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The clinical value of digital occlusal analysis in the treatment of patients with temporomandibular disorders. A review of the literature

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Abstract: Temporomandibular disorders (TMD) are a muscular subset of temporomandibular joint disorders, that can cause orofacial pain. They can be triggered by overactive masticatory muscles due to prolonged disclusion times (DT), occlusal interferences, and occlusal surface friction. Regarding diagnostics, digital occlusal analysis systems are used to determine the parameters of opposing tooth contact and pressure, the ratio of forces on the right and left sides of the oral cavity, to accurately calculate disclusion and occlusion times, and to precisely measure resultant force during maximum and partial intercuspidation. Even though they can be an appropriate tool in modern orthodontic and prosthodontics treatments, these methods are rarely used for patients undergoing multidisciplinary treatment. The aim of this review was to summarize the current knowledge on the clinical application of digital occlusal analysis in the treatment of temporomandibular joint disorders using next-generation systems (T-Scan Novus III, Occlusense) and to identify future research directions for the use of this technology.

Keywords: temporomandibular disorders, TMD, bruxism, digital occlusal analysis, T-Scan Novus.

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Introduction

Temporomandibular disorders (TMD) are a muscular subset of temporomandibular joint disorders that can cause orofacial pain [1]. The range of pain symptoms can be broad, encompassing both pain triggered solely by palpation or associated with lower jaw movements, as well as

spontaneous pain, often accompanied by radiating discomfort [2]. The symptoms can be triggered by overactive masticatory muscles due to prolonged disclusion times (DT), occlusal interferences, and occlusal surface friction that occur during mandibular excursive movements [3–5]. Occlusal disturbances, in turn, have a significant impact on TMD [6].

Regarding diagnostics, in a daily dental practice, articulating paper is a commonly used method for occlusion control [7]. However, its use only allows for the checking of opposing tooth contacts without providing additional data, and it carries a high margin of false-positive results [8–10]. Electronically measured, computer-assisted analysis of maximum intercuspidation, along with a substantial amount of data regarding the spatial relationship between the maxilla and mandible, is an appropriate tool in orthodontic and prosthodontics treatments [11, 12]. Digital occlusal analysis systems effectively highlight issues related to prolonged DT, occlusal interferences, and occlusal surface friction, allowing for their simple and effective elimination [13]. These data are essential in modern diagnostics and treatment, particularly for conditions, such as bruxism, characterized by clenching and grinding, often driven by psychological, emotional, and stress-related factors [14, 5]. Current treatment methods for bruxism include physiotherapy, splint therapy, traditionally performed in the laboratory based on impressions or designed and printed using the CAD CAM method [15–17], psychotherapy and eventually treatment with botulinum toxin type A.

During the treatment of patients suffering from TMD, including bruxism, shortening the DT can bring measurable benefits. As noted by Kerstein, reducing DT through enameloplasty has shown a significant relief in muscle pain, particularly in the masseter and temporal muscles, as well as other craniofacial structures in many patients [13]. Disclusion time reduction (DTR) is an objective treatment protocol that utilizes digital occlusal analysis and electromyography to treat occlusally activated craniofacial pain [18]. DTR therapy involves shortening the pre-treatment prolonged DT to a short DT through direct enameloplasty, guided by occlusion and disclusion time analysis, as well as force synchronized with electromyographic recordings of the stomatognathic system muscles [4, 6, 19]. The latest generation of digital occlusal analysis systems (T-Scan III Novus, Occlusense) are used to determine the parameters of opposing tooth pressure, the ratio of forces on the right and left sides of the oral cavity, to accurately calculate disclusion and occlusion times, and to precisely measure resultant force during maximum and partial intercuspidation [4]. The systems directly calculate and clearly present the disclusion and occlusion time, measured in seconds. The time graph accurately displays the first and last contact of opposing teeth down to thousandths of a second, along with the minimal force of tooth contact [20, 11]. Digital occlusal analysis systems, such as T-Scan Novus or Occlusense, are also becoming excellent tools for assessing the accuracy and effectiveness of relaxation splints in treatment [21].

Despite technological advancements in modern dentistry, digital occlusal analysis remains a rarely used diagnostic tool for patients undergoing multidisciplinary treatment. The aim of this review was to summarize the current knowledge on the clinical application of digital occlusal analysis in the treatment of temporomandibular joint disorders using next-generation systems (T-Scan Novus III, Occlusense) and to identify future research directions for the use of this technology.

From all identified studies (1205), 9 publications from the PubMed and Cochrane database from the period 2000–2024 were selected and analyzed, as they met the inclusion criteria. The keywords used included: "digital analysis of occlusion," "T-Scan Novus," "disclusion time reduction therapy," "temporomandibular disorders."

A detailed description of the analyzed articles in this review is summarized in Table 1.

Table 1. A detailed description of the analyzed articles containing data on the use of T-Scan Novus in TMD diagnosis and therapy.

