Capabilities of the T-Scan 10 Novus System in the Diagnosis of Occlusion

Abstract

The physiological restoration of occlusal relationships is important for the normal functioning of the masticatory system. Currently, qualitative and quantitative occlusal indicators are used in clinical practice for occlusion registration. In the past, articulation paper, foil, silk marks, waxes, etc. were the only tools available to access and balance the bite force. However, these methods do not detect simultaneous contact, nor do they quantify time and force. With the introduction of T-Scan, this changes. The evolution of T-Scan from the 1st generation to the 8th generation (1987-2016) has revolutionized the concept of occlusal analysis. The latest version of the T-Scan Novus system, is software version 10.0 that was released in 2018. The T-Scan Novus system is made up of hardware (handpiece, sensor) and Microsoft Windows-based software.

The registered occlusion is transformed by a computer into a dynamic film (dynamic occlusion video). Recorded occlusal contacts are then illustrated as 2- and 3-dimensional graphics. The improved features of the software provide detailed digital information about the occlusal relationships, which enhances the quality of their analysis.

T-Scan Novus helps to avoid errors in the subjective judgment of the dentist and to control changes in occlusal contacts.

Keywords: T-Scan Novus, digital occlusion analysis, occlusal indicators, OccluSense

Introduction

According to Viram U, the term “occlusion” should not be limited to the morphological contact between the teeth; rather, it implies a dynamic morpho-functional interaction between all components of the masticatory system – the teeth, the periodontal tissues, the Temporomandibular joints, the craniofacial bones, and the neuromuscular system (1).

“Static” occlusion can be determined when the lower jaw is closed and stationary, while “dynamic” occlusion occurs when the mandible is moving relative to the maxilla. The occlusion is individual and depends on the shape, size, and position of the teeth, as well as the size of the dental arch, and the shape and pattern of craniofacial growth (2). Furthermore, the occlusal contacts change constantly. Any interventions to the occlusal contacts, the insertion of prosthetic restorations, orthodontic tooth movements, or when teeth are extracted, induces changes in the occlusal proportions. It has been confirmed that even changes as small as 15 μ in the occlusal-articulating relationship, can lead to significant untoward patient effects that must be eliminated (3). In addition, premature occlusal contacts and occlusal-articulating interferences can often cause occlusal trauma, which in turn, can induce changes in the periodontal tissues, the teeth, and bone, in the masticatory muscles, and the temporomandibular joints. Therefore, it is important to note that the physiological restoration of occlusal relationships is essential for the normal functioning of the masticatory system, making the analysis and evaluation of occlusal contacts crucial for achieving normal occlusal-articulating relationships (4).

1. Occlusal indicators

Both qualitative and quantitative indicators are used in the diagnosis of occlusion (5-8).

Qualitative methods are:

- Articulating paper
- Articulating foils
- Articulating silk
- Metallic shim stock film
- High spot indicator
- Wax
- Alginate impression material
- Silicone impression material
- Occlusal sprays
- Photo-occlusion
- Occlusion sonography

Quantitative methods are:

- T-Scan 10 Novus System
- OccluSense System (Version 1)

In clinical practice qualitative indicators are most commonly used, due to their ease of application and their low cost. With qualitative methods, only the localization of the occlusal contact points is possible, while their time-sequence and relative strength cannot be determined. However, some authors suggest the strength of the contacts can be determined by the size and color of the perceived marking. In actuality, research clearly shows this is not a precise evaluation, as there is no size and color correlation to the differing occlusal force levels (9-12).

Articulating paper has been widely accepted as the gold standard for diagnosis of occlusion (13). The sensitivity and reliability of this indicator depend on the thickness, strength, and elasticity of the recording materials, a wet or dry oral environment, and the clinician's interpretation (5, 14, 15), none of which objectively measure occlusal force, occlusal contact timing, or the applied pressures.

However, by using quantitative indicators, the sequence, strength, and density of the contacts can be differentiated, as there exists quantitative measures for determining occlusal-articulating relationships (16, 17). The T-Scan Novus system (Version 10, Tekscan, Inc., S. Boston, MA, USA) and OccluSense system (version 1, Dr. Jean Bausch GmbH & Co. KG, Koln, Germany) are commercially available digital occlusal analysis systems.

