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Review Article

The T-scan system: A digital approach to occlusal analysis in modern dentistry

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Abstract

Occlusion is fundamental to preserving the functional integrity of the stomatognathic system. Conventional techniques for assessing occlusion primarily depend on subjective patient responses and visual judgment, often lacking measurable data concerning the force and timing of occlusal contacts. Introduced in 1984 and now in its tenth generation of software, the T-Scan system offers a computerized, objective, and dynamic method for occlusal evaluation. Utilizing a pressure-sensitive Mylar sensor, the device records the timing and relative intensity of occlusal forces, helping clinicians identify early contacts, imbalanced force distribution, and potential temporomandibular joint issues. The system delivers real-time two-dimensional and three-dimensional visual outputs under both temporal and force analysis settings. Its versatility extends across various dental disciplines, including prosthodontics, implantology, orthodontics, restorative procedures, and post-operative monitoring. T-Scan enhances diagnostic precision, facilitates patient understanding, and may streamline treatment processes. However, it is not without limitations, such as its inability to measure absolute force, variability in sensor performance, and reduced reliability in certain clinical scenarios. Despite these challenges, the system has shown sufficient sensitivity and specificity to be a reliable tool in clinical practice. By enabling more accurate occlusal adjustments and promoting evidence-based treatment planning, T-Scan plays a significant role in advancing contemporary approaches to occlusal diagnostics and care.

Keywords: Computerized Occlusal analysis, Digital Analysis, Dynamic Mapping, T-Scan.

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1. Introduction

Occlusion can be defined as "the act or process of closure or of being closed or shut off," or more specifically, as "the static relationship between the incising or masticating surfaces of the maxillary and mandibular teeth or their analogues".[1] For optimal function, occlusal contacts must harmonize with the overall stomatognathic system. The concept of occlusion goes beyond just the morphological interaction between teeth—it encompasses the dynamic, functional interplay of all elements within the masticatory system, including the teeth, periodontal structures, neuromuscular components, temporomandibular joints (TMJs), and craniofacial bones.[2-4]

In the context of occlusion, *nearby contacts* are defined as zones with either contact or a gap of up to 0.5 mm between opposing tooth surfaces. In contrast, *non-contacts* refer to separations ranging from 0.5 to 2 mm. Among the various occlusal theories, Bonwill's concept of bilateral balanced occlusion is widely accepted.[5]

Occlusal trauma typically results from uneven distribution of forces across the dentition, where opposing teeth may not contact simultaneously. Contributing factors often include premature contacts or excessive cusp height in restorations. Studies have indicated that heightened bite forces or abnormal lateral stresses can lead to damage in dental and periodontal structures, as well as in implants—frequently culminating in bone resorption or implant failure. Additionally, protrusive interferences can negatively affect the TMJs or force the mandible into a pathologic position, resulting in muscular discomfort or myalgia. Undetected occlusal discrepancies or interferences during mastication can generate harmful forces that may provoke clenching, facial and cervical muscle soreness, and even impinge upon

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nerves within the TMJ, contributing to various temporomandibular disorders (TMDs).[6] Hence, a thorough occlusal evaluation is crucial to prevent and manage such complications.

Traditionally, clinicians have relied on various occlusal indicators such as articulation paper, silk strips, impression waxes, elastomeric materials, and shimstock foil to detect contact points during adjustments. These conventional methods, however, depend heavily on patient perception and fail to measure occlusal force quantitatively. In response to these limitations, advanced technologies such as the T-Scan system have emerged for digital occlusal analysis. The T-Scan offers notable advantages, including high sensitivity, reproducibility, and the ability to record the sequence of occlusal contacts, the timing, and the distribution of relative forces. The most recent iteration in use is the T-Scan III system.[7]

2. Historical Development & Clinical Utility

The T-Scan system was initially introduced in 1984 by Maness and colleagues, making it the first computerized device to analyze occlusal contact using both force and timing metrics. It marked a shift toward grid-based occlusal analysis technology. By 1987, the system was made commercially available through Tekscan. The early model utilized epoxy-based sensors embedded with conductive ink, capable of recording occlusal contact timing and intensity.[8]

In 1991, Kerstein RB and Wright N utilized the first-generation T-Scan to study disocclusion time in patients with myofascial pain, emphasizing the system's diagnostic potential.[9] Later, in 2010, Bernd Koos and associates conducted a clinical evaluation involving 45 patients and validated the T-Scan's accuracy and repeatability.[10]

Table 1: Evolution of the T-scan system (Kerstein, 2020)[11]

