Journal of Research in Medical and Dental Science
2021, Volume 9, Issue 11, Page No: 187-193

Available Online at: www.jrmds.in
eISSN No.2347-2367: pISSN No.2347-2545

Digital Occlusal Analyser T-Scan: A Review

Jaykumar R Gade, Megha J Agrawal*, Sayali G Dandekar, Minal N Soni, Karan V Jaiswal, Anil Ingole

Department of Prosthodontics and Crown and Bridge, Swargiya Dadasaheb Kalmegh Smruti Dental College and Hospital, Nagpur, India

ABSTRACT

Occlusion is a very important topic for various field s of dentistry. Various methods have been used for assessing the pattern of occlusion. Articulating paper is the most common method for evaluating the correct occlusion. T-scan is the digital occlusal analysis system use to assess and evaluate the occlusal contact in real time and the force of occlusion. The search strategy of this article includes the use of key concepts such as occlusal indicators, T-scan system, digital occlusal indicator, and sensor. The literature is search using these keywords and the articles were selected. Selected articles were organized, and subtopics were evaluated and confirmed. The aim of this article is to provide a detail review of T-scan system which includes assembly, sensor, calibration, mechanism, data interpretation, application, benefits, limitation, and discussion.

Key words: T-scan, Occlusion, Trauma, Implants

HOW TO CITE THIS ARTICLE: Jaykumar R Gade, Megha J Agrawal, Sayali G Dandekar, Minal N Soni, Karan V Jaiswal, Anil Ingole, Digital Occlusal Analyser T-Scan: A Review, J Res Med Dent Sci, 2021, 9(11): 187-193

Corresponding author: Megha J Agrawal
e-mail ✉ : meghaagrawal566@gmail.com
Received: 05/09/2021
Accepted: 08/11/2021

INTRODUCTION

Occlusion is "the act or process of closure or of being closed or shut off" or "the static relationship between the incising or masticating surfaces of the maxillary or mandibular teeth or tooth analogues" [1]. For appropriate functioning, occlusal contacts must be in synchronization with the stomatognathic system. The idea of occlusion is not only limited to morphological contact interactions between teeth but also the dynamic morpho functional interactions between all constituents of the masticatory system, including teeth, periodontal tissues, the neuromuscular system, the temporo-mandibular joint and the craniofacial bones [2-4].

When mandibular teeth meet maxillary teeth, occlusal contacts are made. Nearby contacts are the areas that range from a contact to a gap of 0.5 mm between the occluding surfaces, while noncontacts are the areas where there is a 0.5-2 mm separation between contacting surfaces of the teeth. Among the various occlusal concepts existing, the concept introduced by Bonwill is more accepted one that is the bilateral balanced occlusion [5].

Occlusal trauma occurs due to uneven distributions of pressure on occluding teeth that often do not contact simultaneously. Unusual occlusal contacts and excessive occlusal height of a restoration usually leads to occlusal trauma. It has been illustrated that dental, periodontal tissues and even dental implants may deteriorate under higher bite forces and/or excursive overload, finally leading to bone loss and failure complications. Atypical protrusive interferences [6-8] lead to harmful effect on temporo-mandibular joints or by moving the mandible into a physiologically unsound position leading to muscle pain (myalgia). Destructive forces occurs if premature or interfering contacts (such as excursive on the non-working side) points are not detected through the masticatory system and may also leads to parafunction such as clenching [9,10], sore neck and facial muscles, and endanger nerves within the temporo-mandibular joint (TMJ), which has been noticed in various temporo-mandibular disorders (TMDs) [11]. In contrast, unstable centric occlusion and/or disorders such as disuse osseous atrophy occurs due to low occlusal height [12-14]. Therefore, assessment of the occlusion is pivotal to retrieve from these occlusal issues.

