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Digital occlusal analysis using T scan: Its role, mechanism, accuracy and application

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ABSTRACT

Occlusal considerations play a vital role for in any treatment success. Occlusion is speciality of interdisciplinary science. It attracts the interest of various specialties like Prosthodontics, Oral surgery, Implantology, Periodontics, Pedodontics, Endodontics. Various method and techniques are available for adjusting occlusion, articulating paper being one of the common and traditionally used methods. But it has certain considerable drawbacks like inability to measure force and time and the sequence of teeth contacts. These inherent shortcomings are totally overcome using T scan. In various field like myofuctional and temporomandibular joint

dysfunction, T scan is proven advantageous. The purpose of this review article is to offer an insight on T scan treatment modality, with its mechanism, assemblage, advantages, limitations for better understanding and clinical applications.

Keywords: T scan, Computerized Occlusal analysis, Digital Analysis

1. INTRODUCTION

Correct occlusal diagnosis can be achieved by an objective measurement of occlusion (Pyakurel et al., 2013). Articulating papers are used currently and were also been used previously for determination of the amount of force and location of contact for occlusal contacts. But there is always an interrogation on the reliability of this procedure and modality. Articulating paper can also be deformed due to presence of saliva. Various methods are available currently for occlusion evaluations; with T scan being one of the modern technologies to evaluate occlusion (Sidana et al., 2013). Sensitivity, reliability, reproducibility are the major advantages when T scan is used for the digital occlusal analysis (Koos et al., 2010), (Kerstein et al., 2017), (Cerna et al., 2015) as it has the ability to record the very first contact of tooth, relative force and timing (Pyakurel et al., 2013). The current version of T scan used recently is T scan III.

2. HISTORICAL BACKGROUND

Manness et al. in 1984 was the first to invent T scan and Tekscan commercially marked it in 1987. Maness, Benjamin, Podoloff, Bobick and Golden gave the first literature updates regarding T scan in 1987. They stated use of both force and time method. It is one of the first grid based technology (Sidana et al., 2013). From T Scan I, it is upgraded to T scan III (Cerna et al., 2015). Kerstein RB & Wright N in 1991 studied disocclusion reduction time with T scan generation 1 sensor. They evaluated the myofacial pain of patient by using T scan. A complete Treatment plan was established along with the determination of anterior guidance. Post-treatment, T scan and EMG reports suggested that the muscular activity become normal in reduced time. Bernd Koos et al. in 2010 conducted a study consisting of 45 patients (19 female and 23 male average ages 26). He concluded that T scan possesses accuracy and repeatability.

Garg AK in 2007 studied the role of T scan in implantology and found that it had a significant role in it. He described role of T scan III in dental implant occlusion and bruxism, and concluded that T scan occlusal analysis assist practitioners for betterment treatment, uniformity in data aggregation, placing and repair of dental implant. The various T scan types, the stage wise development, the year of its modification and recording time is described in Table 1 & 2.

Table 1 The types, years and the modifications in the T-scan (Kerstein, 2020)

T scan	Year	Development	Recording of contact timing in Seconds
T scan I	1984	Intraoral relative force occlusal contact timing, an epoxy-based, sensor having conductive with ink columns and rows Generation 1 sensor	0.01
T scan II	1995	T scan for windows Saving patients data base, 2D, 3D evaluation, 256 force levels, customize dental arches, force versus time graph, the quadrant force divide tool, percentage force, center of force and trajectory Generation 1,2,3 sensor	0.01
T scan III	2004-2006	Saving patients data base, 2D, 3D evaluation, 256 force levels, customize dental arches, force versus time graph, the quadrant force divide tool, percentage force, Center of force and trajectory, customized desktop view, zoom	0.003

		graph of force versus time, software addition, synchrony with EMG, individual time of tooth Generation 4 sensor	
T scan III (Software 5,6,7)	2004	Saving patients data base, 2D, 3D evaluation, 256 force levels, customize dental arches, force versus time graph, the quadrant force divide tool, percentage force, center of force and trajectory synchrony with EMG Generation 4 sensor	0.003
T scan III with Turbo mode	2008	In addition to above, speedy recording thrice more efficient Generation 4 sensor	0.003
T scan 8	2012	In addition to above, it is more simple graphical version for easy learning Generation 4 sensor	0.003
T scan 9		In addition to above, Novus handle, ergonomically Generation 4, 5 sensor	0.003
T scan 10	2018	In addition to above, Novus handle, state of art, sensitivity wizard, digital impression overlay, implant warning features Generation 5 sensor	0.003

Table 2 The development of Sensor generation (Kerstein, 2020)