The OccluSense system is a new digital occlusion product that was released in 2019. OccluSense is a wireless system, which includes a recording handle and sensor (Figure 1), that transmits occlusal data via a Wi-Fi connection to an iPad Application. The patient's recorded occlusal information is displayed on the app.

Figure 1. OccluSense recording handle with sensor

Presently and very importantly, there are no published durability, repeatability, or accuracy studies about the OccluSense system or its sensors, such that to date, Occlusense has not been independently tested for its attributes or its capabilities in any published study (8). And, no published OccluSense occlusal treatment research studies exist that have determined how OccluSense data sets can be used safely with patients, to clinically improve an occlusion.

However, 37 years of research studies encompassing hundreds of force and timing studies exist about the T-Scan technology. A recent Systematic Review (18) evaluated 231 total papers of which 129 were T-Scan based research studies. The authors reported much scientific evidence supports the use of T-Scan, as it measures relative occlusal forces and timing objectively, accurately, and repeatedly (18). This present review aims to examine the capabilities of the T-Scan 10 Novus system in the diagnosis of occlusal-articulation relationships.

2. History of T-Scan System

Maness developed the first computerized system, in 1984 known as T-Scan I (T-Scan version 1, Tekscan Inc. S, Boston MA USA), that could record 16 levels of relative occlusal forces in real-time (in 0.01 seconds/frame) across 3 seconds using a first generation epoxy sensor impregnated with conductive ink (16). The evolution of the T-Scan technology over the past 37 years that began in 1984, involved multiple T-Scan iterations after T-Scan I, with T-Scan II in 1995, to T-Scan III in 2004 with software versions 5, 6, 7. Then, Turbo recording (0.003 seconds/frame) was developed in 2008 as part of T-Scan III, as was the T-Scan High Definition sensor (HD sensor, Tekscan Inc., S. Boston, MA, USA), which was further evolved into T-Scan 8 by 2014 (19). The T-Scan Evolution handpiece (Evo, Tekscan Inc., South Boston, MA USA) was redesigned in 2015 into the T-Scan Novus handpiece, that accompanied software version 9.1, and a new Novus HD sensor (Novus HD sensor, Tekscan Inc., S. Boston, MA, USA). The latest updated software version T-Scan 10 was first introduced in 2018 (20).

3. T-Scan 10 Novus System

Today's T-Scan 10 Novus system is a State of the Art computer technology for measured digital occlusal analysis. It records and measures 256 occlusal contact relative forces and time-sequence data in real-time, using a thin, 100 um thin, flexible, pressure-sensitive, electrically charged high definition sensor (21, 22). The system is comprised of the Novus recording handle, 2 differing sized sensor supports, 2 differing sized HD sensor (High Definition) Novus specific sensors. The recording handle connects to a computer workstation or laptop with a USB cable (Figure 2).

Figure 2. The T-Scan 10 Novus System

3.1. T-Scan Novus Handpiece

The T-Scan Novus has a new ergonomically improved handpiece when compared to older versions, with specifically designed sensor supports, and a redesigned HD sensor that fits the Novus handpiece (Figure 3). Working with the handpiece is facilitated by easy-access buttons, which can initiate a recording with a start/stop button, and playback the recording either forwards or backwards, frame-by-frame. Also, the upper surface of the handpiece has a stand-by indicator that instructs the user that the handle is ready to activate a recording. The sensor supports lock into the sides of the handpiece to properly position the sensor within the support and handpiece. The Novus handpiece itself, houses electronics that capture the occlusal force data at a standard speed of 175 Hz, and up to 500 Hz in Turbo mode. The electronics transfer the recorded occlusal contact force and timing data captured by the sensor to the T–Scan software as the patient closes into or excurses across its surface.

