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Original Article

Dentistry Section

Effectiveness of T-Scan Technology in Identifying Occlusal Interferences and its Role in the Management of Temporomandibular Disorders: A Systematic Review

POOJA UCHALE[1], SURYAKANT DEOGADE[2], ARUN KHALIKAR[3], SATTYAM WANKHADE[4], SUKRIT TANEJA[5], SAMIKSHA LALSARE[6]

ABSTRACT

Introduction: Occlusion is a significant issue that affects the masticatory system's health. Temporomandibular Disorders (TMD) have long been linked to occlusal interferences. Identification and management of such disorders using a T-scan-guided approach have been gaining popularity; however, the effectiveness is still not established.

Aim: To evaluate the effect of T-scan on the reduction of Visual Analogue Scale (VAS) scores of pain and improvement in the symptoms associated with TMD. The benefits of reducing Disocclusion Time (DT) were also evaluated.

Materials and Methods: The Medical Literature Analysis and Retrieval System Online (MEDLINE) database via PubMed and Excerpta Medica Database (EMBASE) were searched for studies reporting the use of T-scan in Temporomandibular Joint (TMJ) disorders to check the DT and patient-related outcomes. The search was performed from January 1991 to November 2022. A total of 10 studies were included in the systematic review, which includes clinical studies, observational studies, and interventional studies. Data extraction was performed, and risk of bias assessment was done using the Newcastle-Ottawa scale (NOS) for non randomised studies, and the Cochrane tool was utilised for randomised clinical trials. A qualitative analysis of all the studies was carried out.

Results: The T-scan-guided occlusal correction or equilibration procedures led to improvement in subjective symptoms and VAS in TMD patients. Reduction in DT positively affected muscle activity, causing relief of chronic symptoms.

Conclusion: As per the findings of the present review, T-scan technology can be successfully used in the precise identification and diagnosis of occlusal discrepancies in patients suffering from myofascial symptoms.

Keywords: Myofascial pain management, Occlusal equilibration in temporomandibular disorders, Occlusion

INTRODUCTION

A balance among the teeth, periodontium, masticatory muscles, and TMJ is crucial for the proper functioning of the masticatory system [1,2]. Premature occlusal contacts and interferences can lead to changes in the masticatory system [3]. The term "occlusal interferences" [3] is used for any undesirable contacts that impede the smooth movements of the mandible. Such interferences are known to cause muscle imbalance, excessive forces in the TMJ, and inflammation, potentially leading to joint instability and TMD. There is also a negative effect on the involved teeth as they are subjected to excessive forces in a direction outside of their long axis [4].

The TMD encompasses various clinical problems involving the muscles of mastication, TMJ, and related structures [5]. Signs and symptoms of TMD may include pain, impaired function, malocclusion, asymmetry, restricted range of motion, articulation noise, and locking. The treatment of TMD is extensive and depends on the diagnosis. Treatment options can be non invasive, such as occlusal splint therapy, massage therapy, pharmacotherapy, etc., as well as invasive, such as surgical intervention [6].

Occlusal assessment as part of the initial oral examination to identify and rule out severe unintended occlusal deviations is considered essential [7]. The causal relationship between occlusal factors and TMD is still not firmly established. Malocclusion is defined as any deviation from acceptable contact with the dentition or normal occlusion. The relationship between malocclusion and TMDs is complex and remains an area of ongoing research and debate [8]. However, Mohlin B and Kopp S suggested that TMD patients had a higher incidence of non working side contact compared to the non patient group [9]. In routine practice, the diagnosis of TMD largely depends on a careful history and clinical examination [10].

The static relationship between teeth is commonly studied using occlusal paper, shim stocks, occlusal wax, and silicone impressions [4]. Temporomandibular imaging has limitations concerning reliability mainly due to the complex anatomy of the joint and associated false positive results [11].