T-Scan Version	Year	Key Features	Contact Timing (seconds)
T-Scan I	1984	Epoxy-based, ink grid, intraoral force recording	0.01
T-Scan II	1995	Windows interface, 2D/3D views, trajectory, customizable dental arches	0.01
T-Scan III	2004-2006	Synchronized EMG, zoom features, detailed force-time graphs	0.03
T-Scan III (Software 5-7)	2004	Patient data storage, EMG sync, 2D/3D visualization	0.03
T-Scan 8	2012	Simplified graphics for learning purposes	0.03
T-Scan 9	–	Introduction of ergonomic Novus handle	0.03
T-Scan 10	2018	Enhanced interface, digital impression overlay, implant safety alerts	0.03

3. Sensor Generations Overview

Across its development, five generations of T-Scan sensors have been introduced (Kerstein, 2020) - 1st Generation (1984): Consisted of a pressure-sensitive epoxy matrix with Mylar laminations and conductive ink.2nd Generation (1992): Featured urethane-based dielectric within Mylar casing, enhancing flexibility and resistance to cracking.3rd Generation (1997): Utilized a dual-layer Mylar construction with pressure-sensitive ink grid, offering better thermal stability and reduced drift.4th Generation (2002): Included HD capabilities, increased the recording zone by 33%, and minimized non-recording area by 50%.5th Generation (2018): Combined dual-layer Mylar and Novus handle, offering larger HD sensors for improved data precision.[11]

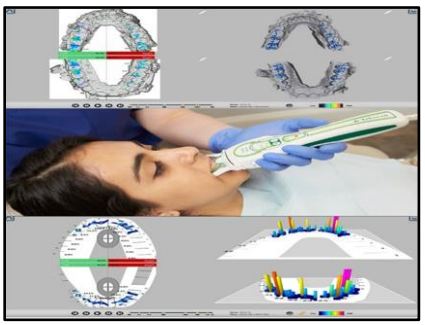

Figure 1: Occlusal force analysis using T-scan system

4. Components and Working Modes

The T-Scan system comprises a pressure-sensitive sensor (U-shaped), a handle, sensor holder, system unit, computer software, USB connection, and a calibration unit. It functions in two primary modes:

1. Time Mode: Visualizes occlusal contacts in 3D, highlighting the first three contact points with corresponding time values.
2. Force Mode: Analyzes contact location and intensity in both 2D and 3D, with output displayed as an animated sequence.

The patient, seated upright, bites in centric relation on the sensor. The system registers occlusal dynamics, showcasing data such as relative force, contact sequence, and bite timing in both 2D and 3D formats.[12]

5. Working Mechanism

Occlusal contact alters the sensor's electrical resistance, converting pressure data into visual imagery. Two analyses are provided: Time Analysis: Highlights the sequence of contacts using color-coded indicators. Force Analysis: Visualizes occlusal force intensity and location using varying colour shades.

Force mode subtypes:

1. Instantaneous: Captures a single force snapshot at a specific mandibular position.
2. Sequential: Monitors occlusal contacts throughout the jaw's movement, generating a continuous movie-like visualization.

Instead of measuring absolute occlusal forces, the system tracks relative force values, which ensures consistent and comparative evaluation across different sessions, independent of muscle activity variation.[13]

6. Clinical Applications

Diagnostics: Early detection of occlusal imbalances and dysfunctions. Prosthodontics: Helps in identifying high points on restorations and ensuring occlusal stability. Implant Dentistry: Assists in assessing force distribution to prevent overload and implant failure. TMJ Disorders: Combined with EMG, helps in analyzing mandibular movement and muscular activity. Orthodontics: Aids in pre- and post-treatment occlusal assessments to ensure proper bite alignment. Restorative Dentistry: Detects occlusal discrepancies in restorations, reducing failure and discomfort. Surgical Evaluation: Useful post-operatively to assess occlusal harmony after procedures such as orthognathic surgery.[14]

6.1. Advantages

1. Provides 3D visualization of occlusal contact timing and location.
2. Enables early detection of occlusal interferences during functional movements.
3. Facilitates precise force analysis across dental arches.
4. Enhances patient understanding and compliance with treatment plans.
5. Reduces treatment time and risk of implant complications or prosthetic failures.
6. Records can be stored for longitudinal monitoring.

6.2. Limitations

1. Sensor sensitivity is not uniform and requires calibration before use.
2. Sensor thickness may interfere with proprioception and occlusal accuracy.[15]
3. Sharp occlusal contacts may distort sensor output, creating recording artifacts.
4. It cannot reliably detect interferences smaller than 0.6 mm.
5. Time and force analysis modes may show slight inconsistencies in occlusal contact representation.
6. Absolute bite force measurement is not possible; only relative forces are recorded.
7. Manual recording techniques (e.g., handheld loading) can introduce variability between trials, though increasing the sample size can help mitigate random errors.[16]

