Original Article

Mechanism, accuracy and application of T-Scan System in dentistry-A review

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Abstract

Occlusion is a common topic of discussion in many fields of dentistry: Orthodontics, Prosthodontics, Implant Dentistry, Oral and Maxillofacial Surgery, Periodontics, and Pedodontics. Different methods have been used to evaluate the correct occlusion. Recently, T-Scan has become more popular to record the pattern of occlusion. Even though T-Scan system precisely and dynamically records the time, force and area of occlusal contacts, views on the reliability of the T-Scan system as a method for occlusal contact registration has always been questioned, especially regarding its repeatability and accuracy. This paper broadly reviews the mechanism, methodology, accuracy, characteristics and clinical application in the different fields of dentistry.

Key Words: Accuracy, clinical application, occlusion, sensor, T-scan.

Background

To establish a diagnosis of occlusal pathology, it is essential to have an objective knowledge of the patients' mandibular dynamics and to develop a method that enables the dentist to analyze. To analyze occlusions, recently, T-Scan has been widely used as a reliable and easy-to-use clinical diagnostic device that senses and analyses occlusal contact force using paper-thin disposable sensors.

Maness et al. in the year 1987 reported the development of the prototype of a new computerized occlusal analysis device (T-Scan system; Sentek Crop, Boston, Mass)[1] With a history of over 25 years, T-Scan has evolved as a very important diagnostic tool for determination of correct occlusal pattern and resulted in high quality treatment results which were not possible earlier. The entire system has undergone tremendous revisions of hardware, sensor and software to come up to the latest Version of T-Scan III system (version 7.0). This new version is a vast improved over the earliest "T-Scan I" system. T-Scan quantifies the amount of relative occlusal force, which enables us to predictably identify and to locate traumatic occlusal contacts.

Different methods of ruling out and recording occlusion

The use of visual assessment technique and the test which examines teeth for mobility and fremitus have been the primary modality to rule out occlusal pathology for a long time. But with the evolution of time, other methods like measuring occlusal features with a millimeter rulers, testing occlusal contacts with articulating ribbon/paper or occlusal wax, registering occlusion with silicones, mapping occlusion with occlusal sketch, photographs and the use of occlusal sonography have finally reached to a stage of computer aided determination of occlusal contact points, and the use of T-scan pressure sensitive films.

T-Scan

Assembly

The T' Scan System is a dental device used to analyze teative occlusal force that is recorded intraorally by

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a pressure-mapping sensor. The system components include a sensor and support, a handle assembly, the system unit, computer software and a printer. The sensor is the key component. The T-Scan allows the quantification of occlusal contact data by registering parameters such as bite length as well as the timing and force of tooth contact, and stores the data on a hard drive which can be played incrementally for data analysis in a time-based video.

Sensor

T-Scan sensors are available in two sizes: large and small. Large size sensor can accommodate arch up to 66 mm wide and 56 mm deep and contains 1370 sensels whereas small size sensor can accommodate arch up to 58mm wide and 51mm deep and contains 1122 sensels. Each sensel within a T-Scan sensor is limited to 256 possible values[2] and the system provides eight different sensitivity settings. Within each setting, forces at each sensel are displayed as the percent of the maximum force recorded. The individual cusps of the teeth apply bite force over a relatively small number of sensels, typically 25 to 250 at full closure. The thickness of the sensor is 0.1mm[3].

Calibration of Sensor

Reliable registration of absolute forces requires calibrations of the T-Scan sensors. Reliable recording of absolute bite forces with T-Scan sensors first requires reducing the variance resulting from the positioning on the sensor and the saturation of individual sensels. This might be accompanied by distributing the forces at each cusp over a wide area of the sensors. Once the variance has been reduced to acceptable levels, then each sensor must be calibrated with known forces in a way that mimics the contact of the patient's teeth.