Various occlusal indicators were used by clinicians to analyse occlusal contacts. In clinical practice, the conventional methods used are articulation paper, silk strips, impression waxes, impression materials and shim-stock foil, for guiding contact selection during occlusal adjustment and are all often combined with the patient's occlusal "feel" feedback. The capability to quantify occlusal forces has not been demonstrated by any of these listed static dental materials' methods. The most used method is the articulation paper to determine excessive force in differing occlusal contacts. Various ink markings on the tooth surface appears when the patients occlude upon strips of articulation paper. Various studies about articulation paper analyses the physical properties like thickness, composition, ink substrate and plastic

deformation [14-16]. But none of these scientific researches proves that articulation paper mark size, or mark appearance characteristics, can accurately describe varying occlusal loads exists [17,18]. In addition to determine which contacts are forceful and which are not, "subjective interpretation" is required by the operator [19,20]. Studies conducted on mounted epoxy casts that were subjected to varying applied occlusal loads, concluded that there is no direct relationship between paper mark area (size) and applied occlusal load [17,18]. Furthermore, when articulating paper is handled intraorally during patient intercuspations it is subject to fragmentation and perforation showing that its' marking repeatability is poor [21]. Inspite of this, it has been advocated repeatedly in textbooks on occlusion that mark area is representative of the load contained within the mark [22-27]. To obviate this subjectivity in the interpretation of the articulation paper markings, T-Scan computerized occlusal force analysis system has been introduced by dental research [28].

This review will elucidate on T-scan technology in detail, its functional aspect and multi-disciplinary approach for delivering better services to patient.

History/Background

The evolution of the T-scan technology over the past 36 years had its beginning with T-scan I in 1984. First pressure sensitive ink - Mylar encased sensor (G1) technology a new computerized system known as T-scan was developed by Maness et al. in 1984 that can record occlusal forces easily and conveniently [5,29]. In 1987, Tek scan developed T-Scan, the first ever grid-based sensor technology precisely designed for occlusal analysis and it is a powerful diagnostic tool in response to the dentists need of seeking an accurate way to dynamically measure occlusion [5]. The first generation (G1) sensor has undergone many changes in its design and improvement in its registration capacity based on several clinical studies [30]. Then the same company developed T-scan II for Windows in 1995, T-scan III (software versions 5, 6, and 7) in 2004 and the last generation sensor high definition (HD) sensor which is substantially more sensitive and thinner than the previous sensors [31]. Later the development of Turbo recording in 2008, to the 2014 version known as T-scan 8 (Tekscan Inc., South Boston, MA, USA) [32]. The T-scan handpiece model got updated in 2015 as T-scan Novus (software version 9.1) and the latest updated one being T-scan v10 software version introduced in 2018 [33]. The original design of the T-SCAN system has been repeatedly modified and improved both in the software and hardware until the present-day version of the system - T-Scan III [34].

T-scan system

T-Scan is a computerized occlusal force analysis device. In prosthetic and restorative dentistry, it plays an essential part in clinical functional analysis. When the patient bites on the occlusal sensor, occlusal data is seen on the computer screen. It is characterized as dynamic 2D and 3D images with coloured columns ranging from BLUE (optimum force) to RED (high force) and the data is stored on a hard drive that can be played back in video format [35,36]. This measurable occlusal data helps the clinicians to make precisely targeted adjustments during occlusal equilibration following prosthetic, restorative, orthodontic or implant procedures. Tscan [37] latest generation technology permits the clinician to record the force, timing, balance, and location of contacts in real time. It analyses the order of the occlusal contacts and measures the percentage of the force changes and the efficiency of the occlusion from the first occlusion contact through to maximum intercuspation [38-40]. It can rapidly determine prematurity, high points, regions of excessive force, non-uniform force concentration and analyse disclusion time accurately.

Windows system requirements

Windows® Based

- Windows 7, 8 or 10.
- Microsoft, NET framework 4.0.
- Intel Core™2 Duo Processor or newer (Intel Celeron processor are not recommended).
- 2 GB RAM.
- 5 GB of Disk Space.
- Dedicated video card.

Virtual Windows Based (running on apple computer using VMware fusion 5 or Parallels Desktop 7 Virtualized system)

- MacBook Pro 13" or larger (early 2011 models or newer).
- 8 GB RAM.
- 75 GB of Disk space.