Generation	Make up	Advantages	Year	Thickness
1	Mylar laminated ink grid which is sensitive to pressure made up of epoxy matrix	Records occlusal contact	1984	93.98 microns
2	Mylar casing instead of epoxy matrix, dielectric made from urethane	More flexible, more resistant to cracking, more half-life, new pressure ink within row and column	1992	93.98 microns
3	Two layers of Mylar enclosing a screen-printed grid of pressure resistive ink rows and columns in between the Mylar	Improved hysteresis, drift, temperature stability	1997	82.82 microns
4	Two layers of Mylar enclosing a screen-printed grid of pressure resistive ink	High definition (HD), 33 % active recording area increased, 50% non-recording reduced	2002	82.82 microns

	rows and columns in between the Mylar			
5	Two layers of Mylar encasing a grid of resistive ink rows and columns printed between them	Novus Handle (HD) recording sensors HD. Lager than generation 4	2018	Approximately 100 microns

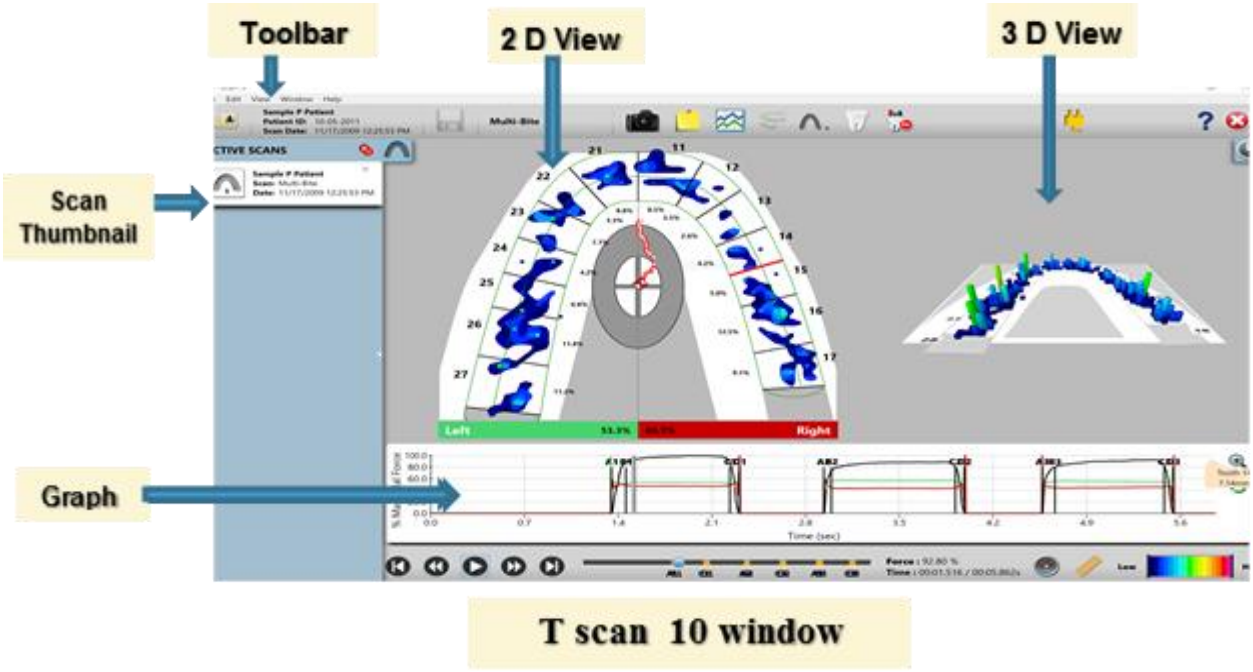

Figure 1 Depicts the T-scan 10 window- software view

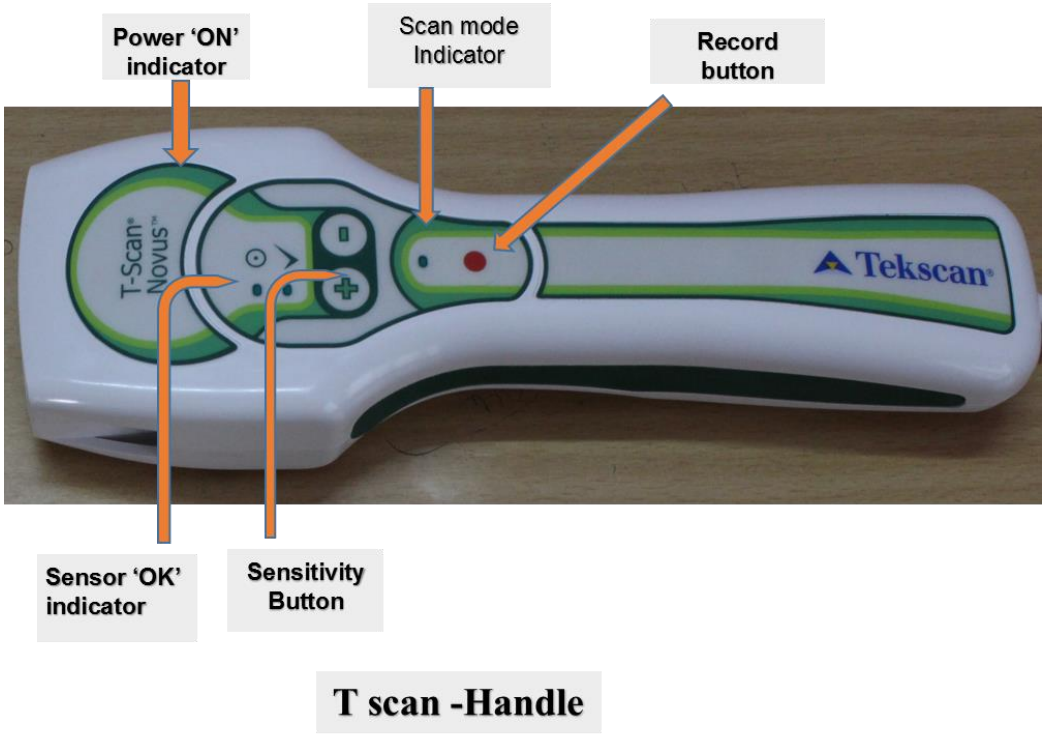

Figure 2 Depicts handle of the T-scan

T-SCAN MACHINE - HANDLE , SUPPORTER,
SENSOR AND SOFTWARE

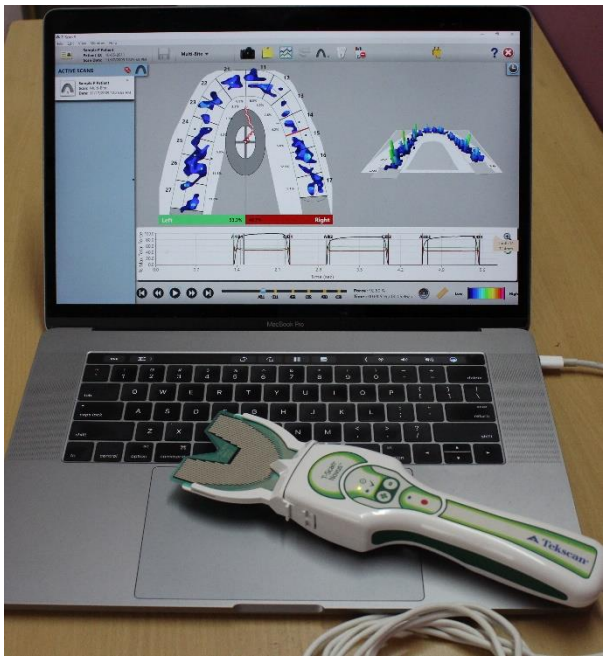

Figure 3 Depicts handle, supporter, sensor and the software window

The Assemblage (Description of the parts of the system)

