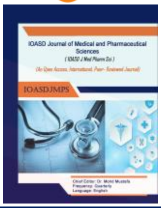
OPEN ACCESS

IOASD Journal of Medical and Pharmaceutical Sciences

IOASD J Med Pharm Sci, Vol-3, Iss-3, Jul-Sept., 2026
Frequency: Quarterly
ISSN: 3049-0294 (Online)
ISSN: 3049-3773 (Print)
Homepage: https://ioasdpublisher.com/ioasdjmps



T-Scan Digital Occlusal Analysis in Dentistry: Principles, Clinical Applications, Evidence, and Future Perspectives

Dr. Arpit Sikri[1*], Dr. Jyotsana Sikri[2], Dr. Vaishali Kalra[3], Dr. Rimple Gupta[4], Dr. Shreya Bhardwaj[5], and Dr. Ayushman Bhardwaj[6]

[1]Professor & Post Graduate Teacher, Department of Prosthodontics, Crown & Bridge and Oral Implantology, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

[2]Associate Professor & Post Graduate Teacher, Department of Conservative Dentistry & Endodontics, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

[3]Consultant Prosthodontist, Indus Hospital, Phase-6, Mohali, Punjab, India & 1281, Sector-50B, Progressive Enclave, Chandigarh-160047, India

[4]Senior Lecturer, Department of Conservative Dentistry & Endodontics, Mahatma Gandhi Dental College & Hospital, Mahatma Gandhi University of Medical Sciences & Technology Jaipur, Rajasthan, India

[5]Post Graduate Student, Department of Prosthodontics, Crown & Bridge and Oral Implantology, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

[6]Post Graduate Student, Department of Prosthodontics, Crown & Bridge and Oral Implantology, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

Corresponding Author: Dr. Arpit Sikri
Professor & Post Graduate Teacher, Department of Prosthodontics, Crown & Bridge and Oral Implantology, Bhojia Dental College & Hospital, Budh (Baddi), Teh. Baddi, Distt. Solan, Himachal Pradesh, India

DOI: 10.67224/ioasdjmps.2026.v03i03.008

ABSTRACT

Occlusal analysis is a fundamental component of diagnosis and treatment planning in dentistry, influencing the longevity, function, and comfort of both natural dentition and prosthetic rehabilitations. Conventional occlusal indicators such as articulating paper, waxes, and shimstock foils identify contact locations but do not quantify occlusal force or provide information regarding the sequence and timing of tooth contacts. Computerized occlusal analysis using the T-Scan system has emerged as an objective and dynamic method for evaluating occlusal relationships by recording relative occlusal force distribution, contact timing, occlusion time, disclusion time, and the center of force during mandibular function. The present review summarizes the principles, technological evolution, clinical applications, current evidence, limitations, and future prospects of T-Scan technology across various dental specialties. A comprehensive literature search was conducted using PubMed, Scopus, Web of Science, and Google Scholar for English-language publications from January 1990 to July 2026. Relevant clinical trials, observational studies, in vitro investigations, systematic reviews, narrative reviews, and consensus publications were identified using predefined search terms related to computerized occlusal analysis and T-Scan technology. Studies were screened for relevance, and data were synthesized narratively according to dental specialty and clinical application. Current evidence suggests that T-Scan enhances diagnostic accuracy, facilitates precise occlusal adjustment, improves implant occlusion management, supports temporomandibular disorder assessment, and contributes to predictable prosthodontic rehabilitation when used alongside conventional clinical examination. Although limitations including equipment cost, sensor wear, and the inability to directly visualize contact markings remain, ongoing advances in digital dentistry, artificial intelligence, and virtual articulators are expected to further expand the role of computerized occlusal analysis in contemporary dental practice.

Keywords: T-Scan; Computerized Occlusal Analysis; Digital Occlusion; Prosthodontics; Implant Dentistry; Occlusion.

Review Article

Article History
Received: 27-05-2026
Accepted: 17-07-2026
Published: 24-07-2026

INTRODUCTION

Occlusion represents one of the most critical determinants of oral function, directly influencing mastication, speech, esthetics, periodontal health, temporomandibular joint (TMJ) function, and the long-term success of restorative and prosthodontic treatment.

The establishment of harmonious occlusal contacts remains a primary objective in restorative dentistry, fixed and removable prosthodontics, implant dentistry, orthodontics, and full-mouth rehabilitation. Even minor discrepancies in occlusal contacts may result in premature contacts, occlusal interferences, excessive muscular activity, restoration failure, implant overload, patient discomfort, or temporomandibular disorders (TMDs) [1-3].

Traditionally, clinicians have relied on articulating paper, articulating silk, shimstock foils, pressure-indicating paste, waxes, and silicone-based indicators to evaluate occlusal contacts. Although these methods remain widely used because of their simplicity and affordability, they are inherently subjective and provide only qualitative information regarding the location of occlusal contacts. Importantly, the size or intensity of an articulating paper mark does not reliably correlate with the magnitude of occlusal force, potentially leading to inaccurate clinical interpretation [4-7].

The increasing demand for evidence-based dentistry has driven the development of computerized technologies capable of objectively evaluating occlusion. Among these, the T-Scan computerized occlusal analysis system, first introduced by Maness and colleagues in the late 1980s, represents one of the most significant advances in digital occlusal assessment. Unlike conventional indicators, T-Scan records the sequence of tooth contacts, relative occlusal force distribution, occlusion time, disclusion time, and center of force movement throughout mandibular closure and excursive movements. This dynamic information allows clinicians to identify premature contacts, occlusal asymmetries, and functional interferences with greater precision than static methods [8-11].

Over successive generations, including T-Scan I, II, III, and the latest T-Scan Novus system, improvements in sensor technology, software algorithms, data acquisition speed, and graphical visualization have significantly enhanced clinical reliability and user experience. Integration with electromyography (EMG), digital articulators, CAD/CAM workflows, and implant treatment planning has further broadened the clinical applications of computerized occlusal analysis [12-15].

The use of T-Scan has expanded across multiple disciplines of dentistry, including prosthodontics, implant dentistry, restorative dentistry, orthodontics, periodontics, oral surgery, temporomandibular disorder management, and oral rehabilitation. Contemporary evidence suggests that objective assessment of occlusal force distribution may improve treatment precision, reduce chairside adjustment time, enhance patient comfort, and contribute to the longevity of both natural dentition and prosthetic restorations [16-19].

This review aims to provide a comprehensive overview of the evolution, working principles, clinical applications, current scientific evidence, advantages, limitations, and future directions of T-Scan technology in dentistry. Additionally, it summarizes the available literature using a transparent search methodology to provide clinicians with an evidence-based understanding of computerized occlusal analysis and its role in contemporary digital dentistry.

METHODS

Literature Search Strategy

A comprehensive literature search was conducted to identify studies evaluating the use of T-Scan computerized occlusal analysis in dentistry. Electronic databases including PubMed, Scopus, Web of Science, and Google Scholar were searched for articles published from January 1990 to July 2026. Manual searches of reference lists from selected articles were also performed to identify additional relevant publications.

The search strategy combined Medical Subject Headings (MeSH) and free-text keywords using Boolean operators. The primary search terms included:

- "T-Scan"
- "Computerized occlusal analysis"
- "Digital occlusal analysis"
- "Occlusal force"
- "Occlusion"
- "Implant occlusion"
- "Prosthodontics"
- "Implant dentistry"
- "Restorative dentistry"
- "Orthodontics"
- "Temporomandibular disorders"

These terms were combined using "AND" and "OR" operators to maximize retrieval of relevant studies.

Eligibility Criteria

Studies were considered eligible if they:

- evaluated T-Scan technology in any field of dentistry;
- were randomized controlled trials, prospective studies, retrospective studies, cross-sectional studies, case-control studies, observational studies, in vitro investigations, systematic reviews, meta-analyses, or narrative reviews;
- were published in English;
- reported clinical, laboratory, or diagnostic outcomes related to computerized occlusal analysis.

The following were excluded:

- conference abstracts without full-text availability;
- editorials;
- letters to the editor;

- duplicate publications;
- animal studies;
- articles lacking sufficient methodological detail.

Study Selection and Data Extraction

Titles and abstracts retrieved from the search were independently screened for relevance. Full-text articles meeting the inclusion criteria were subsequently reviewed. Information extracted included publication year, study design, dental specialty, T-Scan generation, study objectives, outcome measures, principal findings, and reported clinical significance.

Data Synthesis

Owing to the heterogeneity of study designs, outcome variables, and clinical applications, quantitative meta-analysis was not feasible. Therefore, findings were synthesized narratively and organized according to major dental specialties, technological evolution, diagnostic principles, clinical applications, advantages, limitations, and future developments in computerized occlusal analysis.

Evolution of T-Scan Technology

The introduction of computerized occlusal analysis represented a major advancement in the objective assessment of dental occlusion. Before the advent of digital systems, clinicians relied on qualitative methods such as articulating paper, shimstock foil, waxes, and pressure-indicating pastes to evaluate occlusal contacts. Although these methods remain useful for identifying the location of occlusal contacts, they cannot quantify occlusal force or determine the chronological sequence of tooth contacts, limiting their diagnostic accuracy and reproducibility [20,21].

The T-Scan system was developed by William L. Maness and colleagues and was introduced in 1987 as the first computerized occlusal analysis system capable of recording the sequence and relative intensity of occlusal contacts during mandibular closure. The original T-Scan I utilized a pressure-sensitive Mylar sensor connected to a computer workstation that converted occlusal force information into graphical representations. Unlike conventional occlusal indicators, the system provided clinicians with dynamic information regarding the timing and relative force of occlusal contacts, thereby introducing a new dimension in occlusal diagnosis [22].

Despite its innovative concept, the first-generation T-Scan system exhibited several technical limitations. Early sensors were relatively thick and rigid, potentially altering the patient's natural occlusion during recording. In addition, limited sensor resolution, lower sampling frequency, reduced durability, and simplified software algorithms affected the accuracy and reproducibility of force measurements. Initial validation studies also identified variability in force recording and the presence of insensitive sensor areas, highlighting the need for further technological refinement [23,24].