Also run-on iMac or Mac Mini, similarly configured.

Assembly

The T-Scan System is a computerized device that consists of:

- Device with a flat U-shaped pressure measuring disposable sensor.
- Sensor holder.
- A handle assembly with cable.
- System unit.
- Computer software.
- USB interface to connect to computer/laptop.
- A Printer.

The hand-held device is the hardware for the system which contains the U-shaped sensor, fitting into the patient's mouth between occlusal surfaces of teeth and is connected to the USB port of a computer [41].

Sensor

It is the key component use to record occlusal registration. Reliable measurements of occlusal biting forces obtained quantitatively by the sensor. It helps in

recording the sequence of occlusal contacts in terms of time (as a film) and the associated force with each occlusal contact.

The first generation (G1) blue sensor was comprised of a Mylar laminated pressure sensitive ink grid, which was formed in the shape of a dental arch. When inserted intraorally and loaded, the sensor relayed real time occlusal contact sequences and relative force information that interpreted 16 levels of intraoral force in 0.01-second time increments [42]. A second-generation T-Scan sensor (G2) was thinner and more flexible.

In conjunction with the T-Scan II, Tek scan developed their own proprietary resistive ink to be used in the third generation (G3) of T-Scan sensors. This new ink was designed to improve the sensor's hysteresis, drift, and repeatability. It consisted of two layers of Mylar encasing a screen-printed grid of resistive ink rows and columns printed between them. Each intersection between a row and a column represents one sensing element (sensel), which is the force and time recording element of the sensor. Applied force loaded to each sensel creates a change in resistance to the ink which results in a voltage drop in each loaded sensel. The hardware (parallel electronics) provides a current to the sensor, conditions the signal to the sensor, and performs the data acquisition for the sensor, as the various voltage drops occur throughout the sensor.

In 2002, the sensor design was altered again so that the active sensing element (sensel) size was increased by 33% while the inactive sensel area decreased by 50%. This design, the fourth generation or the high definition (HD) sensor, places the sensel much closer together within the recording grid [43].

T-scan III v10 utilizes an ultra-thin (0.004-inch, 0.1 mm), reusable sensor that is shaped to fit the dental arch. The HD sensor's structural design consists of two layers of Mylar encasing a grid of resistive ink rows and columns printed between them. T-Scan sensors are available in two sizes: large and small. Large for broad mediolateral and long anteroposterior dental arches and small for thin mediolateral and short anteroposterior dental arches [44]. 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 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 [45].

Calibration of sensor

Calibrations of the T-Scan sensors are required for reliable registration of absolute bite forces. First it 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. A reliable calibration would allow transforming T-Scan sensor output during biting in human subjects into absolute force units [46].

Recording technique

The patient is seated comfortably in upright position with looking forward. The mandible is kept parallel to the floor. The recording handle with the sensor and sensor support is placed into the patient's mouth with the sensor support pointer between the two maxillary central incisors and keeping the scanning handle as parallel to the occlusal plane as possible. The recording is initiated by pressing the button on the recording handle. The patient is asked to close the mouth till complete intercuspation is reached, without making any excursive movements. After the handle button is pressed the arch model is automatically created on the screen [5].

Mechanism

When the patient bites on the sensor, the resultant change in electric resistance is converted into an image on the screen. The program can be operated under two modes: time analysis and force analysis. Time analysis provides information on the location and timing of contacts displaying on the screen with the first, second and third or more contacts in different colours. On the top of the monitor screen the timing of each successive contact about the first will be displayed. Force analysis shows the location of contacts and their relative force in five different shades of colour. On the bottom of the screen, bite length can be read. Within the force analysis mode, two sub modes can be selected, namely the 'instantaneous' which records contacts at specific mandibular positions obtained as a force snapshot, an instantaneous single record of force and the 'sequential' which analyses the contact throughout mandibular movement obtained as a force movie, a 3-second continuous recording of force consisting of some 180 frames [48,49].

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. It can assess the initial occlusal contact, the order in which 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 [35].