a. Sensor: It is thin film composed of polyester 0.1 mm in thickness (Pyakurel et al., 2013). Two type of sensor are there: small and large. The large one has the dimensions as follows: anteroposteriorly 56 mm, mediolateraly 66 mm, 1370 sensel. Smaller one has the dimensions as follows: anteroposteriorly 51 mm, mediolateraly 58 mm (Sidana et al., 2013).

b. Handle: It acts as supporting system for sensor; it records and scans the data at the rate of 0.003 sec time interval (Kerstein, 2020). It acquires the data, works on it and is presented on computer screen (Sidana et al., 2013)

c. Sensor Calibration: Calibration is must for reliable registration of data (figure 1, 2 & 3). In order to register reliable data, reduction of the variance due to positioning and soaking of each sensel is done by asking patient to bite on sensor in order to get accustomed to the bite adaptation of sensor. After variance is normalized or the sensors are stabilized it depicts patient's natural bite (Pyakurel et al., 2013).

The Working

There are two working modes: a) Time mode b) Force mode.

a) Time mode: It displays all the contact on screen with spotlight showing earliest three contacts with their relative time value. It can be viewed in 3D (Kerstein, 1991).

b) Force mode: Mode of force analysis presents the data on the basis of location of contact and force. Lower limit of force measurement is 100 gm., at any given point whereas the higher limit is 1.1 kg. Occlusal information in form of data 2D and 3D graphic can be viewed. It can be displayed in the form of a movie (Sidana et al., 2013).