Reference	Analyzed parameters	Used treatment method	Comparators (number of patients)	Results
Bozhova [22]	OT, DT	none	patients with bruxism (21) vs healthy controls (13)	longer OTs in a control group compared to the bruxism group, shorter DTs in a control group compared to the bruxism group
Nota [23]	OT	none	military pilots with bruxism (14) vs healthy controls (14)	shorter mean OT in subjects with bruxism compared to control subjects
Vlădutu [24]	static and dynamic occlusion, masticatory muscles assessment	none	subjects with bruxism (20) vs healthy subjects (20)	a moderate positive correlation between occlusal force values in MIP across both dental arches and the frequency of daytime grinding events, Participants with anterolateral guidance showed higher awake bruxism indexes and more clenching events at night. The bruxism group exhibited longer durations for all three mandibular movements
Gümüş [21]	OT, DT, left-right and anterior-posterior contact distributions	full-arch maxillary stabilization splint	bruxism patients (20) vs controls (20)	no differences in the posterior contact of bruxism patients before and after treatment, differences in posterior contact were noted between bruxists and non-bruxists before treatment, but these differences disappeared after treatment
Shopova [25]	OT, DT, occlusal contacts	3D printed stabilization splint	1 (case report)	proper articulation of the 3D printed stabilization splint
Thanathornwong [26]	occlusal force	canine-protected hard stabilization splints	participants with sleep bruxism (30)	a high level of agreement between the occlusal force measured with T-Scan III and the force predicted by the model
Bozhkova [27]	occlusal contacts	splint therapy	15 patients with bruxism	split adjustment
Thumati [28]	DT, closure-into-MIP, right, left, and protrusive excursions pre- and post-treatment/ placebo	ICAGD vs placebo	100 students with a history of TMD randomized into 2 groups	Before treatment, DT and symptom scales were similar between the groups. After 1 week, all three measures decreased in the treatment group and continued to decline over six months. Symptom frequency, functional restrictions, and pain were initially higher in the treated group but reduced after ICAGD compared to the controls.

Reference	Analyzed parameters	Used treatment method	Comparators (number of patients)	Results
Thumati [19]	OT, DT, tooth contact sequence, changing occlusal forces, fluctuating muscle activity levels of the temporalis and masseter muscle	ICAGD	100 patients with myofascial pain	reduction of symptom in a one week, no recurrence was seen in 3 years

OT — occlusion time, DT — disocclusion time, MIP — maximum intercuspidal position, ICAGD — Immediate Complete Anterior Guidance Development

Clinical decision-making improvement in TMD with T-Scan Novus application

As mentioned before, the new digital occlusal analysis systems efficiently identify problems associated with extended disclusion time, occlusal interferences, and surface friction, enabling their effective resolution [13]. In Bozhkova study, the aim was to evaluate and compare the occlusion and disocclusion times between young adults with bruxism and those without this disorder. Analysis was performed among thirty-four patients (group 1–13 controls, group 2–21 symptomatic subjects) and occlusion and disclusion times were performed with the use of T-Scan Novus occlusion diagnostic device. Results showed that the occlusion times in the control group were observed to be longer compared to the bruxism group. Additionally, the disocclusion times in group 1 were found to be shorter than those recorded in group 2. This study suggested that assessing of occlusion and disclusion times can help with the diagnosis of early-stage bruxism in younger individuals [22]. The application of the T-Scan computerized occlusal analysis system (Tek-Scan Inc.) to assess occlusion times during 4 mandibular opening-closing movements was also employed in a case-control study comparing military pilots with bruxism symptoms to a healthy control group [23]. The study indicated that military pilots affected by bruxism presented a statistically significant lower mean occlusion time, compared with control subjects.

The literature also describes the use of T-Scan Novus in the bruxism diagnosis utilizing the tool dia-BRUXO. In the study by Vlădutu *et al.*, the occlusal relationships were assessed in students with bruxism by employing the T-Scan III system and examined their correlation with masticatory muscle activity measured through surface electromyography (sEMG). Results validated the effectiveness of sEMG recordings in diagnosing bruxism and highlighted the relationship between dental occlusion and bruxism [24].

The latest systematic review about applications of T-Scan in various dental practice disciplines summarized the knowledge on the use of this technology also in the diagnosis of TMD [29]. The authors cited studies on the application of older version of T-Scan in the measurable simultaneous occlusal contact assessment, showing that time-related occlusal discrepancies were contributory to temporomandibular joint intracapsular disease [30]. This systematic review cited also two studies which separately found with the use of T-Scan II and III that the occlusion time and DT were

significantly longer in patients with TMD compared to healthy individuals [3, 31]. The researchers suggested that the extended durations of occlusion time and DT could be contributing factors to TMD, as they lead to repeated microtrauma in the masticatory muscles due to prolonged tooth contact during closures or extended friction during excursions. The T-Scan III was also applied in the study by Gümüş *et al.* which indicated that individuals with bruxism predominantly exhibited occlusal contacts located in the posterior region, with a higher frequency compared to healthy individuals [21].

