the true and measured contact order, contact applied load, contact quality, and proper contact isolation where problematic.
REFERENCES