Data interpretation

The data recorded is shown as a force film, in which the center of force trajectory shows the history of the path of the centre of the force from the beginning of the force movie recording to the current displayed frame. The amount of relative occlusal force is displayed in 3-dimensional coloured bar graphs. The colour and height of each bar quantifies the intensity of force per contact. The magnitude of occlusal load is colour coded the maximum being shown in red and the minimum force in blue [50].

Thus, by gaining information on the earliest occlusal contact, it can be adjusted, and simultaneous occlusal contact can be established. The consequence of this occlusal therapy is that the patient can feel a more widespread contact sensation at the end, the reason being that the establishment of true and measurable bilateral simultaneous occlusal contacts is achievable using the T-scan [47].

Applications

- Diagnostic screening: Natural dentition with occlusal disturbance or occlusal trauma is the reason of many pathologies in the mouth. T-scan acts as valuable tool in diagnosing occlusal trauma.
- Patient education (treatment acceptance, improve longevity, enhanced comfort, eliminate extra visits), occlusal diagnosis and equilibration.
- 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. T-Scan system was used as a diagnostic screening method for occlusal stability in intercuspal position and occlusal balancing.
- Implantology: Dental implants may deteriorate under excursive overload and higher bite forces, eventually leading to bone loss and implant failure. T-Scan shows in thousands of a second time intervals how force is applied to adjacent teeth and implants.
- Temporomandibular Disorders: Prolonged disclusion time, frequency of premature contacts and asymmetry in the occlusal force, and intracapsular joint disorder led to numerous temporomandibular joint related problems. The application of T-Scan and kinesiographic techniques in combination with electromyography is used to locate certain factors such as chronology and strength of contact points, muscular activity, or certain mandibular movements.
- Case Finishing: As articulating paper does not measure force, balance, or timing, it is not a media to rely on. T-Scan allows a clinician to case finish with accuracy and confidence.
- Orthodontics: 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.
- 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 rule out over/under restored tooth and saved the time of finishing restoration and recall visits.
- Oral and maxillofacial surgery: Mandibular and dentoavleolar fractures are common in road traffic accident. This leads to a minor or major disoclusion leading to reduction in bite forces. 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. It also plays a major role in determining the accuracy of occlusion after orthognathic surgery.

Benefits

- It measures location and timing of tooth contact and occlusion in 3D.
- Premature contacts and interferences can be identified in the dynamic occlusion instead of static.
- It is a reliable tool to detect early contacts and effectively used to check occlusal balances.
- Allows symmetry of force relationships to be analyzed in the dental arch.
- Help in achieving the precise diagnosis.
- Increased quality of care.
- Enhanced patient education and increase patient involvement and treatment acceptance
- Decreased treatment time.
- Reduced risk of implant failure, traumatized teeth, unstable dentures, ineffective splints, and porcelain fractures.
- Increased comfort of patients with dental prosthesis.
- Data can be recorded and saved.
- Legal documentation of outcome.
- Build your practice.
- Increased referral business from other physicians.

LIMITATIONS

- Due to inadequate flexibility of the foil, uncontrolled shift in mandible have been seen, which results in incorrect data [51].
- The surface of the sensor film does not always show uniform sensitivity and the sensor film requires pre-conditioning for an accurate recording [52].
- The sensors could alter the occlusion and interfere with the occlusion.
- Thinner occlusal registration materials provide more stable records of the contact points. To fulfil this, the T-Scan sensors are made as thin as possible (0.1mm) which are still relatively thicker as compared to occlusal indicators like articulating silk. Thick sensor may inhibit dental proprioception.
- The sensors may be damaged when forces are concentrated over a small area, such as a sharp tooth cusp. This may lead to inexact recording of the

occlusal contact and/or artifacts in the produced images.
- The T-Scan system can reproduce occlusal interferences only exceeding 0.6mm in dimension.
- Also, the two unlike modes of the system (force and time analysis modes) may mimic 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 variances are small.
- It lacks reproducibility of data.
- Inability to measure absolute bite force value.