Mechanism

When patients bite on the sensor, the resultant change in electric resistance is converted into images on the screen. The program can be operated in two modes: time analysis and force analysis. The former provides information on the location and timing of contacts displaying on the screen with the first, second and third or more contacts in different colors. The latter shows the location of contacts and their relative forces in five different shades of colors. Within the force analysis mode, two submodes can be selected, i.e., the 'instantaneous' which records contacts at specific mandibular positions and the `sequential' which analyses the contacts throughout mandibular movement. The occlusal forces in T-Scan are only displayed in relative force values instead of absolute values since applied forces would change between different intercuspations with the change in muscular forces. Recording force variability would occur when absolute force values are measured. Therefore, by measuring relative force levels across elapsed time on the different cusps and fosse, the contacts that strike too early, can be readily located with too much or too little occlusal force. T-Scan III analyzes the order of the occlusal contacts while simultaneously measures the changes in force percentages of the same contacts, from the moment the teeth begin contacting to maximum intercuspation. Therefore, it can assess the initial occlusal contact, the order that all the occlusal contacts occur in, and the amount of relative occlusal force loading at each contact. It enables us to assess the force changes, all during the process of contact evolutions. Computer-guided occlusal adjustments can then be employed to alter a poorly contacting tooth sequence into a contact sequence where multiple equal-intensity contacts occur simultaneously throughout the arches bilaterally.

Accuracy of T-scan

Precise analysis of occlusal contacts is a problem in functional diagnostics that has not yet been satisfactorily resolved.[4,5] But in 1987, the development of a prototype computerized occlusal analysis (T-Scan; Tekscan Inc, South Boston, Mass)[1] claimed to record the occlusal contact by computer analysis of information from a pressure sensitive film which overcomed all the problems in recording occlusion. But Moini et al.[6] then compared the reproducibility of T-scan with silk marking paper and reported that it was not as accurate as the silk ribbon. However, there were many flaws in these studies. Harvey et al.[7] found substantial variability in the results with unpredictable variation scattered among the uses, levels of force and articulator immediate side sift treatments when performing a preliminary test of reproducibility of a computerized occlusal system. The study conducted by Hsu et al.[8] on sensitivity and reliability of T-scan system concluded that sensors did not have the same sensitivity throughout their surface and the T-scan always recorded fewer occlusal contacts than were actually present as checked by occlusal foils. Mizui et al.[9] measured the timing and force of occlusal contacts in normal subjects and patients with an unspecified craniomandibular disorder (CMD) using T-scan system and found that in normal subjects the timing and force of occlusal contacts were symmetrical and the centre of effort was located in the first molar region. A study conducted by Yamamura et al.[10] showed that T- Scan

is only effective between the load of 0.98 N to 20.59 N and the value is not reproducible at higher loads. In vitro study on accuracy and repeatability of the T-Scan II system conducted by Hirano et al[11] reported that T-Scan force recordings were acceptably precise, especially for the moderately high level and default level. Koos et al.[12] reported that the level of accuracy is acceptable and no interferences arouse from change in foil or repeated measuring was detected with T-Scan III. The author didn't find any inaccuracy as mentioned in the past, which may be due to an upgrade in T-Scan III. Throckmorton et a1.[13] reported that without either shim stock or bite guard, the T-Scan sensors are not reliable enough for recording of absolute occlusal forces. Shim stock on T-Scan is more reliable than bite guards in accuracy.

Advantages & Disadvantages

Studies have shown that it can measure location and timing of tooth contact and occlusion in 3D. The tooth contact information is presented by demonstrating moments of time in the sagittal axis and transverse axis of the occlusal plane. Premature contacts and interferences can be identified in the dynamic occlusion instead of static. Not only can the distribution of forces per tooth be displayed but also distribution of forces in two halves of the jaw can be calculated. Moreover, the force distribution can be further separated into anterior and posterior relationships[12]. The pattern of the contacts and corresponding forces over time can be depicted and the center of force at each time-point can be indicated by a cursor (in the form of a red diamond). This allows symmetry of force relationships to be analyzed in the dental arch. This method is not as accurate as the silk ribbon in detecting occlusal contacts. Some other studies claimed that photoelastic and electronic sensors were relatively thick sensors that may inhibit dental proprioception. Inability to measure the absolute force value while measuring bite force is a major drawback. Another major drawback of T-Scan system is that it lacks reproducibility of data[14].

Factors to be considered while reading occlusion

The major factors which need to be considered while recording occlusion are age, sex and state of dentition[15], attitude of the investigator[16], position of the transducer in the mouth[17], vertical facial morphology[18] and head position[19-23]. Additional factors that may influence occlusal force data are extent to which the teeth and jaws are separated when the measurements are made, whether the force is exerted unilaterally or bilaterally and the patients head posture during measurements.