Figure 3. T-Scan Novus Handpiece

3.2. T-Scan Sensor

The correct intraoral position of the sensor in a patient's mouth during a digital occlusal examination is provided by sensor supports, which are available in two sizes - large and small, that match the 2 sensor sizes (Figure 4). Each T-Scan Novus high definition sensor is 100µ thick (23, 24, 25). The sensor is composed of an electrically conductive network of small square areas sensitive to pressure, called sensels. Differing applied occlusal contact force levels displace the electricity in each loaded sensel, where high force displaces significant sensel electricity, and light forces displace small amounts of electricity. Small sensors fit a dental arch up to 51 mm deep and 58 mm wide, and contain 1122 sensels, while large sensors fit a 56 mm deep and 66 mm wide dental arch that contains 1370 sensels. The T-Scan software converts each sensel's amount of electrical displacement into 256 levels of color-coded forces, that describe a patient's occlusal force distribution. The recorded data can be played as a dynamic occlusal force video forwards or backwards continuously, or frame-by-frame to make a detailed, high-precision occlusal diagnosis (26, 27).

Figure 4. A small and large T-Scan Novus HD Sensor

3.3a. Closure into Maximum Intercuspation (MIP) Recording technique

The Novus Handpiece with the sensor and sensor support is placed firmly between the maxillary Central Incisor facial embrasure of the patient (Figure 5). The recording is initiated by pressing the red button on the handpiece, and the patient is instructed to occlude into maximum intercuspation firmly, continuing to hold their teeth together firmly for 1-3 seconds and then open to disarticulate their teeth.

Figure 5. Proper positioning of the T-Scan sensor support within the Central Incisor facial embrasure prior to initiating a recording

Closure into MIP recordings:

- Measure the Occlusion Time (OT) - the elapsed time from first to last contact of a patient self-closure into their static intercuspation

- Illustrate the closure contact sequence from 1st contact to static intercuspation and beyond into maximum intercuspation
- Assesses the right side - left side force percentage imbalance
- Illustrate the trajectory path of the Center of Force in a closure movement
- Used sequentially in series, during occlusal treatment, to balance the occlusion (a recording is followed by an adjustment set, followed by a new recording, followed by 2nd adjustment set, followed by a 3rd new recording, followed by a 3rd adjustment set, etc., until OT $\leq$ 0.2 seconds and the right - left force balance is nearly equal)

The T-Scan also can record a patient's left, right, and protrusive mandibular excursions, made from a firm patient closure into their maximum intercuspation.

3.3b. Lateral and/or Protrusive Excursive Recording technique

To record a lateral excursive or protrusive movement (with the sensor placed intraorally and sensor support resting firmly between the Central Incisor facial embrasure), the patient is instructed to occlude firmly into complete intercuspation (MIP), hold their teeth firmly and fully intercuspated for 1-3 seconds, and then slide their mandibular teeth across and over their maxillary teeth either to the left, right, or forwards, keeping their anterior teeth in contact during the movement.

Excursive Movement Recordings:

- Measure the posterior Disclusion Time (DT)
- Illustrate the presence of occlusal surface excursive frictional contacts
- Assesse the quality of the anterior guidance mechanism
- Used in the diagnosis and treatment of excursive masticatory muscular hyperactivity and muscular TMD symptomatology, as well as in occlusal wear, and abfraction formation

3.4. Data interpretation

The registered occlusal contacts with T-scan Novus are illustrated graphically for analysis in 2 and 3-dimensional images (Figure 6), or as a video that can be analyzed frame-by frame. The software transforms the force and timing data into different color ranges to depict 256 levels of force, displayed graphically as a dynamic occlusion video within software dental arches. Maximum force is shown in red and pink, with medium forces graded in green and yellow, and lower forces is blue and dark blue. The right arch-half total force % is displayed in a red bar at the bottom of the 2D arch, while the left arch-half total force % is displayed in green.