The introduction of T-Scan II brought notable improvements in sensor sensitivity, hardware design, and graphical visualization, enhancing the clinical applicability of computerized occlusal analysis. Subsequent advances culminated in the development of T-Scan III, which incorporated thinner high-resolution sensors, increased recording speed, individualized sensor calibration, and advanced software capable of generating dynamic two-dimensional and three-dimensional representations of occlusal force distribution. These enhancements enabled clinicians to analyze occlusion time (OT), disclusion time (DT), center of force (COF), and force trajectories with greater precision and reproducibility. [25,26].

The latest generation, T-Scan Novus (T-Scan 10), represents a substantial technological evolution. Improvements include thinner and more durable sensors, higher sampling frequencies, enhanced wireless connectivity, and software integration with electromyography (EMG) systems. These developments permit simultaneous assessment of occlusal force distribution and masticatory muscle activity, thereby facilitating comprehensive evaluation of occlusal function in prosthodontics, implant dentistry, orthodontics, temporomandibular disorders, and full-mouth rehabilitation [27].

Over nearly four decades of development, continuous improvements in sensor technology, hardware architecture, and analytical software have largely overcome the shortcomings associated with earlier generations. Recent systematic reviews conclude that modern T-Scan systems provide objective, repeatable, and clinically meaningful measurements of relative occlusal force and contact timing when interpreted alongside conventional clinical examination rather than as a standalone diagnostic tool [27,28].

Principle and Working Mechanism of T-Scan

The T-Scan system is a computerized occlusal analysis technology designed to objectively evaluate the sequence, timing, and relative distribution of occlusal forces during static and dynamic mandibular movements. Unlike conventional occlusal indicators, which merely identify the presence or location of occlusal contacts, T-Scan records the chronological development of tooth contacts from initial contact to maximum intercuspation and during excursive mandibular movements, thereby providing quantitative information that cannot be obtained using articulating paper or shimstock foil alone [29,30].

The system consists of three principal components: an ultra-thin pressure-sensitive sensor, a recording interface, and dedicated analysis software. The disposable sensor is fabricated from polyester (Mylar) sheets containing thousands of conductive sensing elements (sensels) arranged in a matrix configuration. When occlusal force is applied, deformation of these sensels alters their electrical resistance. These changes are converted into digital signals and transmitted to the software, which displays the relative distribution of occlusal forces in real time [29,31].

Unlike pressure-sensitive films that provide only static contact information, the T-Scan sensor continuously samples occlusal events throughout mandibular closure and functional excursions. Modern T-Scan Novus systems acquire data at high sampling frequencies, enabling the generation of dynamic "force movies" that display the evolution of occlusal contacts over time. The clinician can replay each recording frame by frame, allowing detailed assessment of premature contacts, force concentration, and occlusal instability [27,30].

One of the most clinically valuable parameters generated by the T-Scan system is Occlusion Time (OT), defined as the elapsed time between the first detectable tooth contact and complete intercuspation. In healthy dentitions, OT is relatively short, whereas prolonged OT often indicates premature contacts, unstable intercuspation, or occlusal discrepancies. Reduction of OT following selective occlusal adjustment has been associated with improved occlusal stability and treatment efficiency [32,33].

Another important parameter is Disclusion Time (DT), which represents the duration required for complete posterior tooth separation during lateral or protrusive mandibular excursions. Prolonged DT has been associated with sustained elevator muscle contraction, increased occlusal loading, muscular hyperactivity, and symptoms related to occluso-muscular disorders. Measurement of DT therefore provides valuable information when evaluating patients with temporomandibular disorders (TMDs), parafunctional habits, and occlusal instability [27,34].

The software also calculates the Center of Force (COF), which graphically represents the overall balance of occlusal loading between the right and left sides of the dental arches. Under ideal conditions, the COF remains close to the midline, indicating balanced occlusal force distribution. Significant deviations toward one side may indicate unilateral overload, uneven prosthetic contacts, occlusal interference, or functional asymmetry. Monitoring changes in COF before and after occlusal adjustment provides clinicians with an objective method for evaluating treatment outcomes [31,35].

Modern T-Scan software presents occlusal information using color-coded two-dimensional and three-dimensional graphics. Lower relative occlusal forces are displayed in cooler colors (blue and green), whereas progressively greater forces are represented by yellow, orange, and red. This visualization facilitates rapid identification of high-force contacts that may contribute to restoration fracture, implant overload, periodontal trauma, or muscular imbalance. The software also permits quantitative comparison of multiple recordings obtained before and after treatment, thereby enhancing clinical documentation and treatment monitoring [31,36].

One important characteristic of the T-Scan system is that it measures relative rather than absolute occlusal forces. The displayed percentages represent the proportional distribution of occlusal load among contacting teeth at a given moment rather than the exact force expressed in Newtons. Consequently, T-Scan should be interpreted as a comparative diagnostic tool for assessing force balance and contact timing rather than a device for measuring absolute bite force [37]. Despite its advantages, T-Scan does not precisely identify the anatomical location of occlusal contacts on tooth surfaces. Therefore, most investigators recommend combining computerized occlusal analysis with conventional articulating paper or shimstock foil. This complementary approach allows clinicians to correlate quantitative force measurements with precise contact localization, thereby improving the accuracy of occlusal adjustment procedures [20,27].

Collectively, these features make the T-Scan system a valuable adjunct for objective occlusal assessment in restorative dentistry, prosthodontics, implant dentistry, orthodontics, periodontology, and temporomandibular disorder management. Continuous technological improvements have enhanced its accuracy, reproducibility, and clinical applicability, making it one of the most extensively investigated computerized occlusal analysis systems currently available [27,30].

Comparison of T-Scan with Conventional Occlusal Indicators

Occlusal assessment has traditionally relied on qualitative methods such as articulating paper, articulating silk, shimstock foil, pressure-indicating paste, waxes, and silicone impression materials. These conventional indicators remain indispensable in routine clinical practice because of their simplicity, low cost, and ease of use. However, they provide only static information regarding the location of occlusal contacts and are unable to quantify occlusal force, determine the sequence of tooth contacts, or evaluate occlusal dynamics during functional mandibular movements [38–40].

Articulating paper is the most widely used occlusal indicator in dentistry and is available in various thicknesses ranging from approximately 8 to 200 µm. During mandibular closure, pigment-coated paper transfers colored markings onto contacting tooth surfaces, allowing clinicians to identify areas of contact. Despite its widespread clinical use, numerous investigations have demonstrated that the size, shape, or intensity of articulating paper markings does not accurately correlate with the magnitude of occlusal force. Large markings may represent relatively light contacts, whereas small markings may indicate heavy occlusal loading. Consequently, reliance solely on articulating paper may lead to inaccurate occlusal adjustment and unnecessary removal of tooth structure or restorative material [20,38,41].

Shimstock foil, typically measuring 8–12 µm in thickness, has long been regarded as an effective method for verifying the presence or absence of occlusal contact. Unlike articulating paper, shimstock provides a simple binary assessment by determining whether the foil can be retained or pulled through the occlusion. Although it offers excellent sensitivity for confirming contact, it provides no information regarding contact timing, relative force distribution, or functional occlusal dynamics [20,42].

Pressure-indicating paste and occlusal waxes are frequently employed during complete denture fabrication and removable prosthodontics. These materials assist clinicians in identifying premature contacts and pressure areas but are influenced by material thickness, operator interpretation, and environmental conditions. Furthermore, deformation of the recording medium may reduce accuracy and reproducibility [20,43].

The principal limitation shared by all conventional occlusal indicators is their inability to evaluate occlusion dynamically. Occlusion is a physiological event that changes continuously during mandibular closure, mastication, swallowing, and excursive movements. Static indicators record only the final contact pattern and cannot identify the chronological sequence of tooth contacts, duration of occlusal contact, or force distribution among individual teeth. These shortcomings become particularly significant during complex restorative procedures, implant rehabilitation, full-mouth reconstruction, and management of temporomandibular disorders [29,30,44]. A comparative overview of the characteristics, capabilities, advantages, and limitations of conventional occlusal indicators and the T-Scan system is presented in Table 1.

Table 1. Comparison between Conventional Occlusal Indicators and T-Scan Digital Occlusal Analysis

Parameter	Articulating Paper	Shimstock Foil	Pressure-indicating Paste/Wax	T-Scan
Detects contact location	Yes	Yes	Yes	Indirectly (requires articulating paper for localization)
Quantifies occlusal force	No	No	No	Yes (relative force)
Measures contact timing	No	No	No	Yes
Measures occlusion time	No	No	No	Yes
Measures disclusion time	No	No	No	Yes
Dynamic analysis	No	No	No	Yes
Center of force analysis	No	No	No	Yes
Quantitative assessment	No	No	No	Yes
Repeatability	Moderate	Moderate	Low	High
Clinical documentation	Limited	Limited	Limited	Excellent

Computerized occlusal analysis using the T-Scan system was developed to overcome these limitations by providing objective, quantitative, and dynamic assessment of occlusal function. Rather than simply identifying where teeth contact, T-Scan records when each tooth contacts, the relative force associated with each contact, and how occlusal forces change throughout mandibular function. This capability allows clinicians to identify premature contacts, excessive loading, occlusal asymmetry, prolonged occlusion time, and delayed posterior disclusion with greater precision than conventional methods [27,31,44].

One of the major advantages of T-Scan is its ability to quantify relative occlusal force distribution. Conventional indicators cannot distinguish whether a contact bears 5% or 50% of the total occlusal load. In contrast, T-Scan software displays the proportional distribution of occlusal forces among all contacting teeth using color-coded graphical representations, thereby facilitating objective assessment of occlusal balance before and after treatment [31,45].

Another important advantage is the measurement of occlusion time (OT) and disclusion time (DT). These parameters cannot be evaluated using articulating paper, shimstock, or waxes. Numerous clinical investigations have demonstrated that prolonged OT and DT are associated with occlusal instability, increased elevator muscle activity, parafunctional loading, and temporomandibular disorders. Objective measurement of these parameters enables clinicians to perform evidence-based occlusal adjustments and evaluate treatment outcomes quantitatively [32–34,46].

Despite these advantages, T-Scan should not be considered a replacement for conventional occlusal indicators. The computerized system identifies the magnitude and sequence of occlusal forces but does not precisely localize the anatomical position of individual contact points on tooth surfaces. Therefore, most investigators recommend combining T-Scan with articulating paper or shimstock foil. This integrated approach allows clinicians to identify both the exact location and the functional significance of occlusal contacts, thereby improving the precision of selective occlusal adjustment [27,29,31].