Use of T-Scan Novus in splint therapy

The application of splint therapy for bruxism treatment facilitates the normalization of the vertical dimension of occlusion (VDO), promotes the medialization of the mandible to adjust the condyle's position within the joint fossa, and aids in disc release, while also establishing a balanced and stable occlusal relationship for the mandible [32, 33]. As a forward-looking and promising application, utilizing digital technology may enable creation of more accurate constructs and facilitate the precise adjustment of occlusal relationships. In one case report about 56-year-old female patient with bruxism, T-Scan Novus system was used for digital examination of the occlusion which enabled the proper articulation of the 3D printed stabilization splint [25]. In the context of estimating occlusal force, in a study about created clinical decision support model, 30 participants with sleep bruxism were enrolled to treat with canine-protected hard stabilization splints and the occlusal forces were measured using T-Scan III. A strong correlation was observed between the occlusal force measured in patients with T-Scan III and the occlusal force estimated by the model. The findings indicate that the multiple regression model effectively predicts occlusal force based on the digital measurements of the size and color of articulating paper markings in individuals with bruxism [26]. In a study which aimed to identify the differences in occlusal changes between individuals with bruxism and healthy individuals when using a full-arch maxillary stabilization splint, T-scan III was used to assess occlusion and disclusion times, along with the left-right and anterior-posterior contact distributions, both prior to splint therapy and three months following the treatment. Authors concluded that no differences were detected in the posterior contact of bruxism patients before and after receiving stabilization splint therapy. However, a distinction in posterior contact was noted between bruxists and healthy individuals prior to the treatment, which was no longer present after the intervention [21]. T-Scan Novus was also applied in one pilot study for digital examination of the occlusion and split adjustment in 15 patients with bruxism, showing once again the validity of using this technology in such therapy [27].

Enameloplasty and future directions for the use of T-Scan Novus in procedure execution

The T-Scan system, along with the measurement-driven occlusal adjustment technique known as Immediate Complete Anterior Guidance Development (ICAGD), is a clinically recognized procedure that facilitates rapid and lasting relief from muscular dysfunction symptoms in TMD patients, all without necessitating the use of any appliances, deprogrammers, orthotics, or splints [13, 18, 19, 34]. Kerstein observed that decreasing DT through enameloplasty has led to considerable relief from muscle pain, especially in the masseter and temporal muscles, along with other craniofacial areas, in numerous patients [13]. In a recent multi-center randomized controlled study on

the use of DTR among one hundred students with a history of chronic muscular myofascial pain dysfunction symptoms, ICAGD reduced pain, symptom frequency, functional restrictions and emotional depression within 1 week, which continued for 6 months. In this study, T-Scan Novus/EMG was applied to record pretreatment or pre-placebo multi-bite closure-into-MIP (Maximum Intercuspal Position) data, and the right, left, and protrusive excursions of all subjects. Moreover, it was used to assess pre-treatment DT values for comparison to the post-ICAGD coronoplasty values in the treated group, and for post-placebo polishing comparison in the controls. The technology enabled to perform the same ICAGD procedure on separate subject groups in different cities [28]. The value of using T-Scan during the ICAGD procedure was also confirmed in the study by Thumati, which aimed to evaluate the effect of occlusal equilibration using ICAGD on the subjective symptoms of myofascial pain. The author confirmed that symptoms diminished within a week, as evaluated by the ordinal scale and that occlusal equilibration through digital analysis with T-Scan, which quantifies force relative to time, should be performed to ensure smooth, interference-free functional movements [19].

Conclusions

Even though digital occlusal analysis can be an appropriate tool in a modern treatment of patients with TM, these methods are rarely used for patients undergoing multidisciplinary treatment and the validation of their use is based on limited literature particularly in the context of modern treatment methods such as direct enameloplasty. Studies have demonstrated the utility of the T-Scan system, from its early versions to the latest T-Scan Novus, in assessing prolonged disclusion time, occlusal interferences, and occlusal surface friction, enabling their simple and effective elimination through various traditional and modern treatment techniques. With now available results of the randomized study on the use of T-Scan Novus/EMG in the ICAGD procedure, establishing the position of this technology in performing direct enameloplasty requires conducting additional similar prospective studies. Certainly, T-Scan Novus enhances both occlusal diagnosis and treatment by replacing the subjective nature of traditional occlusal analysis with precise, measurable metrics for occlusal force and timing.

Disclosures

Authors' contribution: conceptualization, W.M., M.P.; methodology, W.M., M.P.; formal analysis, W.M., W.C.; investigation, W.M., W.C., M.S., M.P.; data curation, W.M., W.C., M.S.; writing — original draft preparation, W.M., W.C., M.S., M.P.; writing — review and editing, W.M., M.S., M.P..; supervision, M.P.; project administration, W.M.

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Conflict of interest

None declared.

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