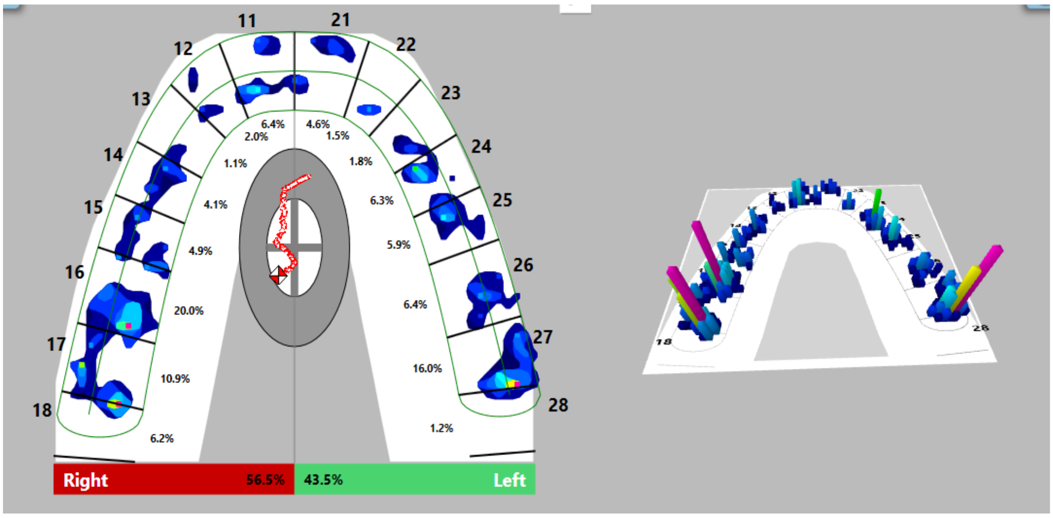


Figure 6. T-Scan force data displayed in color-coded ranges within Dental the 2D (left) and 3D(right) dental arches. High force is red/pink; medium force is green/yellow; low force is blue/dark blue

For better analysis of the distribution of occlusal forces, the T-Scan dental arch can be divided into four quadrants (Figure 7), which assesses antero-posterior occlusal force differences. The right anterior quadrant total force % is displayed in a red flag; the left quadrant total force % is displayed in a green flag; the right posterior quadrant total force % is displayed in a blue flag; and the left posterior quadrant total force % is displayed in an orange flag. The quadrant division horizontal line can be moved anteroposteriorly, to determine a variety of different quadrant occlusal relationships. The line position in Figure 7 divides the 2D dental arch at the distal of the canine teeth bilaterally, to separate the anterior teeth total force % from the posterior teeth total force %.

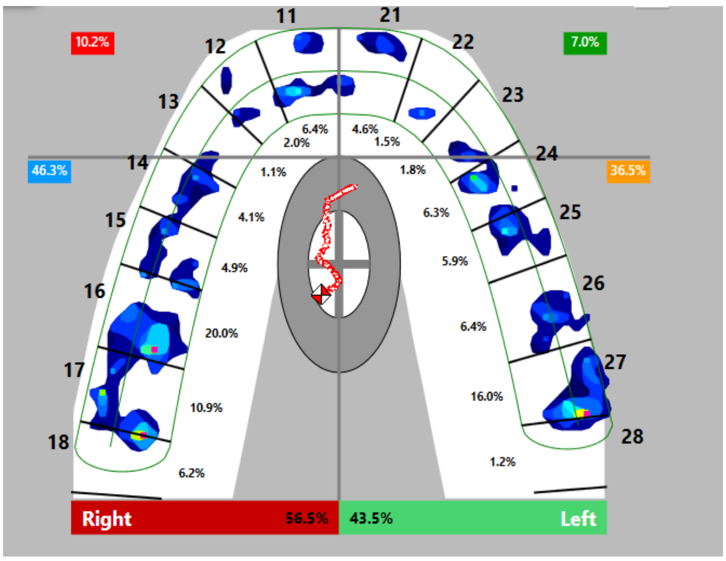


Figure 7. The T-Scan dental arch model divided into four quadrants to display each quadrant's total force %, in the red, green, blue and range flags.

The T-Scan Novus can detect and analyze the following patient parameters:

- The first contact
- The sequence of contact order from 1st contact into complete intercuspation
- The maximum bite force
- The occlusal force distribution in % of the left and right sides of the dentition in Maximum Intercuspation (MIP)
- the Center of Force (COF) Summation and its Trajectory, which indicates the movement of forces around the dental arch during occlusion into MIP, in vertical opening, and during lateral excursive disclusion
- The Occlusion Time (OT)
- The Disclusion Time (DT)

A Digital examination of the occlusion not only helps the clinician to accurately analyze the occlusal relationships, but also engages the patient's attention and curiosity. The patient can visually assess their own uneven occlusal force distribution from the different software features and color-coded registered occlusal force designations, as well as from their arch-half or quadrant force percentages imbalances (19).