DISCUSSION

The basics of T-Scan technology and its components have been explained in this article. Along with the brief of how the T-Scan HD sensor records the relative occlusal force, occlusal contact time sequences and the hardware and software features is given.

By viewing the force and time data and correlating it to the locations (only) of articulating paper marks, the sequence of contacts and the forces contained within each labelling can be visualized, and interpreted. Then, corrective occlusal adjustments made to natural teeth, dental prosthesis and implant prosthesis, can be made with knowledge of the order and force content within a specific (or a series) of marks. Occlusal force control on dental materials, dental implants, and/or natural teeth can then be measurably designed to insure material, implant, or occlusal surface survival.

Bilateral simultaneous contact can be clinically established through measurement of the occlusal contact sequence. This insures no one region of the dental arch contacts too early (forced to absorb excess early stress) or too late (unable to assist the other regions in force dissipation). Both precision force and time control is afforded by the operator through measurement with the recording sensor which replaces the "hit or miss" operator subjective interpretation of coloured ink marks on teeth. Precision occlusal endpoints, where all teeth meet in 0.2 seconds or less, all posterior teeth disclose in 0.4 seconds or less from excursive commencement, and 50% right side -50% left side force balance, is readily attainable when corrections are guided by the T-Scan III system.

Moini et al. [53] compared the reproducibility of T-scan with silk ribbon and reported that it was not as accurate as the silk ribbon. Then study conducted by Hsu et al. [54] on sensitivity and reliability of T-scan system concluded that sensors did not have the same sensitivity throughout their surface. Koos et al. [55] reported that the level of accuracy is acceptable, and no interferences arouse from change in foil or repeated measuring was detected with T-Scan. Throckmorton et al. [30] concluded that without either shim stock or bite guard, the T-Scan sensors are not reliable enough for recording of absolute occlusal forces. Although the T-Scan sensors are available in two different sizes to accommodate arches of different dimensions, the literature search did not identify any articles reporting the use of this system in children and patients with limited mouth opening. An important aspect of the T-Scan system is that the contact timing and the force analysis can be studied on the software. Thus T-Scan is able to provide a definitive diagnosis of the occlusal force balance and masticatory muscular function.

The product is now marketed in its third version as T-Scan III with software version 10. Moreover, the newer software provides a better representation of the intraoral dental arch in the analysis program of the software when compared to previous versions.

Safety issues

T-Scan systems are classified as Class I devices by the FDA. They have low-risk profiles since they are not "life-supporting, life-sustaining or of substantial importance in preventing impairment of health nor present a potential unreasonable risk of illness or injury".

CONCLUSION

Even though determining a correct occlusion is a challenging task, T-Scan act as occlusal mapping device to record the pattern of occlusion and widely used in dentistry nowadays and claims to correct the occlusion. The data is obtained from T-scan can be analyzed in three ways:

- It shows the duration and relative magnitude of all tooth contacts
- It identifies disproportional loading forces and transient impact forces acting on specific teeth
- It identifies active tooth contact occurring within the functional range of mandibular movement and the interaction between working and nonworking interferences.

T-Scan system has presented sufficient sensitivity and specificity as a diagnostic tool and presented higher reliability in intra-oral conditions in the presence of saliva. This technology reduces the subjective interpretation of occlusal analysis data and provides registration of dynamic occlusal information. It helps in assessing treatment outcomes. Though its cost is very high, but it is a valuable method for clinical evaluation and understanding of the occlusal difficulties and also it offered an important tool for teaching purposes.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

CONFLICT OF INTEREST

There is no conflict of interest with this publication.