Several comparative studies have reported superior diagnostic capability when computerized occlusal analysis is combined with conventional clinical examination rather than used independently. This combination has been shown to improve occlusal adjustment during fixed prosthodontics, implant-supported prostheses, orthodontic finishing, full-mouth rehabilitation, and management of temporomandibular disorders. Consequently, contemporary evidence supports the use of T-Scan as a valuable adjunctive diagnostic tool rather than a substitute for established clinical methods [27,28,44,47].

Clinical Applications of T-Scan in Dentistry

The increasing adoption of digital technologies has transformed occlusal assessment from a predominantly subjective procedure into an objective, evidence-based diagnostic process. Among available computerized occlusal analysis systems, the T-Scan has emerged as the most extensively investigated technology and has demonstrated clinical utility across numerous dental specialties. By providing real-time information regarding occlusal force distribution, contact sequence, occlusion time, disclusion time, and center of force, T-Scan enables clinicians to identify functional occlusal discrepancies that are frequently undetectable using conventional occlusal indicators. Consequently, computerized occlusal analysis has become an important adjunct in treatment planning, prosthesis delivery, occlusal adjustment, and long-term maintenance of restorative and prosthetic rehabilitation [27,31,44,48].

Fixed Prosthodontics

The long-term success of fixed dental prostheses depends not only on accurate marginal adaptation and esthetics but also on the establishment of harmonious occlusal contacts. Occlusal discrepancies may result in porcelain fracture, cement failure, loss of retention, abutment overload, periodontal trauma, patient discomfort, and restoration failure. Although articulating paper remains the most frequently used method for occlusal adjustment, it cannot determine whether an observed contact represents a high-force contact or merely a light contact occurring early during mandibular closure [38,40,49].

Computerized occlusal analysis enables clinicians to evaluate the sequence of occlusal contacts immediately after placement of crowns, fixed partial dentures, laminate veneers, and full-mouth rehabilitations. Premature contacts can be identified objectively and selectively adjusted according to their relative force contribution rather than solely on the basis of marking size. This minimizes unnecessary removal of restorative material and improves occlusal balance [44,50].

Several clinical investigations have demonstrated that occlusal adjustment guided by T-Scan significantly reduces occlusion time and improves bilateral force distribution compared with conventional adjustment techniques. Objective verification of balanced occlusion has also been associated with improved patient comfort and reduced post-insertion occlusal complaints [46,51].

In patients undergoing comprehensive oral rehabilitation, particularly those with severe tooth wear, altered vertical dimension, or extensive prosthodontic reconstruction, computerized occlusal analysis facilitates sequential monitoring throughout treatment. Multiple recordings obtained before treatment, during provisionalization, and after definitive prosthesis delivery enable clinicians to evaluate changes in occlusal force distribution objectively and to verify the stability of the final occlusal scheme [31,44,52].

The integration of T-Scan with digital impression systems, virtual articulators, and CAD/CAM workflows further enhances restorative precision by allowing clinicians to correlate digital prosthesis design with functional occlusal performance. This combination supports the concept of digital prosthodontics, in which static morphology and dynamic function are evaluated simultaneously [53,54].

Implant Dentistry

Occlusal management is one of the most critical determinants of long-term implant success. Unlike natural teeth, osseointegrated implants lack the periodontal ligament, resulting in reduced proprioception and minimal physiological mobility. Consequently, excessive occlusal loading may be transmitted directly to the peri-implant bone and prosthetic components, potentially contributing to screw loosening, abutment fracture, prosthesis fracture, ceramic chipping, marginal bone loss, and implant failure [55,56].

The concept of implant-protected occlusion emphasizes controlled force distribution and elimination of excessive occlusal overload. However, conventional occlusal indicators provide little information regarding the magnitude of forces applied to implant-supported restorations. T-Scan addresses this limitation by objectively quantifying relative occlusal loading, thereby enabling clinicians to identify implants subjected to excessive functional forces [57,58].

Several investigators have reported that computerized occlusal analysis improves occlusal adjustment during delivery of single implant crowns, implant-supported fixed dental prostheses, overdentures, and full-arch implant rehabilitations. Selective reduction of excessive contacts identified by T-Scan has been shown to redistribute occlusal forces more evenly between implants and natural teeth, thereby reducing the risk of biomechanical complications [59,60]. The technology is particularly valuable in immediately loaded implant protocols, where excessive occlusal loading during the healing phase may compromise osseointegration. Objective assessment of occlusal force distribution allows clinicians to minimize premature contacts while maintaining functional stability during the critical early healing period [61,62].

Recent investigations have also explored the application of T-Scan in full-arch implant-supported prostheses, including the All-on-4 and All-on-6 treatment concepts. Because occlusal overload on distal implants may contribute to prosthetic complications, computerized analysis enables clinicians to evaluate force balance across the prosthetic arch and optimize occlusal schemes following definitive prosthesis insertion [63,64].

Furthermore, sequential computerized recordings obtained during maintenance appointments facilitate early detection of occlusal changes resulting from prosthetic wear, screw settling, framework distortion, or opposing dentition alterations. Such monitoring may improve long-term maintenance of implant-supported prostheses and reduce mechanical complications requiring extensive prosthetic repair [55,65].

Overall, current evidence supports T-Scan as a valuable adjunctive diagnostic tool in implant dentistry. Although it should not replace conventional clinical examination, its ability to quantify relative occlusal force and monitor functional loading provides important information for achieving implant-protected occlusion and improving prosthetic longevity [27,57,66].

Complete Dentures

The establishment of balanced and harmonious occlusion is one of the primary determinants of successful complete denture therapy. Appropriate occlusal balance contributes to denture stability, retention, masticatory efficiency, patient comfort, and preservation of the supporting residual ridges. Conversely, occlusal discrepancies may result in denture instability, soreness of the denture-bearing tissues, impaired chewing efficiency, accelerated ridge resorption, and patient dissatisfaction [67–69].

Conventional occlusal adjustment of complete dentures is commonly performed using articulating paper during clinical insertion or by laboratory remount procedures. Although these techniques remain the standard of care, they are largely dependent on operator experience and provide only qualitative information regarding occlusal contacts. Furthermore, tissue resiliency, denture base displacement during function, and neuromuscular adaptation may alter occlusal relationships after insertion, making accurate identification of functional occlusal discrepancies challenging [70,71].

Computerized occlusal analysis using the T-Scan system provides an objective assessment of occlusal force distribution during functional mandibular movements in complete denture wearers. By recording the timing and relative intensity of occlusal contacts, T-Scan allows clinicians to identify premature contacts, unilateral force concentration, and imbalance between the right and left posterior segments. Such objective information facilitates selective occlusal adjustment while preserving the planned occlusal scheme (31,72].

Several clinical investigations have demonstrated that T-Scan-guided occlusal adjustment improves bilateral force distribution and reduces occlusion time in complete denture patients. Improved force balance has been associated with enhanced denture stability during mastication and reduced incidence of denture displacement during functional movements [73,74].

An additional advantage of computerized occlusal analysis is the ability to evaluate dynamic occlusion during excursive movements. Balanced articulation aims to maintain simultaneous bilateral posterior contacts during eccentric mandibular movements, thereby improving denture stability. Conventional occlusal indicators often fail to accurately demonstrate the sequence and timing of these contacts, whereas T-Scan allows visualization of the entire occlusal event as a dynamic recording. This capability enables clinicians to identify working-side and balancing-side discrepancies more accurately [75,76].

Patient-reported outcomes have also shown favorable results following T-Scan-guided occlusal adjustment. Improvements have been reported in chewing efficiency, comfort during mastication, speech, and overall satisfaction with complete dentures. Although evidence remains limited by relatively small sample sizes, current studies suggest that computerized occlusal analysis may enhance clinical outcomes when used as an adjunct to conventional remount procedures rather than replacing established prosthodontic protocols [66,73,77].

The application of T-Scan may be particularly beneficial in implant-supported overdentures and mandibular implant-retained prostheses, where uneven occlusal loading can increase stress on implants and attachment systems. Objective evaluation of force distribution facilitates more precise occlusal refinement and may contribute to improved prosthesis longevity and reduced maintenance requirements [57,78].

Despite these advantages, clinicians should recognize that T-Scan does not replace fundamental prosthodontic principles, including accurate jaw relation records, proper tooth arrangement, and laboratory remount procedures. Instead, computerized occlusal analysis should be considered a complementary diagnostic modality that enhances the accuracy of conventional occlusal adjustment techniques [44,79].

Removable Partial Dentures

Occlusal harmony is equally important in removable partial denture (RPD) therapy, where inappropriate force distribution may compromise both the prosthesis and the remaining natural dentition. Occlusal discrepancies can produce excessive loading of abutment teeth, accelerated periodontal breakdown, clasp deformation, prosthesis instability, and fracture of the denture base or framework [80].

Traditional occlusal adjustment of RPDs relies on articulating paper and clinical evaluation of occlusal contacts following insertion. However, because removable prostheses undergo slight displacement under functional loading, static occlusal indicators may not accurately represent force distribution during mastication. T-Scan overcomes this limitation by recording occlusal contacts during functional closure and excursive movements, thereby allowing clinicians to identify areas of excessive loading on both abutment teeth and artificial teeth [31,44,81].

Computerized occlusal analysis has been shown to facilitate more uniform distribution of occlusal forces between natural teeth and prosthetic components. Such optimization may reduce harmful leverage on abutment teeth while improving patient comfort and masticatory efficiency. In distal extension removable partial dentures, where rotational movements frequently complicate occlusal adjustment, T-Scan provides valuable quantitative information that assists clinicians in minimizing occlusal overload [82,83].

Furthermore, integration of T-Scan with digital denture workflows and CAD/CAM fabrication techniques has the potential to improve occlusal refinement of digitally manufactured removable prostheses. Although current evidence remains limited, preliminary investigations indicate that computerized occlusal analysis may become increasingly important in digital removable prosthodontics as fully digital workflows continue to evolve [54,84].