The 2D ForceView Window

The 2D Force View window contains the T-Scan Dental Arch Outline, where the tooth numbers are indicated on the outside of the outline, delineated between the marginal ridge lines. Inside the Arch Outline are the occlusion force percentages of the individual teeth, that change as the movie progress from 1st contact into MIP and then into an excursion. In addition, the COF Trajectory and Icon are displayed in the 2 ForceView (Figure 8).

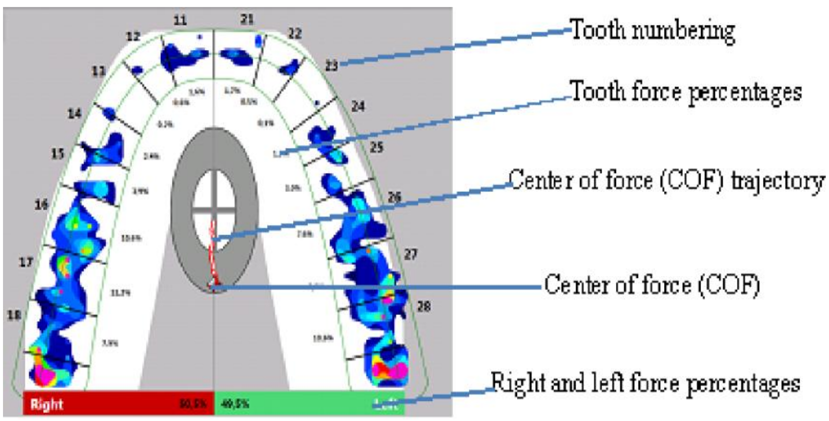


Figure 8. The 2D ForceView Window - The tooth numbers lie outside the T-Scan arch and each tooth's changing occlusal force percentages are on the inside

The Force vs. Time graph displays the force, relevant to the time for the patient's overall bite, from the first contact up to the end of the record (Figure 9). Each graph line is color-coded to provide an easy visual reference to areas of the Arch Model or teeth

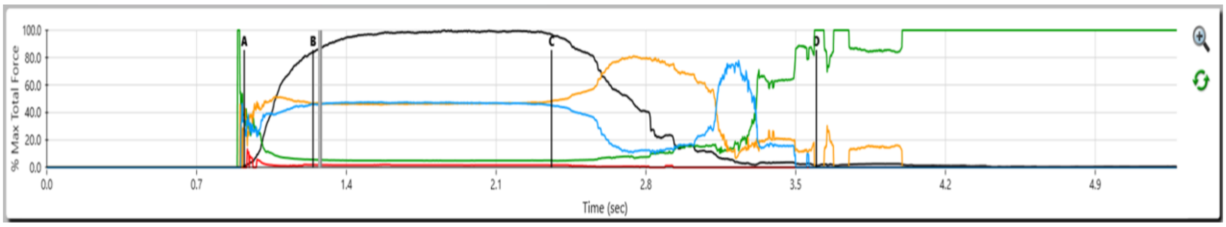
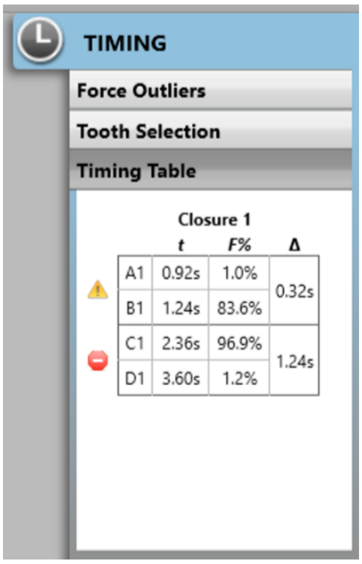


Figure 9. A Force vs. Time graph describing the force changes as a patient closes from 1st contact into Maximum Intercuspation (MIP) (A-B period), then holds their teeth firmly intercuspated in MIP (B-C period), and then makes an excursive movement to the left (C-D period). The 4 colored lines are matched to the 4 quadrants shown in Figure 7, where each colored line describes the individual quadrant force changes that occur during the entire recorded mandibular event. The Black Total Force Line describes the Total Force changes throughout the entire mandibular event, which rises from 0% as the patient closes into MIP (A-B), and drops from 100% when the excursion begins at C, reaching low total force at D.