REFERENCES

1. https://www.academyofprosthodontics.org/lib_ap_articles_download/GPT9.pdf
2. Rues S, Schindler HJ, Turp JC, et al. Motor behavior of the jaw muscles during different clenching levels. Eur J Oral Sci 2008; 116:223-228.
3. Dickerson WG, Chan CA, Carlson J. The human stomatognathic system: A scientific approach to occlusion. Dent Today 2001; 20:100-107.
4. Kois JC, Phillips KM. Occlusal vertical dimension: Alteration concerns. Compend Contin Educ Dent 1997; 18:1169-1174.
5. Somkuwar K. A descriptive quantitative computerized occlusal analysis system: T-Scan. IJAR 2015; 3:508-513.
6. Okano N, Baba K, Ohyama T. The influence of altered occlusal guidance on condylar displacement durinsg submaximal clenching. J Oral Rehabil 2005; 32:714-719.
7. Milosevic A, Samuels RH. The post-orthodontic prevalence of temporomandibular disorder and functional occlusion contacts in surgical and nonsurgical cases. J Oral Rehabil 2000; 27:142-149.
8. Dos Santos Junior J, de Rijk WG. Occlusal contacts: Vectorial analysis of forces transmitted to temporomandibular joint and teeth. Cranio 1993; 11:118-125.
9. Baba K, Ai M, Mizutani H, et al. Influence of experimental occlusal discrepancy on masticatory muscle activity during clenching. J Oral Rehabil 1996; 23:55-60.
10. Carlsson GE, Egermark I, Magnusson T. Predictors of bruxism, other oral parafunctions, and tooth wear over a 20-year follow-up period. J Orofac Pain 2003;1 7:50-57.
11. Cascone P, Fatone FMG, Paparo F, et al. Trigeminal impingement syndrome: The relationship between atypical trigeminal symptoms and antero-medial disk displacement. Cranio J Craniomandibular Practice 2010; 28:177-180.
12. Schelb E, Kaiser DA, Brukl CE. Thickness and marking characteristics of occlusal registration strips. J Prosthet Dent 1985; 54:122-6.
13. Cohn SA. Disuse atrophy of the periodontium in mice. Arch Oral Biol 1965; 10:909-19.
14. Cohn SA. Disuse atrophy of the periodontium in mice following partial loss of function. Arch Oral Biol 1966; 11:95-105.
15. Halperin GC, Halperin AR, Norling BK. Thickness, strength, and plastic deformation of occlusal registration strips. J Prosthet Dent 1982; 48:575-578.
16. Millstein P, Maya A. An evaluation of occlusal contact marking indicators. A descriptive quantitative method. J Am Dent Assoc 2001; 132:1280-1286.
17. Carey JP, Craig M, Kerstein RB, et al. Determining a relationship between applied occlusal load and articulating paper mark area. Open Dent J 2007; 1:1-7.
18. Saad MN, Weiner G, Ehrenberg D, et al. Effects of load and indicator type upon occlusal contact markings. J Biomed Mater Res B Appl Biomater 2008; 85:18-22.
19. Carossa S, Lojacono A, Schierano G, et al. Evaluation of occlusal contacts in the dental laboratory: Influence of strip thickness and operator experience. Int J Prosthodont 2000; 13:201-204.
20. 20. Millstein P. Know your indicator. J Mass Dent Soc 2008; 56:30-1.
21. Gazit E, Fitzig S, Lieberman MA. Reproducibility of occlusal marking techniques. J Prosthet Dent 1986; 55:505-9.
22. Glickman I, Carranza FA. Glickman's clinical periodontology: Prevention, diagnosis, and treatment of periodontal disease in the practice of general dentistry. 5th Edn. Philadelphia; WB Saunders Co. 1979; 951.
23. McNeill C. Science and practice of occlusion. Quintessence Publishing 1997; 421.
24. Okeson JP. Management of temporomandibular disorders and occlusion. 5th Edn. St. Louis; Mosby; 2003; 416-605.
25. Kleinberg I. Occlusion practice and assessment. Knight Publishing 1991; 128.
26. Smukler H. Equilibration in the natural and restored dentition. Quintessence Publishing Co. 1991; 110.
27. Dawson PE. Functional occlusion: From TMJ to smile design. St. Louis Mosby 2007; 47.
28. 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.
29. Maness WL, Benjamin M, Podoloff R, et al. Computerized occlusal analysis: a new technology. Quintessence Int 1987; 18:287-92.
30. Throckmorton GS, Rasmussen J, Caloss R. Calibration of T-Scan® sensors for recording bite forces in denture patients. J Oral Rehabil 2009; 36:636-43.
31. Gözler S, Vanlioglu B, Evren B, et al. The effect of temporary hydrostatic splint on occlusion with computerized occlusal analysis system. Indian J Dent Res 2012; 23:617-22.
32. Kerstein RB. Handbook of research on computerized occlusal analysis technology applications in dental medicine. Global Publishers 2015.
33. https://www.tekscan. com/dental