Recordings technique

T scan has a sensor that is horseshoe shaped that is is pushed in to handle. Sensitivity is customized for every patient by restricting 3 pink bars maximum. Bite of patient on sensor provides the data on screen in pictorial form as 3D, 2D with timing, relative force and 1st, 2nd, 3rd contact in-sequence. Video graphic database format for the same is also created**.**

Applications

Occlusal Corrections after definitive rehabilitation: Overcoming the disadvantages of using Articulating paper which are unable to record force, balance and timings whereas T scan is capable of recording all these parameters (Kerstein, 2020) and (Sutter, 2014). T

scan is important tool for case finishing. In all functional movements post definitive rehabilitation contact verification followed by correction can be performed with accuracy using T scan.

Implant dentistry: Occlusal overloading being the proven factor for implants complications. It is very cumbersome task to identify overloading contact by articulating paper, sometime it not achieved with accuracy. Occlusal overloading can be identified by T scan (Pyakurel et al., 2013), (Sidana et al., 2013) and (Garg, 2007). Implant occlusion can be successfully managed using T scan (Dario, 1995) and (Luo et al., 2019).

Diagnostic screening: Occlusal trauma is a major cause of occlusal derived pathology. Detrimental forces causing trauma is identified by T scan (Pyakurel, 2013), (Sidana et al., 2013). As T scan is capable of quantifying relative forces with accurate information about timing of forces, it is also useful for diagnostic screening.

Orthodontic treatment: Abnormal forces derived due to malocclusion in many patients can be recognized by T-Scan and can help in normalizing it (Pyakurel et al., 2013), (Sidana et al., and Trpevska et al., 2014). Normalization of post treatment forces results in less chances of relapse. Thus T scan can prevent complications and is very supportive for successful treatment of orthodontics.

Temporomandibular joint: Extended disocclusion time and abnormal forces resulting from interference ultimately causes TMJ issues (Ferrato et al., 2017). T-Scan also overcomes the disadvantage of reduction of disocclusion time with accuracy and ability to record forces and sequence of teeth contact that is not seen with usage of articulating paper.

Fixed and Removable Prosthodontics: Distribution of uniform occlusal force play vital role in Prosthodontics treatment success. Relative forces can be evaluated by using T scan (Throckmorton et al., 2009). T scan is useful in occlusal load determination in complete denture (Boening and Walter, 1992).

Posturology: Head posture is affected by occlusal abnormalities; it is improved by occlusal equilibration by T scan (Makofsky et al., 1991). Various studies demonstrated that body posture is affected by occlusal abnormalities. It can be accurately addressed by T scan frequently and verified.

Frictional dentinal hypersensitivity: Dentinal hypersensitivity is sharp pain experienced for short duration. Generally it is due to open dentinal tubules with some exceptions based on other contributing factors in some cases. Abnormal frictional contact force may cause chronic cold sensitivity; this kind of frictional dental hypersensitivity can be effectively managed by equilibration with T scan (Yiannios et al., 2017).

Myofunctional pain: Abnormal occlusal functional forces results in Oro-facial related muscular pain. It may be due to extended disocclusion time. Identification of abnormal forces and disocclusion time reduction can be done by T scan (Kerstein, 1994), which in turn effectively reduces myofunctional pain.

EMG and JVA (Joint Vibration Analysis): Electromyography helps to evaluate the muscle activity inclusive of Occluso-muscular disorder. In addition JVA evaluates the internal joint derangement. T scan III can synchronize with EMG and JVA. In combination with EMG and JVA, T scan is very effective tool for patients for diagnosing the causative factors and thus contributes in formulation of treatment plan.

Gnathology: Gnathological postural position can affect the performance of professional sport player. Many wear splint during sport activity. Equilibration of splint with T scan has shown to improvise Gnathological postural position resulting in enhanced sport performance (Baldini et al., 2012).

Other applications include: Disocclusion reduction time (Kerstein, 2020) Digital work flow, Clenching, Tinnitus and Menniere's disease, Di-Berardino et al. in 2016 studied 47 tinnitus patients by using T scan III. Also has proven useful in educating patients, Splint treatment analysis, Bruxism diagnosis-treatment planning and evaluation, Medico-legal document formulation, Research Practice builder, Immediate complete anterior guidance development (Kerstein, 1992), CEREC (Kerstein, 2008) (table 3).