In this left excursion, the left posterior quadrant (Orange line rises) controls the early excursion to the right of line C, which then lessens in force near 3.0 seconds. At this time-point, the right posterior quadrant rises in force (Blue line) as balancing side contacts increase. Then at 3.5 seconds, the anterior left quadrant finally (Green line) begins to control the left excursion, as both the orange and blue lines drop to the bottom of the graph, indicating both posterior quadrants lose force, and the anterior left quadrant increases in force (Green line reaches the top of the graph). And the anterior right (Red) quadrant line stays at the bottom of the graph as the right anterior quadrant shows very low forces throughout this recording.

The Timing Table below shows the time durations of the occlusal contacts during the different parts of the recording in Figure 9. The time-duration from A -B denotes the length of the Occlusion Time (OT), and time-duration from C - D denotes the length denotes length of the Disclusion Time (DT) (Figure 10).



	t	F%	Δ
A1	0.92s	1.0%	0.32s
B1	1.24s	83.6%	
C1	2.36s	96.9%	1.24s
D1	3.60s	1.2%	

Figure 10. The Timing Table calculates the Occlusion Time (OT) duration of a patient closing into Maximum Intercuspation (MIP) (the A-B period; Figure 9), and the Disclusion Time (DT) of mandibular excursions (the C-D period; Figure 9). When one or

both are too long, warning symbols appear that alert the clinician these values are non-physiologic. In this example, the OT is slightly prolonged (being ideal at < 0.2 seconds), and the Disclusion Time of the left excursion is quite elongated (being ideal at < 0.4-0.5 seconds).

The Occlusion Time (A–B) is the elapsed time in seconds, measured from the first tooth contact until the last tooth contact rises in force. Static intercuspation always occurs before the patient achieves maximum bite force. The OT describes the degree of bilateral time simultaneity present in a patient's occlusion. The ideal duration of OT is ≤ 0.2 seconds.

The Disclusion Time is the elapsed time in seconds, measured from the beginning of an excursive movement made in any direction (left, right, or forward) with all teeth in maximum intercuspation, until only canines and/or incisors are in contact. The ideal duration of DT is ≤ 0.5 seconds (28).

The T-Scan also features Warning Alarms for occlusal overloading of implants, and when poor recordings are made (Figure 11). Implant Loading Alerts provide immediate feedback on any implant that may be under excessive force, or when the implant strikes too early during a closure movement. Or if the implant is in contact for too long during an excursive movement. The Alert ensures the clinician is notified to be concerned about the loading pattern of that implant.