34. Kerstein RB. Current applications of computerized occlusal analysis in dental medicine. Gen Dent 2001; 49:521-30.
35. Pyakurel U, Long H, Jian F, et al. Mechanism, accuracy and application of T-Scan system in dentistry-A review. J of Nep Dent Assoc 2013; 3:1-5.
36. https://www.tscan.nl/wpcontent/uploads/2016/12/DTL-T-Scan-Clinical-eBook.pdf
37. https://www.tekscan.com/ company/history
38. Kim KA, Oh WS, Lee JJ. Recording an accurate maxillomandibular relationship by adding vertical stops to the occlusal rims. J Prosthet Dent 2019; 121:242-245.
39. Yanikoğlu ND, Güldağ MU, Duymuş ZY. Determination of the occlusal vertical dimension: use of maxillary and mandibular posterior teeth measurement in edentate subjects. Eur J Prosthodont Restor Dent 2005; 13:75-77.
40. Foong KW, Patil PG. Fabrication of maxillary single complete denture in a patient with deranged mandibular occlusal plane: A case report. Saudi Dent J 2019; 31:148-154.
41. Karan Abrol, Sakshi Abrol. T-Scan–The dental advisor International J Applied Dent Sci 2019; 5:25-27.
42. Maness WL. Force movie, a time and force view of occlusion. Compendium 1989; 10:404-408.
43. Kerstein R, Lowe M, Harty M, et al. A force reproduction analysis of two recording sensors of a computerized occlusal analysis system. J Craniomandib Pract 2006; 24:1-10.
44. Komali G, Ignatius AV, Srivani GS, et al. T-scan system in the management of temporomandibular joint disorders–A review. J Indian Acad Oral Med Radiol 2019; 31:252-256.
45. Kerstein RB. Computerized occlusal analysis technology and Cerec case finishing. Int J Comput Dent 2008; 11:51-63.
46. Throckmorton GS, Rasmussen J, Caloss R. Calibration of T-Scan® sensors for recording bite forces in denture patients. J Oral Rehab 2009; 36:636-43.
47. Nalini MS, Sinha M. Role of T-scan in digital occlusal analysis–A review. Int J Res Reports Dent 2018; 1-7.
48. Cartagena AG, Sequeros OG, Garcia VG. Analysis of two methods for occlusal contact registration with the T-Scan system. J Oral Rehab 1997; 24:426-32.
49. Lyons MF, Sharkey SW, Lamey PJ. An evaluation of the T-Scan computerised occlusal analysis system. Int J Prosthodont 1992; 5:166.
50. Trpevska V, Kovacevska G, Benedeti A, et al. T-scan III system diagnostic tool for digital occlusal analysis in orthodontics-a modern approach. Prilozi 2014; 35:155-60.
51. Kumagai H, Suzuki T, Hamada T, et al. Occlusal force distribution on the dental arch during various levels of clenching. J Oral Rehabil 1999; 26:932–35.
52. da Silva M, Caramelo F, Ramalho J, et al. In vitro study on the sensibility and reproducibility of the new T-Scan III HD system. Rev Port Estomatol Cir Maxilofac 2014; 55:14-22.
53. Reza Moini M. Neff PA. Reproducibility of occlusal contacts utilizing a computerized instrument. Quintessence Int 1991; 22:357-60.
54. Hsu M, Palla S, Gallo LM. Sensitivity and reliability of the T-scan system for occlusal analysis. J Craniomandib 1992; 13:17-23.
55. Koos B, Godt A, Schille C, et al. Precision of an instrumentation-based method of analyzing occlusion and its resulting distribution of forces in the dental arch. J Orafac Orthop 2010; 71:403-410.