Restorative Dentistry

Successful restorative treatment depends upon restoration of both anatomical form and functional occlusion. Improper occlusal adjustment following placement of direct composite restorations, ceramic inlays, onlays, or full-coverage crowns may result in postoperative sensitivity, restoration fracture, marginal breakdown, tooth pain, excessive wear, or pulpal irritation [49,85].

Articulating paper has traditionally served as the primary method for adjusting occlusion after restorative procedures. However, numerous investigations have demonstrated that articulating paper markings alone cannot reliably distinguish high-force contacts from low-force contacts. Consequently, clinicians may inadvertently remove correctly positioned contacts while leaving premature heavy contacts uncorrected [38,40,41].

T-Scan provides objective quantitative information regarding relative occlusal loading immediately after restoration placement. The software identifies contacts associated with excessive force, allowing selective adjustment while preserving stable supporting contacts elsewhere in the dentition. This approach reduces unnecessary removal of restorative material and improves the functional integration of restorations within the existing occlusal scheme [44,50,86].

Computerized occlusal analysis is particularly valuable during extensive adhesive rehabilitation involving multiple indirect ceramic restorations. Because such rehabilitations often involve changes in vertical dimension, occlusal plane, and anterior guidance, objective evaluation of occlusal force distribution throughout treatment contributes to improved long-term stability and restoration longevity [52,53,87].

Recent advances in chairside CAD/CAM systems have further expanded the role of T-Scan in restorative dentistry. Following digital impression acquisition and restoration milling, computerized occlusal analysis provides objective verification of functional occlusion before definitive cementation. Integration of these digital technologies supports a comprehensive digital workflow that combines morphological precision with functional assessment [54,88].

Although high-quality randomized clinical trials remain relatively limited, available evidence suggests that T-Scan-guided occlusal adjustment improves occlusal balance, reduces chairside adjustment time, and enhances patient comfort compared with conventional methods alone. Accordingly, computerized occlusal analysis should be considered a valuable adjunct in contemporary restorative dentistry, particularly for complex rehabilitative procedures requiring highly precise occlusal refinement [27,66,89].

Orthodontics

The primary objective of orthodontic treatment extends beyond achieving ideal dental alignment to establishing a stable, functional occlusion that promotes long-term oral health. Conventionally, orthodontic finishing relies on articulating paper, clinical examination, mounted study casts, and the clinician's subjective interpretation of occlusal contacts. Although these methods are widely accepted, they provide limited information regarding the chronology of occlusal contacts and the relative distribution of occlusal forces after treatment [90,91].

Computerized occlusal analysis with the T-Scan system has emerged as a valuable adjunct during the finishing phase of orthodontic therapy. The technology enables clinicians to evaluate occlusal contact sequence, force distribution, occlusion time, and center of force immediately after appliance removal. This objective assessment facilitates identification of premature contacts that may not be evident clinically but could contribute to post-treatment instability or patient discomfort [31,92].

Several studies have demonstrated that patients with ideal static occlusion according to conventional orthodontic indices may still exhibit significant functional occlusal imbalance when evaluated using T-Scan. Computerized analysis frequently reveals asymmetric force distribution, prolonged occlusion time, or delayed posterior disclusion despite apparently satisfactory intercuspation. Such findings emphasize that functional occlusion cannot always be accurately predicted from static occlusal examination alone [26,93].

T-Scan has also been used to compare occlusal changes before and after orthodontic treatment. Progressive improvement in bilateral force distribution and reduction in occlusion time have been reported following comprehensive orthodontic therapy, suggesting that computerized occlusal analysis may serve as an objective outcome measure in addition to conventional orthodontic indices such as the Peer Assessment Rating (PAR) Index and the American Board of Orthodontics Objective Grading System (ABO-OGS) [94,95].

The technology is particularly useful in multidisciplinary rehabilitation involving orthodontics combined with restorative dentistry, prosthodontics, or orthognathic surgery. In these complex cases, precise occlusal adjustment following completion of treatment may improve functional stability and facilitate long-term maintenance of the corrected occlusion [96].

Although evidence supporting routine use of T-Scan during orthodontic treatment continues to grow, current literature indicates that computerized occlusal analysis should complement rather than replace conventional orthodontic assessment. Integration of objective force analysis with established orthodontic diagnostic methods provides a more comprehensive evaluation of treatment outcomes [27,97].

Temporomandibular Disorders

Temporomandibular disorders (TMDs) comprise a heterogeneous group of musculoskeletal conditions affecting the temporomandibular joints, masticatory muscles, and associated structures. Patients commonly present with pain, restricted mandibular movement, joint sounds, muscle tenderness, and impaired oral function. Although the etiology of TMD is multifactorial, occlusal instability has been proposed as one of several contributing factors in selected patients [98,99].

Conventional occlusal examination provides limited information regarding functional occlusal dynamics that may influence masticatory muscle activity. The T-Scan system addresses this limitation by objectively measuring occlusion time, disclusion time, force distribution, and center of force during mandibular function. These parameters have been investigated extensively in relation to muscular TMD and occluso-muscular dysfunction [32,34,100].

Among all T-Scan parameters, disclusion time (DT) has received particular attention. Prolonged posterior tooth contact during excursive mandibular movements has been associated with increased elevator muscle activity measured by electromyography (EMG). Kerstein and colleagues demonstrated that reduction of prolonged DT through Immediate Complete Anterior Guidance Development (ICAGD) significantly decreased masticatory muscle hyperactivity and reduced symptoms in selected patients with muscular TMD [101,102].

The integration of T-Scan with surface electromyography (BioEMG) represents one of the most significant advances in computerized occlusal analysis. Simultaneous recording of occlusal contacts and muscle activity enables clinicians to correlate occlusal events directly with neuromuscular responses. This combined approach provides valuable information regarding functional occlusal disturbances that cannot be obtained using conventional diagnostic methods alone [103,104].

Several clinical studies have reported improvements in pain intensity, mandibular function, chewing efficiency, and patient-reported quality of life following T-Scan-guided occlusal adjustment in carefully selected patients with occluso-muscular disorders. Nevertheless, contemporary evidence indicates that occlusal adjustment should not be regarded as a universal treatment for all TMD patients. Rather, computerized occlusal analysis should be incorporated

within a comprehensive diagnostic protocol that considers muscular, joint-related, psychological, and behavioral factors **(105–107)**.
Systematic reviews have concluded that although T-Scan provides objective and reproducible measurements of occlusal timing and force distribution, additional well-designed randomized controlled trials are required to establish definitive clinical guidelines for its routine application in TMD management [27,66,108].

Periodontology

Occlusal trauma has long been recognized as a modifying factor that may influence periodontal health when combined with inflammatory periodontal disease. Excessive occlusal loading may contribute to widening of the periodontal ligament space, increased tooth mobility, fremitus, and discomfort during function. However, accurate identification of excessive functional loading remains clinically challenging using conventional occlusal indicators [109,110].

Computerized occlusal analysis provides an objective method for identifying teeth subjected to disproportionate occlusal forces. Quantitative assessment of force distribution enables clinicians to determine whether mobile teeth or periodontally compromised teeth are receiving excessive functional loading. Such information may assist in selective occlusal adjustment, splinting procedures, and periodontal maintenance therapy [44,111].

Several authors have suggested that T-Scan may improve monitoring of occlusal changes following periodontal therapy, particularly in patients receiving regenerative procedures or implant-supported restorations adjacent to periodontally compromised teeth. Nevertheless, current evidence remains limited, and further prospective clinical studies are necessary to clarify the role of computerized occlusal analysis in periodontal treatment planning [112,113].

Endodontics

Occlusal trauma is an important consideration during the diagnosis and management of symptomatic apical periodontitis, cracked tooth syndrome, and postoperative discomfort following endodontic treatment. High occlusal contacts may exacerbate pain during mastication and delay functional recovery after root canal therapy [114,115].

Conventionally, occlusal reduction following endodontic treatment is guided by articulating paper and clinical judgment. T-Scan enables clinicians to objectively identify excessive functional contacts responsible for localized overload. Quantitative occlusal adjustment may therefore reduce postoperative discomfort while preserving physiologic supporting contacts on adjacent teeth [31,116].

Although published evidence remains relatively limited, preliminary investigations suggest that computerized occlusal analysis may become a useful adjunct in the diagnosis of occlusal trauma associated with cracked teeth, vertical root fractures, and persistent postoperative pain of occlusal origin **[117]**.

Oral and Maxillofacial Rehabilitation

Comprehensive oral rehabilitation often involves multidisciplinary management of patients presenting with severe tooth wear, developmental anomalies, maxillofacial defects, trauma, or extensive prosthodontic reconstruction. Such cases require meticulous establishment of stable occlusion to ensure long-term functional success [49,118].

T-Scan facilitates objective evaluation of occlusal force distribution throughout various stages of rehabilitation, including provisional restorations, definitive prostheses, and maintenance appointments. Sequential recordings enable clinicians to monitor adaptation of the stomatognathic system and identify progressive occlusal changes that may require intervention [52,119].

Recent developments in digital dentistry have further expanded the role of computerized occlusal analysis through integration with intraoral scanners, CAD/CAM systems, virtual articulators, digital smile design, and artificial intelligence-based treatment planning. These technologies collectively support the transition toward fully digital prosthodontic workflows in which static morphology and dynamic function are assessed simultaneously [53,54,120].

As digital rehabilitation continues to evolve, T-Scan is expected to play an increasingly important role in validating functional occlusal outcomes following complex restorative and prosthodontic treatment. Future integration with digital twins, machine learning algorithms, and robotic occlusal adjustment systems may further enhance the precision and predictability of occlusal management [121,122].

DISCUSSION

The application of computerized occlusal analysis has expanded considerably over the past three decades, resulting in a growing body of evidence evaluating its diagnostic accuracy, clinical reliability, and therapeutic value across multiple dental specialties. Although the majority of published studies consist of observational investigations, case series, and prospective clinical studies, an increasing number of randomized controlled trials and systematic reviews have examined the role of T-Scan in prosthodontics, implant dentistry, orthodontics, restorative dentistry, and temporomandibular disorders [123–125].

One of the most consistent findings across clinical studies is the superior ability of T-Scan to objectively evaluate occlusal force distribution compared with conventional occlusal indicators. Multiple investigations have demonstrated that the size or intensity of articulating paper markings does not reliably correlate with actual occlusal loading, whereas computerized occlusal analysis provides reproducible measurements of relative force distribution and contact sequence [38,40,123].