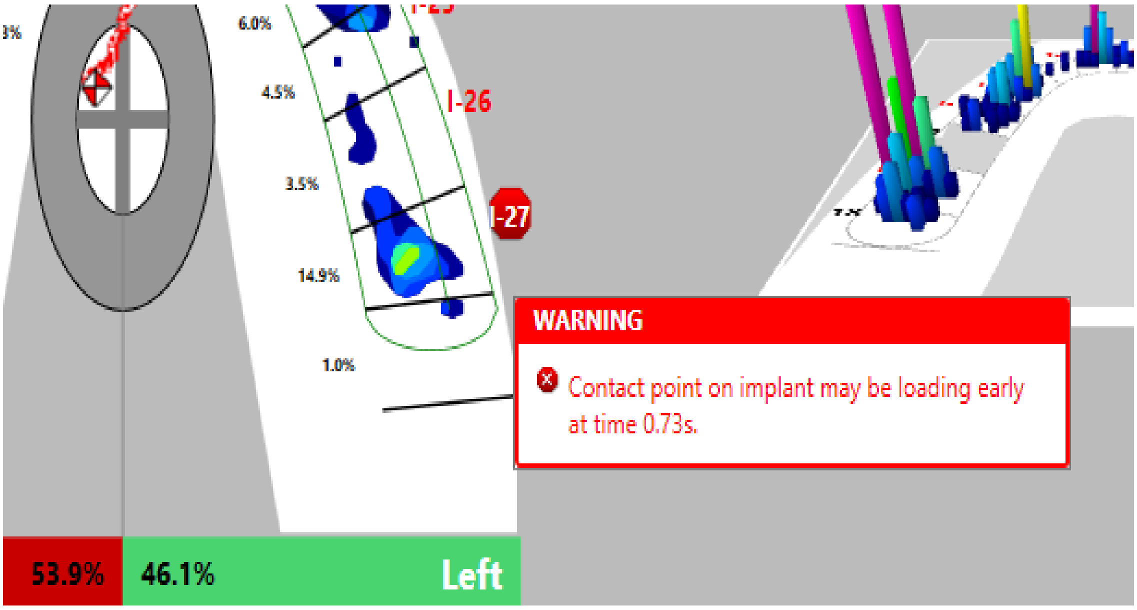


Figure 11. Implant Loading Alerts notify the clinician that the implant may be receiving excessive force, or is time-early, or is time-prolonged

T-Scan can be synchronized with Electromyography software (BioEMG III, Bioresearch Assoc., Milwaukee, WI, USA) in real-time, that measures up to 8 masticatory muscles (Figure 12).

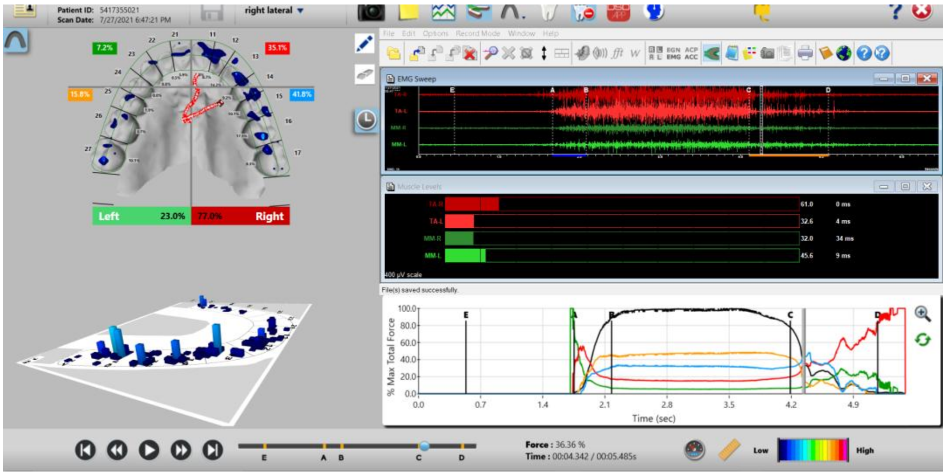


Figure 12. – The T-Scan synchronized to EMG of 4 muscles, illustrating a right excursion with high muscle firing occurring in the bilateral Temporalis and Masseter muscles early in the excursion because of the right posterior teeth controlling (Blue line) the early excursion.

An additional software option is the Digital Impression Overlay (Figures 12, 13). This feature makes it possible to observe the occlusal force and timing data superimposed over a digital impression, by importing an. stl file of an intraorally-scanned dental arch into the T-Scan Patient Record (Figure 13) (19).