7. Discussion

The T-Scan system represents a significant advancement in computerized occlusal analysis, offering a dynamic, quantifiable method to assess occlusal contact timing and relative force distribution. This technology addresses many limitations of traditional occlusal assessment tools such as articulating paper and shim stock, which are inherently subjective and limited to static, visual evaluations. With the incorporation of high-definition sensors and updated software, the T-Scan system allows for real-time recording and visualization of occlusal contacts in both 2D and 3D formats, enabling clinicians to make precise and evidence-based occlusal adjustments.[17]

The ability to correlate the sequence and magnitude of contacts with their specific intraoral locations enhances the clinical relevance of occlusal adjustments. This is particularly beneficial when managing prosthetic restorations, implant-supported prostheses, and occlusal imbalances. The system facilitates the establishment of bilateral simultaneous occlusal contacts, ensuring that no region of the arch is subjected to excessive early force or delayed loading. Achieving such balance is critical for promoting functional harmony and preventing undue stress on restorative materials or biological structures.

The objectivity provided by T-Scan technology eliminates the guesswork often associated with traditional methods. Operators can measure and control both force and timing with precision. For instance, ideal occlusal endpoints—where all teeth contact within 0.2 seconds and posterior disclusion occurs within 0.4 seconds of initiating an excursive movement—can be reliably attained with the aid of T-Scan-guided corrections. Additionally, the system enables clinicians to achieve a symmetrical distribution of occlusal force (50% right and 50% left), which is essential for long-term stability of the occlusion.[18]

Despite these advantages, several studies have highlighted limitations of the T-Scan system. Moini et al., 1991 reported that its accuracy was lower than that of traditional silk ribbon methods.[19] Hsu et al.,1992 found that sensor sensitivity was not uniform across the sensor surface,

potentially affecting the reliability of recordings.[20] Throckmorton et al.,2009 emphasized that the system is not suitable for measuring absolute bite forces without the use of additional aids like shim stock or bite guards.[21] Furthermore, although T-Scan sensors are available in multiple sizes to accommodate varying dental arch dimensions, there is limited evidence regarding their effectiveness in pediatric populations or individuals with restricted mouth opening.

Koos et al.,2010 however, demonstrated that the system maintains a satisfactory level of accuracy and that the replacement of sensors or repeated measurements did not introduce significant variation.[22] Moreover, the evolution of the software—now in its tenth version—has led to improvements in the graphical representation of the dental arch, making occlusal analysis more anatomically accurate and clinically useful.

An important feature of the T-Scan system is its capacity to separately analyze contact timing and force distribution, offering a comprehensive overview of occlusal function and muscular coordination. This dual analysis allows clinicians to make a definitive diagnosis of occlusal imbalances, facilitating better treatment planning in various disciplines such as prosthodontics, implantology, restorative dentistry, and orthodontics.[23]

The T-Scan system has undergone notable improvements; newer sensors are thinner and more adaptable, enhancing patient comfort and allowing for more precise detection of bite forces and contact timing. T-Scan v10 software is the latest release in digital occlusion technology, which reveals the force, timing, balance, and location of contacts in the mouth in real-time. Incorporate occlusion as part of the intraoral workflow, integrate biometric data, and work more efficiently with improved chairside functionality. NEW features and enhancements to simplify digital occlusion, T-Scan v10 boasts improvements to the database, security, and patient files and reports. Design and functionality features allow for capturing bite data more efficiently.[24]

In conclusion, while the T-Scan system is not without limitations, it provides a significant enhancement over traditional occlusal assessment tools. Its ability to objectively measure contact timing and relative force distribution contributes to improved diagnostic accuracy and more predictable treatment outcomes. Future developments should aim to improve sensor sensitivity and adapt the technology for broader applications, including use in pediatric and special-needs populations.[25]

8. Conclusion

Accurate assessment and correction of occlusion remains a complex clinical challenge. The T-Scan system, functioning as a computerized occlusal mapping tool, offers a valuable solution by enabling precise analysis of occlusal contact patterns. It is increasingly adopted in clinical dentistry due to its ability to provide objective data on occlusal function. The system allows for comprehensive evaluation in three key aspects: (a) it displays the timing and relative intensity of all tooth contacts, (b) it detects excessive occlusal loads and brief impact forces on individual teeth, and (c) it reveals active contacts within the functional mandibular range, including the relationship between working and non-working interferences. T-Scan has demonstrated strong sensitivity and specificity in clinical diagnostics, and it performs reliably under intraoral conditions, even in the presence of moisture such as saliva. By eliminating the reliance on subjective interpretation, it allows for the registration and evaluation of dynamic occlusal data with high precision. Despite the high cost associated with this technology, it proves to be a valuable asset in both clinical practice and dental education. It enhances the clinician's ability to diagnose occlusal imbalances accurately, monitor treatment outcomes, and improve patient care through data-driven decisions. Thus, the T-Scan system stands as an important tool for advancing the understanding and management of occlusal dynamics in contemporary dentistry.

9. Source of Funding

None.

10. Conflict of Interest

None.

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