Table 3 explains the advantages and limitations of the T-scan system

Advantages	Limitations
3 D evaluations of occlusion	Transfer of location of occlusal
Advancement in diagnosis	contact is not possible
Improvements in quality of treatment	Inability to measure absolute force
Specialty practice	Time and force two different mode
Valid medico-legal document	Sharp cusp can perforate sensor
Marketing tool	0.06 mm exceeding interference only
Digital approach with no paper work	can be registered
No temporary discoloration of teeth	Cost of instrument and sensor is very
like in articulating paper	high and continuous up-gradation

Upper and lower arch can be evaluated in anterior and posterior quadrant Centre of force of each arch can be evaluated Timing of occlusal contact can be evaluated Relative occlusal force can be evaluated Saliva do not interfere with recording	requires additional investment Neuromuscular incoordination of patient affect recording

Safety issues

It is class I device approved by FDA. It is low risk profile device (Jain et al., 2015).

3. DISCUSSION

One of the modern approaches for occlusion inspection is T scan. It was invented in 1981. Thereafter it continuously upgraded from T scan I, T scan II, T scan III, T scan III (software 5,6,7), T scan with turbo mode recordings, T scan 8, T scan 9 and T scan 10. It can record timing of occlusion, maximum intercuspation contact, multi bite record, right and left lateral records, protrusive records, relative force quadrant wise and with individual tooth. It also creates video-graphic database of bite patterns and forces. The scanned data can be saved, exported and reports can be generated for multiple patients. It can record maximum bite forces, in centric occlusion, multibite, protrusive, left and right lateral bite. Relative forces on each tooth, quadrant wise force can also be evaluated. A customized note can be added to each scan in relation to data or patient. Graphs created for each scan has options of "Show" or "Hide". Previously recorded images of intraoral scanner can be overlapped on scan. Upper and Lower both arches can simultaneously be seen with an added option of viewing one arch with graph. Indicator that detects the handle of the device is present which eases out the procedure. Force outliner is faculty is present for highest force. Video-graphic data form of the bite patterns are created which can be reversed and forwarded and speed for the same can be adjusted. Width of each tooth can be fed or option of creating arch by providing central incisor width. Table indicating the duration is also created.

Dental implant is time tested successful treatment option (Ganji et al., 2013), (Shilpa et al., 2018), (Datarkar et al., 2015) but implant occlusion is one of critical area for treatment planning, which can be appropriately managed by T scan (Pyakurel et al., 2013). Starting from diagnosis to case completion, it has wide range of utility. It is more than 35 years old proven technology. World in dental science is shifting towards digitalization (Sidana et al., 2013). T scan plays a vital role in digital workflow. Medico-legal issues are rising in leaps and bounds; so medico-legal document validity is highest with T scan (Pyakurel et al., 2013). Temporomandibular dysfunction evaluation and treatment can be done by T scan successfully (Ferrato et al., 2009). It records force which is decisive factor in occlusion treatment success, it also record time duration of occlusion additionally earliest three contacts of the teeth which further benefits in treatment success (Pyakurel et al., 2013), (Sidana et al., 2013). Over all T scan can has great utility in improving accuracy of treatment.

4. CONCLUSION

Occlusion is one of core critical subject in dental practice. Articulating paper is one of the most common treatment medium used for occlusion, but force measurements, time measurement are the shortcomings faced in routine practice. T scan overcomes the mentioned shortcomings efficiently with adequate reliability and sensitivity. T scan is a versatile device with its multitudes of use in various field of dentistry, like Prosthodontics, Implantology, Oral surgery, Periodontics, Pedodontics and Endodontics (Mukherjee et al., 2017). The only disadvantage being the cost factor but in future with increased usage and awareness about the device can overcome this. More awareness of T scan needs to be created for better utility of device and there is also a further scope for research for creating more scientific data on this specialty.

Future research area

Occlusal consideration in Implantology and survival rate of prosthesis, periodontal disease progression, temporomandibular disorders and Posture and body balance. Trigeminal neuralgia, cervical dystonia, Phantom bite syndrome, emotional depression, migraine, tension headache and muscular related comorbid conditions are common nowadays, which have various etiological factors in association. These can be effectively diagnosed and managed (Khanam et al., 2019; Kerstein, 2020). Various musculo-

cutaneous disorders may also be linked to various nerve injuries or pathologies (Sthapak et al., 2018) can be detected and treated effectively using T scan.

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Conflict of Interest

The authors declare that they have no conflict of interest

Ethical clearance

Manuscript doesn't fall under the category of patient based study also is a literature based review and hence no ethical consideration was required.

Data and materials availability

All data associated with this study are present in the paper.

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