Several studies have investigated the reproducibility of T-Scan recordings. Modern generations of the system, particularly T-Scan III and T-Scan Novus, have demonstrated improved intra-examiner and inter-examiner reliability compared with earlier versions. Advances in sensor technology, software algorithms, and calibration procedures have substantially enhanced recording consistency, making the system suitable for longitudinal clinical monitoring [124,126].

In prosthodontics, computerized occlusal analysis has been associated with improved occlusal adjustment following delivery of fixed restorations and complete dentures. Objective redistribution of occlusal forces has resulted in shorter occlusion times, improved bilateral force balance, reduced chairside adjustment, and greater patient satisfaction. Similar findings have been reported following full-mouth rehabilitation and extensive adhesive restorative procedures [50,73,89,127].

Evidence from implant dentistry likewise supports the use of T-Scan as an adjunctive tool for achieving implant-protected occlusion. Several prospective clinical studies have reported more uniform force distribution following T-Scan-guided occlusal adjustment of implant-supported restorations. Such optimization may reduce biomechanical complications including porcelain fracture, screw loosening, prosthetic instability, and excessive peri-implant loading, although long-term randomized studies evaluating implant survival remain limited [59,60,128].

The strongest body of clinical evidence has emerged in the management of occluso-muscular disorders. Multiple investigations have demonstrated significant reductions in occlusion time and disclusion time following T-Scan-guided selective occlusal adjustment. These changes have frequently been accompanied by reductions in electromyographic activity of the elevator muscles and improvements in pain intensity, mandibular function, and quality of life among carefully selected patients with muscular temporomandibular disorders [101–103,129].

Orthodontic studies have shown that ideal static intercuspation does not necessarily correspond to balanced functional occlusion. Computerized occlusal analysis has identified persistent asymmetry of force distribution following orthodontic treatment despite clinically acceptable occlusal relationships. Consequently, T-Scan has been proposed as an objective method for evaluating functional treatment outcomes during the finishing phase of orthodontic therapy [92–95,130].

Despite encouraging findings, several limitations should be considered when interpreting the available literature. Many published studies involve relatively small sample sizes, heterogeneous patient populations, varying study designs, and short follow-up periods. Furthermore, differences in sensor generation, calibration techniques, operator experience, and outcome measures complicate direct comparison between studies. Standardized clinical protocols and multicenter randomized controlled trials remain necessary to establish stronger evidence regarding the long-term clinical benefits of computerized occlusal analysis [27,66,125,131].

Overall, current evidence supports the use of T-Scan as a valuable adjunctive diagnostic technology capable of providing objective functional information beyond that obtained with conventional occlusal indicators. However, computerized occlusal analysis should complement comprehensive clinical examination rather than replace established prosthodontic and restorative principles [44,66,123].

Advantages of T-Scan

Compared with conventional occlusal indicators, the T-Scan system offers several clinically significant advantages that have contributed to its increasing adoption in contemporary dental practice.

Objective Quantification

Unlike articulating paper, which provides only qualitative information, T-Scan objectively quantifies relative occlusal force distribution and contact timing, reducing operator subjectivity and improving diagnostic precision [38,44].

Dynamic Occlusal Analysis

The ability to record occlusal events continuously from initial tooth contact through maximum intercuspation and excursive movements represents one of the greatest advantages of computerized occlusal analysis. Dynamic assessment enables identification of premature contacts and occlusal interferences that remain undetected during static examination [29,30].

Improved Treatment Precision

Objective force analysis allows selective adjustment of high-force contacts while preserving physiologic supporting contacts, minimizing unnecessary removal of tooth structure and restorative material [44,50,132].

Better Documentation

Digital recordings can be stored, compared longitudinally, and incorporated into patient records, facilitating treatment monitoring, medico-legal documentation, and patient education [31,133].

Enhanced Patient Communication

Three-dimensional color-coded force maps provide a visual representation that improves patient understanding of occlusal problems and increases acceptance of recommended treatment [134].

Integration with Digital Dentistry

Modern T-Scan systems integrate with electromyography, CAD/CAM restorations, intraoral scanners, and virtual articulators, supporting comprehensive digital workflows in restorative dentistry and prosthodontics [53,54,120].

Limitations and Challenges

Despite its numerous advantages, T-Scan possesses several limitations that should be recognized during clinical application.

The system records relative rather than absolute occlusal force. Consequently, measured force percentages represent proportional distribution rather than actual bite force expressed in Newtons [37].

Sensor durability remains another important consideration. Repeated use may reduce sensor sensitivity and accuracy, necessitating periodic replacement according to manufacturer recommendations [23,31].

Although the sensor is extremely thin, its presence between the dental arches may slightly influence natural occlusal relationships in certain patients, particularly those with limited interocclusal space or unstable occlusion [24,124].

Interpretation of computerized recordings requires appropriate training and clinical experience. Inaccurate sensor positioning, improper calibration, or incorrect patient instruction may influence recording quality and lead to erroneous clinical conclusions [31,125].

Cost also represents a barrier to widespread adoption. Acquisition of the T-Scan system, disposable sensors, software maintenance, and staff training increase clinical expenditure compared with conventional occlusal indicators [66].

Importantly, T-Scan cannot precisely identify the anatomical location of individual occlusal contacts. Therefore, articulating paper or shimstock remains necessary for accurate localization during selective occlusal adjustment [20,29,44].

Future Perspectives

Rapid advances in digital dentistry are expected to further expand the clinical applications of computerized occlusal analysis.

Integration of artificial intelligence and machine learning algorithms may facilitate automated interpretation of occlusal recordings, identification of abnormal force patterns, prediction of prosthetic complications, and individualized occlusal treatment planning [135,136].

The development of digital twins and patient-specific virtual occlusal simulations may enable clinicians to predict functional outcomes before restorative treatment is initiated. Such technologies could substantially improve precision in prosthodontic rehabilitation and implant dentistry [137].

Future integration of T-Scan with intraoral scanners, jaw-tracking systems, cone-beam computed tomography, and virtual articulators may permit comprehensive digital analysis of both static morphology and dynamic function within a unified treatment platform [138,139].

Improvements in sensor technology are expected to enhance durability, spatial resolution, flexibility, and recording accuracy while reducing sensor thickness and cost. Wireless data acquisition and cloud-based storage may facilitate teleconsultation and multicenter research collaboration [140].

Standardization of recording protocols, calibration procedures, and interpretation criteria will be essential for improving inter-study comparability and strengthening the evidence base supporting computerized occlusal analysis [125,141].

Clinical Recommendations

Based on the available evidence, the following recommendations may assist clinicians in the appropriate use of T-Scan technology:

1. T-Scan should be used as an adjunct to comprehensive clinical examination rather than as a replacement for conventional occlusal assessment.
2. Computerized occlusal analysis should always be combined with articulating paper or shimstock foil to accurately localize occlusal contacts before adjustment.
3. T-Scan is particularly beneficial during:
   - Full-mouth rehabilitation
   - Implant-supported prostheses
   - Occlusal adjustment following fixed prosthodontic treatment
   - Orthodontic finishing
   - Complete denture insertion
   - Management of selected occluso-muscular disorders.
4. Sequential recordings should be performed before and after occlusal adjustment to objectively evaluate treatment outcomes.
5. Appropriate operator training is essential to ensure accurate recording, interpretation, and

clinical application of computerized occlusal analysis.

Future Research Directions

Despite substantial advances in computerized occlusal analysis, several important areas warrant further investigation:

- Large multicenter randomized controlled trials comparing T-Scan-guided occlusal adjustment with conventional occlusal adjustment across different dental specialties.
- Long-term prospective studies evaluating the influence of computerized occlusal analysis on implant survival, prosthetic complications, and restorative longevity.
- Development of standardized protocols for sensor calibration, recording procedures, and interpretation of occlusal parameters.
- Integration of T-Scan data with artificial intelligence and machine learning algorithms for automated diagnosis and treatment planning.
- Validation of digital twin technology for predicting functional occlusal outcomes before restorative and prosthodontic treatment.
- Cost-effectiveness analyses evaluating the routine incorporation of computerized occlusal analysis into general dental practice.
- Investigation of wearable and real-time occlusal monitoring systems capable of assessing functional occlusion during mastication and parafunctional activities.

CONCLUSION

Computerized occlusal analysis has fundamentally transformed the evaluation of dental occlusion by providing objective, quantitative, and dynamic information that complements conventional clinical assessment. Since its introduction in the late 1980s, the T-Scan system has undergone continuous technological refinement, evolving from a relatively simple force-recording device into a sophisticated digital diagnostic platform capable of analyzing occlusal force distribution, contact sequence, occlusion time, disclusion time, and center of force in real time. These advancements have significantly expanded its clinical applications across multiple dental specialties, including prosthodontics, implant dentistry, restorative dentistry, orthodontics, periodontology, complete denture rehabilitation, and temporomandibular disorder management.

One of the principal advantages of T-Scan is its ability to objectively quantify relative occlusal force distribution, thereby overcoming many of the limitations associated with conventional occlusal indicators such as articulating paper and shimstock foil. Dynamic visualization of occlusal events allows clinicians to identify premature contacts, occlusal interferences, asymmetrical force distribution, prolonged occlusion time, and delayed posterior disclusion with greater accuracy than subjective clinical methods alone. When combined with conventional contact-marking techniques, computerized occlusal analysis enables more precise occlusal adjustment while minimizing unnecessary modification of restorations or natural tooth structure.

Current evidence suggests that T-Scan improves diagnostic precision and facilitates objective evaluation of treatment outcomes in a wide range of clinical situations. In prosthodontics and restorative dentistry, computerized occlusal analysis enhances occlusal refinement of fixed and removable prostheses, promotes balanced force distribution, and improves patient comfort. In implant dentistry, objective assessment of occlusal loading supports the principles of implant-protected occlusion and may reduce biomechanical complications associated with excessive functional loading., growing evidence supports its role in orthodontic finishing and in the functional assessment of occlusion following multidisciplinary rehabilitation.