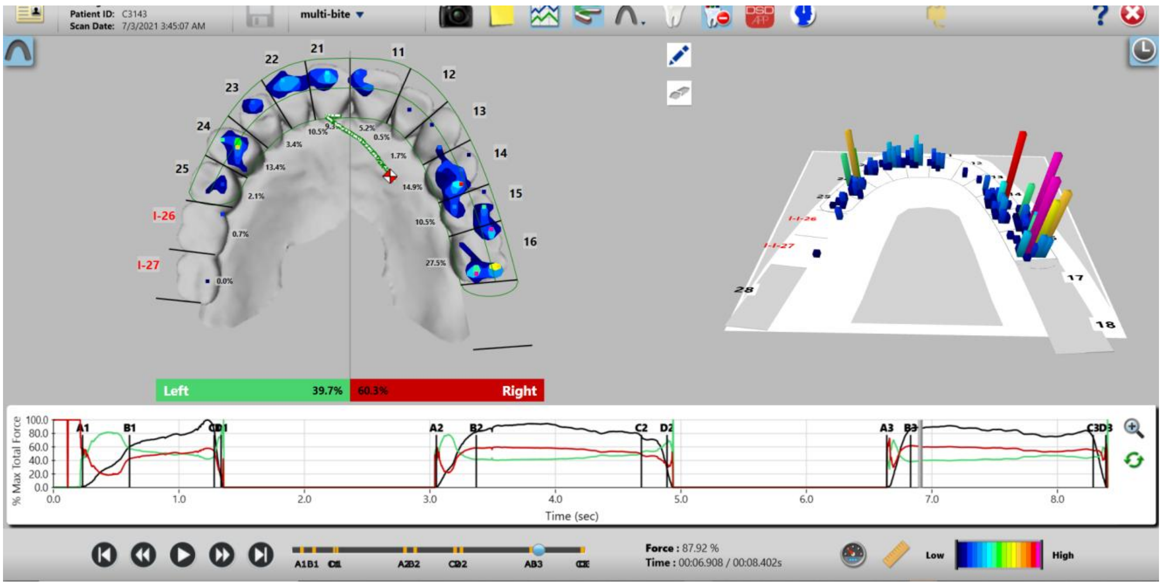


Figure 13. A Digital Impression Overlay used with a 3-Multi-bite recording. The occlusal force and timing data is superimposed over an imported. stl file, to simplify locating the cusp, fossa, or marginal ridge contacts where problem forces occur

3.5. Applications of T-Scan 10 Novus System

The T-Scan 10 Novus system can be used in any clinical situation where bilateral simultaneous occlusal contact is beneficial (7, 29-34), and where friction-free excursive movements will enhance chewing function, and optimize masticatory muscle physiology.

- Removable complete dentures
- Fixed or removable partial dentures
- Complete arch reconstruction solely using implants
- Natural tooth occlusal adjustments
- Disclusion time Reduction (DTR)
- Temporomandibular Disorders (TMD)
- Orthodontic mid -treatment occlusal force distribution assessments, and post-orthodontic case finishing
- Abfraction formation and root recession
- Occlusal trauma
- Locating the painful contact on painful teeth
- Occlusal splints

3.6. The Benefits of T-Scan 10 Novus System (35, 36):

- Improved Occlusal diagnosis
- Increased quality of patient care by reducing the Subjective Interpretation of paper markings, which do not measure occlusal forces by their appearance or size
- Enhanced patient motivation and ease in occlusally educating patients as to their specific occlusal needs
- Reduced treatment times
- Measurably improved restorative treatment outcomes with respect to the installed occlusal force distribution and profile
- The capability to store patient occlusal data that improves occlusal status record-keeping
- Reduced risk of implant failure, unstable dentures, traumatized teeth, ineffective splints, and porcelain fractures.
- Reduced risk of adjusting healthy occlusal contacts that should remain unaltered.
- Markedly improved accuracy in targeting truly problematic excessively forceful, and time-early or time-prolonged occlusal contacts

Conclusion

The new and improved functions of the T-Scan 10 Novus system provides digital information about the occlusion, which allows the clinician to make a highly accurate occlusal analysis, far beyond what can be with mounted stone casts, and visual inspection of the patient making functional occlusal movements.

Importantly, although virtual articulation is becoming more widely adopted, intraoral scanning systems take images (pictures) of the patient’s teeth in motion, but do not capture any actionable occlusal contact force levels or timing data, because no data is gathered from between contacting or excursing teeth. Scanners take pictures of the occlusal surfaces, and of the interarch static interaction of the maxillary and mandibular teeth in MIP. But scanners do not capture any occlusal contact function. As such, scanning and planning the proximity or depth of the occlusal contacts with scanning software and virtual articulated movements, does not negate the need for intraoral occlusal adjustments to be made at case delivery. That can only be accomplished with the T-Scan HD sensor interposed between the teeth as the patient closes into the sensor, or moves across its' surface excursively. No scanner to date has been shown to accurately portray true occlusal force levels or timing of contacts; they only project the possible occlusal contact configurations. However, the T Scan 10 Novus actually measures 256 levels of relative occlusal contact forces in real-time. Therefore, the T-Scan Novus helps to avoid errors in the subjective judgment of the dentist when trying to control changes in the occlusal contacts.

The many researched diagnostic and treatment capabilities of th T-Scan 10 digital occlusion analysis system, indicate that T-Scan is a much better occlusal indicator for patients when compared to other subjectively employed non-digital occlusal indicators (18).

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