Methods for taking occlusal reading

The first step in a T-Scan recording is to create a model of the patient's arch. For this, subject should be asked to sit upright in a dental chair with the Frankfurt horizontal (FH) plane horizontal to avoid the effect of head posture on the occlusal contact pattern[19-23]. To exclude inter-examiner variations[24], all recordings should be performed by the same examiner. All the recordings should be made in the afternoon to avoid possible diurnal variations[24]. Subjects should be previously trained to close in maximum intercuspation. The sensor is inserted into the patient's mouth in such a way as to make its support aligned centrally with the midline of the upper incisors. The patient is then asked to bite on the sensor in a maximum intercuspal position. When occlusal contacts appeared on the screen, the button on the handle should be pressed and the arch model will be automatically created. The recordings allow dentists to see the subjects' mandibular movements on the screen, to train him to bite with maximum intercuspal contacts and to check the position's stability. After this training, the subject should be asked to perform various bites in a natural unforced way. Recordings should thus be made of the lower arch and then printed in two dimensions. The time analysis mode should then be selected from the system menu. Unlike the force analysis mode, the time mode does not allow the subject's bite to be seen on the screen, thus eliminating the operator's subjectivity. This mode gives information on the location and sequence of occlusal contacts, showing in a different color for the location of the first, second and third or more contacts. The top of the monitor screen displays the timing of each successive contact with regard to the first. Contacts occurring at the interface of two teeth should be measured in both zones. Force analysis mode can be chosen later which provides the operator with data on the location and relative force of tooth contact. On the bottom of the screen, bite length can be read. Within force analysis, two additional modes can be selected, i.e., instantaneous (which registers mandibular positions) and sequential (which registers the intensity of contacts during mandibular movement).

Clinical Applications of T-scan in different fields of dentistry

Orthodontics

Most of the patients might suffer from improper occlusal contacts due to severe malocclusion. One of the goals of orthodontic treatment is to improve occlusion achieving proper bite force. The use of T-scan

before and after orthodontic treatment for every patient helps to attain the goal of correcting malocclusion and maintaining the proper bite force.[25]

Implant:

Replacing missing teeth by imbedding the biocompatible materials with no periodontal ligaments is really a challenging task. These biocompatible implants do not have shock absorption and cannot adapt according to the need of occlusal forces. Anticipated occlusal and chewing forces need to be taken under consideration for any implant-supported prosthesis[26]. In addition, potential parafunctional mandibular movements should be noted. T-Scan occlusal analysis system is helpful to meet the needs of patients for reliable measurement of occlusal biting forces.[27]

Restorative dentistry

Improperly restored tooth can cause several problems like headache, TMD related problem, early fracture of the tooth/ restoration and more importantly unbalance bilateral application of force during mastication. T-Scan has played an important role to rule out overly/underly restored tooth and has saved the time of finishing of restoration and recall visits[28].

Temporomandibular Disorder

Prolonged disoclusion time[29], frequency of premature contacts and asymmetry in the occlusal force[29, 30], and intracapsular joint disorder" lead to various temporomandibular joint related problems. The application of T-Scan and kinesiographic techniques in combination with electromyography is of great value to the clinician for substantiating certain clinically hard-to-evidence factors, such as chronology and strength of contact points, muscular activity, or certain mandibular movements[31].

Oral and maxillofacial surgery

Mandibular and dentoavleolar fractures have been a prime end result of many road traffic accidents. This leads to a minor or major disoclusion leading to inefficient bite force even after the treatment. A method for fixing mandibular fracture within the dental arch which uses a combination of a rigid one-piece cast splint and a pliable miniplate screwed at the inferior border of the mandible was developed with the highest priority placed on restoration of occlusion. The T-scan can play a major role in the evaluation of occlusion after post-surgical treatment and was found to be the effective to judge the precision of the new appliance.[32] It also plays a major role in determining the accuracy of occlusion after orthognathic surgery.[33,34]

Prosthodontics

Replacement of single or multiple teeth with crown, bridge, complete or partial denture is routinely performed in dentistry to attain proper function and esthetics. Improper occlusion is a major challenge. The T-Scan system was found to be clinically useful as a diagnostic screening method for occlusal stability of intercuspal position[35].

Conclusions

Even though determining a correct occlusion is a challenging task, T-Scan has been widely used in dentistry nowadays and claims to correct the occlusion. Although the accuracy and ability to get repeatable reading with the T-Scan has been questioned by different studies, it acts as useful occlusal mapping device to record the pattern of occlusion. Continuous modifications and upgrades in the hardware from T-Scan I to T-Scan III claim to overcome these problems encountered earlier but this still need to be verified in future studies.

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