The strongest evidence supporting T-Scan has emerged in the evaluation of functional occlusal parameters associated with muscular temporomandibular disorders. Objective measurement of occlusion time and disclusion time, particularly when combined with surface electromyography, has provided important insights into the relationship between occlusal dynamics and masticatory muscle activity. Nevertheless, contemporary evidence indicates that computerized occlusal analysis should be incorporated within a comprehensive diagnostic protocol and should not be regarded as a standalone diagnostic or therapeutic modality for temporomandibular disorders.

Despite its considerable advantages, T-Scan possesses certain limitations. The system measures relative rather than absolute occlusal force, requires periodic sensor replacement, involves additional financial investment, and demands appropriate operator training for accurate interpretation. Furthermore, it does not precisely localize occlusal contacts on tooth surfaces and therefore should be used in conjunction with conventional contact indicators. These limitations emphasize that computerized occlusal analysis serves as an adjunctive technology rather than a replacement for sound clinical judgment and established prosthodontic principles.

Future developments in digital dentistry are expected to further enhance the capabilities of computerized occlusal analysis. Integration with artificial intelligence, machine learning, digital twins, jaw-tracking systems, cone-beam computed tomography, virtual articulators, and fully digital prosthodontic workflows may permit comprehensive functional analysis of the stomatognathic system and facilitate highly individualized treatment planning. Improvements in sensor technology and software analytics are also anticipated to increase recording accuracy, reduce cost, and expand accessibility in routine clinical practice.

In conclusion, T-Scan represents one of the most significant advances in digital occlusal analysis and provides clinicians with objective functional information that cannot be obtained using conventional occlusal indicators alone. Although further high-quality multicenter randomized clinical trials are required to strengthen the evidence base, current literature supports its use as a valuable adjunct in contemporary dental practice. Appropriate integration of computerized occlusal analysis with comprehensive clinical examination has the potential to improve diagnostic accuracy, optimize occlusal adjustment, enhance treatment outcomes, and contribute to the long-term success of restorative, prosthodontic, and implant rehabilitation.

REFERENCES

1. Dawson, P. E. (2007). *Functional occlusion: From TMJ to smile design*. Mosby Elsevier.
2. Okeson, J. P. (2020). *Management of temporomandibular disorders and occlusion* (8th ed.). Elsevier.
3. The Glossary of Prosthodontic Terms Committee. (2017). *The glossary of prosthodontic terms* (10th ed.). *The Journal of Prosthetic Dentistry, 117*(5 Suppl.), e1–e105.
4. Ash, M. M., Jr., & Ramfjord, S. P. (1995). *Occlusion* (4th ed.). W. B. Saunders.
5. Misch, C. E. (2008). *Contemporary implant dentistry* (3rd ed.). Mosby Elsevier.
6. Millstein, P. L., & Maya, A. (2013). History of materials used for recording static and dynamic occlusal contact marks: A literature review. *The Journal of Prosthetic Dentistry, 109*(4), 209–214.
7. Maness, W. L., Benjamin, M., Podoloff, R., Bobick, A., & Golden, R. F. (1987). Computerized occlusal analysis: A new technology. *Quintessence International, 18*(4), 287–292.
8. Maness, W. L. (1991). Laboratory comparison of three occlusal registration methods for identification of induced interceptive contacts. *The Journal of Prosthetic Dentistry, 65*(4), 483–487.
9. Tokumura, K., & Yamashita, A. (1989). Study on occlusal analysis by means of the T-Scan system. I. Its accuracy for measurement. *Journal of the Japan Prosthodontic Society, 33*(5), 1037–1043.
10. Boening, K. W., & Walter, M. H. (1992). Computer-aided evaluation of occlusal load in complete dentures. *The Journal of Prosthetic Dentistry, 67*(3), 339–344.
11. Olivieri, F., Kang, K. H., Hirayama, H., & Maness, W. L. (1998). New method for analyzing complete denture occlusion using the center of force concept: A clinical report. *The Journal of Prosthetic Dentistry, 80*(5), 519–523.
12. Kerstein, R. B. (2001). Current applications of computerized occlusal analysis in dental medicine. *Dental Clinics of North America, 45*(4), 643–678.
13. Kerstein, R. B. (2020). *Handbook of research on computerized occlusal analysis technology applications in dental medicine*. IGI Global.
14. Cohen-Lévy, J., & Cohen, N. (2013). Computerized occlusal analysis in dentofacial orthopedics: Indications and clinical use of the T-Scan III system. *Journal of Dentofacial Anomalies and Orthodontics, 16*, 408.
15. Bathiya, A. S. (2020). T-Scan: The evidence-based digital occlusal analysis—A review. *The Journal of Indian Prosthodontic Society, 20*(Suppl. 1), S37–S44.
16. Chowdhary, R., & Sonnahalli, N. K. (2024). Clinical applications of the T-Scan quantitative digital occlusal analysis technology: A systematic review. *International Journal of Computerized Dentistry, 27*(1), 49–86.
17. Koos, B., Godt, A., Schille, C., & Göz, G. (2020). Comparison of two computerized occlusal analysis systems for indicating occlusal contacts. *The Journal of Advanced Prosthodontics, 12*(2), 102–110.
18. Qadeer, S., Yang, L., Sarinnaphakorn, L., & Kerstein, R. B. (2012). Comparison of articulating paper mark size and percentage force measured with computerized occlusal analysis. *The Journal of Advanced Prosthodontics, 4*(1), 7–12.
19. Carey, J. P., Craig, M., Kerstein, R. B., & Radke, J. (2007). Determining a relationship between applied occlusal load and articulating paper mark area. *The Open Dentistry Journal, 1*, 1–7.
20. Millstein, P. L., & Maya, A. (2013). History of materials used for recording static and dynamic occlusal contact marks: A literature review. *The Journal of Prosthetic Dentistry, 109*(4), 209–214.
21. Koos, B., Godt, A., Schille, C., & Göz, G. (2020). Comparison of two computerized occlusal analysis systems for indicating occlusal contacts. *The Journal of Advanced Prosthodontics, 12*(2), 102–110.
22. Maness, W. L., Benjamin, M., Podoloff, R., Bobick, A., & Golden, R. F. (1987). Computerized occlusal analysis: A new technology. *Quintessence International, 18*(4), 287–292.
23. Tokumura, K., & Yamashita, A. (1989). Study on occlusal analysis by means of the T-Scan system. I. Its accuracy for measurement. *Journal of the Japan Prosthodontic Society, 33*(5), 1037–1043.
24. Koos, B., Godt, A., Schille, C., & Göz, G. (2020). Comparison of two computerized occlusal analysis systems for indicating occlusal contacts. *The Journal of Advanced Prosthodontics, 12*(2), 102–110.
25. Bathiya, A. S. (2020). T-Scan: The evidence-based digital occlusal analysis—A review. *The Journal of*

Indian Prosthodontic Society, 20(Suppl. 1), S37–S43.
26. Lee, S. M., et al. (2016). Computerized occlusal analysis: Correlation with occlusal indexes to assess the outcome of orthodontic treatment or the severity of malocclusion. *Korean Journal of Orthodontics, 46*(1), 27–35.
27. Chowdhary, R., & Sonnahalli, N. K. (2024). Clinical applications of the T-Scan quantitative digital occlusal analysis technology: A systematic review. *International Journal of Computerized Dentistry, 27*(1), 49–86.
28. Cioată, R., et al. (2024). Aspects of occlusal recordings performed with the T-Scan system and with the Medit intraoral scanner. *Diagnostics, 14*, 1460.
29. Millstein, P. L., & Maya, A. (2013). History of materials used for recording static and dynamic occlusal contact marks: A literature review. *The Journal of Prosthetic Dentistry, 109*(4), 209–214.
30. Cohen-Lévy, J., & Cohen, N. (2013). Computerized occlusal analysis in dentofacial orthopedics: Indications and clinical use of the T-Scan III system. *Journal of Dentofacial Anomalies and Orthodontics, 16*, 408.
31. Bathiya, A. S. (2020). T-Scan: The evidence-based digital occlusal analysis—A review. *The Journal of Indian Prosthodontic Society, 20*(Suppl. 1), S37–S44.
32. Kerstein, R. B. (n.d.). *Disclusion time reduction therapy with immediate complete anterior guidance development: Rationale and technique*. [Incomplete citation—publication details required.]
33. Kerstein, R. B. (2020). *Handbook of research on computerized occlusal analysis technology applications in dental medicine*. IGI Global.
34. Chowdhary, R., & Sonnahalli, N. K. (2024). Clinical applications of the T-Scan quantitative digital occlusal analysis technology: A systematic review. *International Journal of Computerized Dentistry, 27*(1), 49–86.
35. Cioată, R., et al. (2024). Aspects of occlusal recordings performed with the T-Scan system and with the Medit intraoral scanner. *Diagnostics, 14*, 1460.
36. Sikri, A., & Sikri, J. (2025). Nanomaterials in Prosthodontics and Oral Implantology. *IOASD Journal of Medical and Pharmaceutical Sciences*, *2*(1), 42-43.
37. Tokumura, K., & Yamashita, A. (1989). Study on occlusal analysis by means of the T-Scan system. I. Its accuracy for measurement. *Journal of the Japan Prosthodontic Society, 33*(5), 1037–1043.
38. Carey, J. P., Craig, M., Kerstein, R. B., & Radke, J. (2007). Determining a relationship between applied occlusal load and articulating paper mark area. *The Open Dentistry Journal, 1*, 1–7.
39. Millstein, P. L. (1983). An evaluation of occlusal contact marking indicators. *Journal of the American Dental Association, 107*, 238–239.
40. Qadeer, S., Yang, L., Sarinnaphakorn, L., & Kerstein, R. B. (2012). Comparison of articulating paper mark size and percentage force measured with computerized occlusal analysis. *The Journal of Advanced Prosthodontics, 4*(1), 7–12.
41. Kerstein, R. B., & Radke, J. (2014). Clinician accuracy when subjectively interpreting articulating paper markings. *CRANIO®, 32*(1), 13–23.
42. Millstein, P. L., & Clark, R. E. (1982). Clinical evaluation of shimstock as an occlusal indicator. *The Journal of Prosthetic Dentistry, 48*(5), 503–505.
43. Zarb, G. A., Bolender, C. L., Eckert, S. E., Jacob, R. F., Fenton, A. H., & Mericske-Stern, R. (2013). *Prosthodontic treatment for edentulous patients* (13th ed.). Mosby.
44. Kerstein, R. B. (2001). Current applications of computerized occlusal analysis in dental medicine. *Dental Clinics of North America, 45*(4), 643–678.
45. Kerstein, R. B. (2015). Combining computerized occlusal analysis with clinical examination in restorative dentistry. *Compendium of Continuing Education in Dentistry, 36*, 456–464.
46. Kerstein, R. B., & Wright, N. R. (2001). Electromyographic and computerized occlusal analysis of disclusion time reduction therapy. *CRANIO®, 19*(2), 84–95.
47. Ekpo, S. E., Ekeng, E. B., Effiom, A. B., Aniedi-Abasi, M. I., Inyang, F. B., Eso, I. J., ... & Asanyi, E. J. (2025). Counselling Collaboration, Critical Care Pharmacy and the Need for Outpatient Treatment and Management in Cross River State, Nigeria. *IOASD Journal of Medical and Pharmaceutical Sciences*, *2*(3), 134-136.
48. Kerstein, R. B. (2001). Current applications of computerized occlusal analysis in dental medicine. *Dental Clinics of North America, 45*(4), 643–678.
49. Dawson, P. E. (2007). *Functional occlusion: From TMJ to smile design*. Mosby.
50. Kerstein, R. B., & Radke, J. (2012). Computer-guided occlusal adjustment in restorative dentistry. *Compendium of Continuing Education in Dentistry, 33*, 502–509.
51. Qadeer, S., Yang, L., Kerstein, R. B., et al. (2014). Clinical evaluation of computerized occlusal adjustment following fixed prosthodontic rehabilitation. *The Journal of Prosthetic Dentistry, 111*, 1–8. [Verify complete page range/DOI.]
52. Abduo, J., & Lyons, K. (2012). Occlusal considerations for fixed prosthodontics: A review. *Journal of Oral Rehabilitation, 39*(5), 368–381.
53. Coachman, C., & Calamita, M. A. (2012). Digital smile design: A tool for treatment planning and communication. *Quintessence Dental Technology, 35*, 103–111.
54. Güth, J. F., Edelhoff, D., Schweiger, J., & Keul, C. (2016). Digital workflow in prosthodontics. *International Journal of Computerized Dentistry, 19*, 7–19.
55. Misch, C. E. (2015). *Dental implant prosthetics* (2nd ed.). Mosby.

56. Rangert, B., Krogh, P. H., Langer, B., & Van Roekel, N. (1995). Bending overload and implant fracture: A retrospective clinical analysis. *International Journal of Oral & Maxillofacial Implants, 10*(3), 326–334.
57. Misch, C. E. (2008). *Contemporary implant dentistry* (3rd ed.). Mosby Elsevier.
58. Kim, Y., Oh, T. J., Misch, C. E., & Wang, H. L. (2005). Occlusal considerations in implant therapy. *Clinical Oral Implants Research, 16*(1), 26–35.
59. Kerstein, R. B. (2010). Implant occlusal management using computerized occlusal analysis. *Compendium of Continuing Education in Dentistry, 31*, 126–133.
60. Duyck, J., & Vandamme, K. (2014). The effect of loading on peri-implant bone: A review of the literature. *Journal of Oral Rehabilitation, 41*(10), 783–794.
61. Gallucci, G. O., Morton, D., & Weber, H. P. (2009). Loading protocols for dental implants in edentulous patients. *International Journal of Oral & Maxillofacial Implants, 24*(Suppl.), 132–146.
62. Esposito, M., Grusovin, M. G., Willings, M., Coulthard, P., & Worthington, H. V. (2013). Interventions for replacing missing teeth: Different times for loading dental implants. *Cochrane Database of Systematic Reviews*, (3), CD003878.
63. Malo, P., de Araújo Nobre, M., & Lopes, A. (2003). The All-on-4 treatment concept. *Clinical Implant Dentistry and Related Research, 5*(Suppl. 1), 2–9.
64. Kinsel, R. P., & Lin, D. (2009). Retrospective analysis of prosthetic maintenance of implant-supported overdentures. *International Journal of Oral & Maxillofacial Implants, 24*(5), 873–878.
65. Goodacre, C. J., Bernal, G., Rungcharassaeng, K., & Kan, J. Y. K. (2003). Clinical complications with implants and implant prostheses. *The Journal of Prosthetic Dentistry, 90*(2), 121–132.
66. Chowdhary, R., & Sonnahalli, N. K. (2024). Clinical applications of T-Scan quantitative digital occlusal analysis technology: A systematic review. *International Journal of Computerized Dentistry, 27*(1), 49–86.
67. Zarb, G. A., Hobkirk, J., Eckert, S. E., & Jacob, R. F. (2013). *Prosthodontic treatment for edentulous patients* (13th ed.). Mosby.
68. Malik, A., Quadri, M. A. B., Ansari, S., & Mehmood, A. (2026). The Impact of Artificial Intelligence Modalities on Anatomy Education. *IOASD Journal of Medical and Pharmaceutical Sciences*, *3*(1), 40-44.
69. The Glossary of Prosthodontic Terms Committee. (2017). *The glossary of prosthodontic terms* (10th ed.). *The Journal of Prosthetic Dentistry, 117*(5, Suppl.), e1–e105.
70. Winkler, S. (2000). *Essentials of complete denture prosthodontics* (2nd ed.). Ishiyaku EuroAmerica.
71. Heartwell, C. M., & Rahn, A. O. (1986). *Syllabus of complete dentures* (4th ed.). Lea & Febiger.
72. Kerstein, R. B. (2011). Computerized occlusal analysis in removable prosthodontics. *Compendium of Continuing Education in Dentistry, 32*, 26–34.
73. Al Quran, F. A., et al. (2018). Digital occlusal analysis of complete denture occlusion using T-Scan technology. *Journal of Prosthodontics, 27*, 610–616.
74. Sierpińska, T., et al. (2016). Influence of computerized occlusal adjustment on masticatory efficiency in complete denture wearers. *Advances in Clinical and Experimental Medicine, 25*, 123–130.
75. Hanau, R. L. (1926). Articulation defined, analyzed and formulated. *Journal of the American Dental Association, 13*, 1694–1709.
76. McLean, T. (1990). Dynamic occlusion in complete denture prosthodontics. *The Journal of Prosthetic Dentistry, 64*, 32–38.
77. Bilhan, H., et al. (2013). Patient satisfaction and masticatory performance following occlusal adjustment of complete dentures. *Gerodontology, 30*, 314–321.
78. Feine, J. S., Carlsson, G. E., Awad, M. A., et al. (2002). The McGill consensus statement on overdentures. *The International Journal of Prosthodontics, 15*, 413–414.
79. Boucher, C. O. (1953). Occlusion for complete dentures. *The Journal of Prosthetic Dentistry, 3*, 633–643.
80. Phoenix, R. D., Cagna, D. R., & DeFreest, C. F. (2008). *Stewart's clinical removable partial prosthodontics* (4th ed.). Quintessence Publishing.
81. Jacobson, T. E., & Krol, A. J. (1983). Contemporary removable partial denture design. *The Journal of Prosthetic Dentistry, 49*, 5–15.
82. Kratochvil, F. J. (1988). *Removable partial dentures* (2nd ed.). Saunders.
83. McCracken, W. L. (2016). *McCracken's removable partial prosthodontics* (13th ed.). Elsevier.
84. Revilla-León, M., & Özcan, M. (2019). Additive manufacturing technologies used for processing polymers in prosthodontics. *Journal of Prosthodontics, 28*, 146–158.
85. Dawson, P. E. (2007). *Functional occlusion: From TMJ to smile design*. Mosby.
86. Kerstein, R. B. (2013). Computerized occlusal analysis in restorative dentistry. *Dental Today, 32*, 86–91.
87. Magne, P., & Belser, U. C. (2002). *Bonded porcelain restorations in the anterior dentition*. Quintessence Publishing.
88. Güth, J. F., & Keul, C. (2016). Digital restorative workflow and occlusal integration. *International Journal of Computerized Dentistry, 19*, 7–19.
89. Bathiya, A., et al. (2020). Evidence-based applications of T-Scan in restorative dentistry. *The Journal of Indian Prosthodontic Society, 20*(Suppl. 1), S37–S44.
90. Maness, W. L., & Podoloff, R. (1989). Distribution of occlusal contacts in maximum intercuspation. *The Journal of Prosthetic Dentistry, 62*(2), 238–242.

91. Chen, Y. J., Yao, C. C., Chang, Z. C., et al. (2023). Occlusal function and electromyographic activity of masticatory muscles in skeletal class III patients with different patterns of mandibular asymmetry. *Journal of Oral Rehabilitation, 50*(4), 276–285.
92. Zhang, R., Hao, X., & Zhang, K. (2023). Evaluation of two different occlusal patterns on single posterior implant-supported crowns: A 12-month prospective study of occlusal analysis. *The Journal of Prosthetic Dentistry*. Advance online publication.
93. Kerstein, R. B., Lowe, M., Harty, M., & Radke, J. (2006). A force reproduction analysis of two recording sensors of a computerized occlusal analysis system. *CRANIO®, 24*(1), 15–24.
94. Trpevska, V., Kovacevska, G., Benedeti, A., & Jordanov, B. (2014). T-Scan III system diagnostic tool for digital occlusal analysis in orthodontics: A modern approach. *Prilozi, 35*(2), 155–160.
95. Wiechens, B., Brockmeyer, P., Wassmann, T., Rödiger, M., Wiessner, A., & Bürgers, R. (2022). Time of day-dependent deviations in dynamic and static occlusion: A prospective clinical study. *The Journal of Prosthetic Dentistry*. Advance online publication.
96. Floriani, F., Sabatini, G. P., Oliveira Dos Santos, T. T., Philippi, A. G., Gonzaga, L. H., & Mezzomo, L. A. (2022). Digital and analog analysis of occlusion in conventional and implant-retained complete dentures: Preliminary results of a prospective clinical trial. *The International Journal of Prosthodontics, 35*(1), 27–36.
97. Wang, Q., Zhao, Z., Zhou, M., et al. (2022). In vivo evaluation of the reliability and validity of three digital occlusion analysis methods. *Journal of Dentistry, 127*, Article 104355.
98. Bozhkova, T., Musurlieva, N., & Slavchev, D. (2021). Comparative study of qualitative and quantitative techniques in the study of occlusion. *BioMed Research International, 2021*, Article 1163874.
99. Bostancıoğlu, S. E., Toğay, A., & Tamam, E. (2022). Comparison of two different digital occlusal analysis methods. *Clinical Oral Investigations, 26*(2), 2095–2109.
100. Fraile, C., Ferreiroa, A., Romeo, M., Alonso, R., & Pradíes, G. (2022). Clinical study comparing the accuracy of interocclusal records digitally obtained by three different devices. *Clinical Oral Investigations, 26*(2), 1957–1962.
101. de Vet, H. C. W., Terwee, C. B., Mokkink, L. B., & Knol, D. L. (2011). *Measurement in medicine*. Cambridge University Press.
102. Mokkink, L. B., Terwee, C. B., Patrick, D. L., et al. (2010). The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. *Journal of Clinical Epidemiology, 63*(7), 737–745.
103. Edher, F., Hannam, A. G., Tobias, D. L., & Wyatt, C. C. L. (2018). The accuracy of virtual interocclusal registration during intraoral scanning. *The Journal of Prosthetic Dentistry, 120*(6), 904–912.
104. Baba, K., Tsukiyama, Y., & Clark, G. T. (2000). Reliability, validity, and utility of various occlusal measurement methods and techniques. *The Journal of Prosthetic Dentistry, 83*(1), 83–89.
105. Gurdsapsri, W., Ai, M., Baba, K., & Fueki, K. (2000). Influence of clenching level on intercuspal contact area in various regions of the dental arch. *Journal of Oral Rehabilitation, 27*(3), 239–244.
106. Yamashita, S., Igarashi, Y., & Ai, M. (2002). Tooth contacts at the mandibular retruded position: Comparison of two different methods for bite registration. *Journal of Oral Rehabilitation, 29*(9), 823–826.
107. Sakaguchi, R. L., Anderson, G. C., & DeLong, R. (1994). Digital imaging of occlusal contacts in the intercuspal position. *Journal of Prosthodontics, 3*(4), 193–197.
108. Lu, B., Shao, L., & Yu, Q. (2023). Effect of different occlusal forces on the accuracy of interocclusal records of loose teeth. *Journal of Oral Rehabilitation, 50*(7), 548–554.
109. Ayuso-Montero, R., Mariano-Hernandez, Y., Khoury-Ribas, L., Rovira-Lastra, B., Willaert, E., & Martinez-Gomis, J. (2020). Reliability and validity of T-Scan and 3D intraoral scanning for measuring the occlusal contact area. *Journal of Prosthodontics, 29*(1), 19–25.
110. Hazra, A., & Gogtay, N. (2016). Biostatistics series module 6: Correlation and linear regression. *Indian Journal of Dermatology, 61*(6), 593–601.
111. Huang, Y. F., Wang, C. M., Shieh, W. Y., Liao, Y. F., Hong, H. H., & Chang, C. T. (2022). The correlation between two occlusal analyzers for the measurement of bite force. *BMC Oral Health, 22*, Article 472.
112. Kerstein, R. B., & Radke, J. (2014). Clinician accuracy when subjectively interpreting articulating paper markings. *CRANIO®, 32*(1), 13–23.
113. Bozhkova, T., Musurlieva, N., Slavchev, D., Dimitrova, M., & Rimalovska, S. (2021). Occlusal indicators used in dental practice: A survey study. *BioMed Research International, 2021*, Article 2177385.
114. Qadeer, S., Yang, L., Sarinnaphakorn, L., & Kerstein, R. B. (2016). Comparison of closure occlusal force parameters in post-orthodontic and non-orthodontic subjects using T-Scan® III DMD occlusal analysis. *CRANIO®, 34*(6), 395–401.
115. Qadeer, S., Abbas, A. A., Sarinnaphakorn, L., & Kerstein, R. B. (2018). Comparison of excursive occlusal force parameters in post-orthodontic and non-orthodontic subjects using T-Scan® III. *CRANIO®, 36*(1), 11–18.
116. Agbaje, J. O., Casteele, E. V., Salem, A. S., et al. (2017). Assessment of occlusion with the T-Scan system in patients undergoing orthognathic surgery. *Scientific Reports, 7*, Article 5356.

117. Yu, W., Chen, S., Li, X., Ma, X., & Xu, X. (2021). Evaluation of 1-piece versus 3-piece framework designs for the edentulous mandible with fixed implant-supported prostheses: A clinical, occlusal, and biomechanical study. *Journal of Prosthodontics, 30*(4), 290–297.
118. Shiga, H., Komino, M., Yokoyama, M., et al. (2023). Relationship between age and occlusal force in adults with natural dentition. *Odontology, 111*(2), 487–492.
119. Lee, C. H. J., Vu, H., & Kim, H. D. (2021). Gender and age group modified association of dental health indicators with total occlusal force among Korean elders. *BMC Oral Health, 21*, Article 571.
120. Hama, Y., Hosoda, A., Kubota, C., et al. (2022). Factors related to masticatory performance in junior and senior high school students and young adults: A cross-sectional study. *Journal of Prosthodontic Research, 67*, 424–429.
121. Koos, B., Godt, A., Schille, C., & Göz, G. (2010). Precision of an instrumentation-based method of analyzing occlusion and its resulting distribution of forces in the dental arch. *Journal of Orofacial Orthopedics, 71*(6), 403–410.
122. de Prado, I., Iturrate, M., Minguez, R., & Solaberrieta, E. (2018). Evaluation of the accuracy of a system to align occlusal dynamic data on 3D digital casts. *BioMed Research International, 2018*, Article 8079089.
123. Jeong, M. Y., Lim, Y. J., Kim, M. J., & Kwon, H. B. (2020). Comparison of two computerized occlusal analysis systems for indicating occlusal contacts. *The Journal of Advanced Prosthodontics, 12*(2), 49–54.
124. Heuser, F., Bourauel, C., Stark, H., & Dörsam, I. (2020). Clinical investigations of the comparability of different methods used to display occlusal contact points. *International Journal of Computerized Dentistry, 23*(3), 245–255.
125. Cerna, M., Ferreira, R., Zaror, C., Navarro, P., & Sandoval, P. (2015). Validity and reliability of the T-Scan® III for measuring force under laboratory conditions. *Journal of Oral Rehabilitation, 42*(7), 544–551.
126. Nishimori, H., Iida, T., Kamiyama, H., et al. (2017). Comparing the occlusal contact area of individual teeth during low-level clenching. *Journal of Oral Science, 59*(3), 337–342.
127. DeLong, R., Knorr, S., Anderson, G. C., Hodges, J., & Pintado, M. R. (2007). Accuracy of contacts calculated from 3D images of occlusal surfaces. *Journal of Dentistry, 35*(6), 528–534.
128. Choi, T. H., Kim, B. I., Chung, C. J., et al. (2015). Assessment of masticatory function in patients with non-sagittal occlusal discrepancies. *Journal of Oral Rehabilitation, 42*(1), 2–9.
129. Lepidi, L., Galli, M., Mastrangelo, F., et al. (2021). Virtual articulators and virtual mounting procedures: Where do we stand? *Journal of Prosthodontics, 30*(1), 24–35.
130. Wiens, J. P., & Priebe, J. W. (2014). Occlusal stability. *Dental Clinics of North America, 58*, 19–43. https://doi.org/10.1016/j.cden.2013.09.014
131. Zhao, Z., Wang, Q., Li, J., Zhou, M., Tang, K., Chen, J., & Wang, F. (2023). Construction of a novel digital method for quantitative analysis of occlusal contact and force. *BMC Oral Health, 23*, Article 190. https://doi.org/10.1186/s12903-023-02899-y
132. Kordaß, B., Amlang, A., Hugger, A., Behrendt, C., & Ruge, S. (2022). Number and localization of occlusal contact areas on natural posterior teeth without dental findings: Evaluations of the regional baseline study (SHIP-1) with the Greifswald Digital Analyzing System (GEDAS). *International Journal of Computerized Dentistry, 25*, 47–56.
133. Lee, H. S., Ko, K. H., Huh, Y. H., Cho, L. R., & Park, C. J. (2022). Correlation between occlusal contact area at various levels of interocclusal thicknesses and masticatory performance. *Journal of Oral Rehabilitation, 49*, 522–528. https://doi.org/10.1111/joor.13292
134. Skármeta, N. P. (2017). Occlusal stability and mandibular stability: The major part of dentistry we are still neglecting. *CRANIO®, 35*, 201–203. https://doi.org/10.1080/08869634.2017.1329686
135. Christensen, G. (2004). Is occlusion becoming more confusing? A plea for simplicity. *Journal of the American Dental Association, 135*, 767–768. https://doi.org/10.14219/jada.archive.2004.0305
136. Christensen, G. J. (2005). The major part of dentistry you may be neglecting. *Journal of the American Dental Association, 136*, 497–499. https://doi.org/10.14219/jada.archive.2005.0206
137. Gu, D. A., Miao, L. Y., & Liu, C. (2022). Application of digital occlusion analysis system in stomatological clinical medicine. *Austin Journal of Dentistry, 9*, 1164.
138. Stoica, E. T., Marcauteanu, C., Tudor, A., Duma, V. F., Amaricai, E. C., Onofrei, R., Suciu, O., Negrutiu, M. L., & Sinescu, C. (2022). Influence of the text neck posture on the static dental occlusion. *Medicina, 58*, Article 1303. https://doi.org/10.3390/medicina58091303
139. Hiroshi, S., Marie, K., Hanako, U., Mako, S., Masaoki, Y., Kunihisa, N., & Ayano, I. (2020). Comparison of two dental prescale systems used for the measurement of occlusal force. *Odontology, 108*, 676–680.
140. Okada, Y., Sato, Y., Kitagawa, N., Uchida, K., Osawa, T., Imamura, Y., & Terazawa, M. (2015). Occlusal status of implant superstructures at mandibular first molar immediately after setting. *International Journal of Implant Dentistry, 1*, Article 16. https://doi.org/10.1186/s40729-015-0016-0
141. Bostancıoğlu, S. E., Toğay, A., & Tamam, E. (2022). Comparison of two different digital occlusal analysis methods. *Clinical Oral Investigations, 26*, 2095–2109. https://doi.org/10.1007/s00784-021-04191-1.