The aetiology of TMD is multifaceted, among which occlusion can be a significant factor [12]. Thus, a good understanding of the role of dynamic occlusion is essential [13]. Manes developed a computerised system called T-scan [14], which allows clinicians to quantitatively assess occlusal contact during movements [13]. The T-scan I technique was introduced to the TMD field in 1984, supporting the causal relationship of occlusion to TMD. As the T-test-I could measure the degree of occlusal contact timing sequences in 0.01s, a new occlusal functional movement parameter known as posterior DT was isolated [14,15].

The T-scan technology has been shown to provide better occlusal therapy [14] compared to procedures controlled by subjective interpretation [16]. The T-scan system provides an accurate way to convert occlusal timing and force of exposure into quantitative data [17]. DT is the time in seconds, measured from a shifted movement in one direction (right, left, or forward) with all teeth fully shifted until only the canines and/or incisors are in contact [18]. Research suggests that prolonged DT may be a trigger for muscle hyperactivity and TMD symptoms [14,19,20].

The T-scan III/BioEMG synchronisation facilitated the recording of dynamic occlusal contact information with corresponding muscle activity response [21]. A significantly higher frequency of premature contact and prolonged DT and OT is found in TMD patients in studies [22]. A study by Thumati P and Thumati RP assessed the impact of occlusal equilibration using the Immediate Complete Anterior Guidance Development (ICAGD) approach on the subjective signs of myofascial pain. They concluded that occlusal equilibration leads to the alleviation of signs in approximately a week to ten days [23]. The ICAGD protocol reduces the signs of Myofascial Pain Dysfunction Syndrome (MPDS) due to decreased DT in lateral excursions and shows improvement in pain [24].

The purpose of the present systematic review was to evaluate and assess the effect of T-scan on the reduction of the Visual Analogue Scale (VAS) score of pain and improvement in the symptoms associated with TMD, as well as the effect of the reduction in DT.

MATERIALS AND METHODS

It was conducted according to the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) protocols statement. The protocol was registered at PROSPERO International Prospective Register of Systematic Reviews (CRD42022343742).

Focused question: How effective is T-scan in improving symptoms and reducing DT by occlusal interference analysis in patients with TMJ disorders?

The Population, Intervention, Comparisons, and Outcomes (PICO) were defined for the study [Table/Fig-1].

Parameters	Electronic databases	Search strategy
Population/ Participants	Adult patients suffering from unilateral or bilateral Temporomandibular Joint (TMJ) disorders.	#1 {"TMD" (MeSH Terms)} OR {"TMJ disorder" (Title/Abstract)} OR {"TMD patients" (Title/Abstract)} OR {"Temporomandibular disease" (Title/Abstract)} OR {"Myofascial pain" (Title/Abstract)} OR {"Myofascial Pain Dysfunction Syndrome (MPDS)" (Title/Abstract)}
Intervention	Use of T-scan in TMJ disorders, MPDS	#2 {"T-scan" (MeSH Terms)} OR {"T-scan system" (All Fields)} OR {"T-scan technology" (All Fields)} OR {"T-scan-guided ICAGD" (Title/Abstract)}
Comparison	Adult patients suffering from unilateral or bilateral TMJ disorders.	Not relevant
Outcome	**Primary outcome:** Reduction in the VAS score of pain and improvement in symptoms associated with the TMD.	#3 {"disocclusion time (DT)" (All Fields)} OR {"pain scores" (All Fields)} OR {"pain intensity" (All Fields)} OR {"VAS score" (All Fields)}
	Additional/Secondary outcomes: Benefits of reduction in DT.	
Study design		Randomised Control Trial (RCT) Quasi-experimental studies Non RCT Cross-sectional studies
Final search strategy		#1 AND #2 AND #3 (free full texts)

[Table/Fig-1]: Population, Intervention, Comparisons, Outcomes (PICO) along with electronic databases and search strategies.

Inclusion criteria:

- Clinical studies using T-scan in TMD patients.
- Articles published from January 1991 to November 2022.
- Published English language articles.

Exclusion criteria:

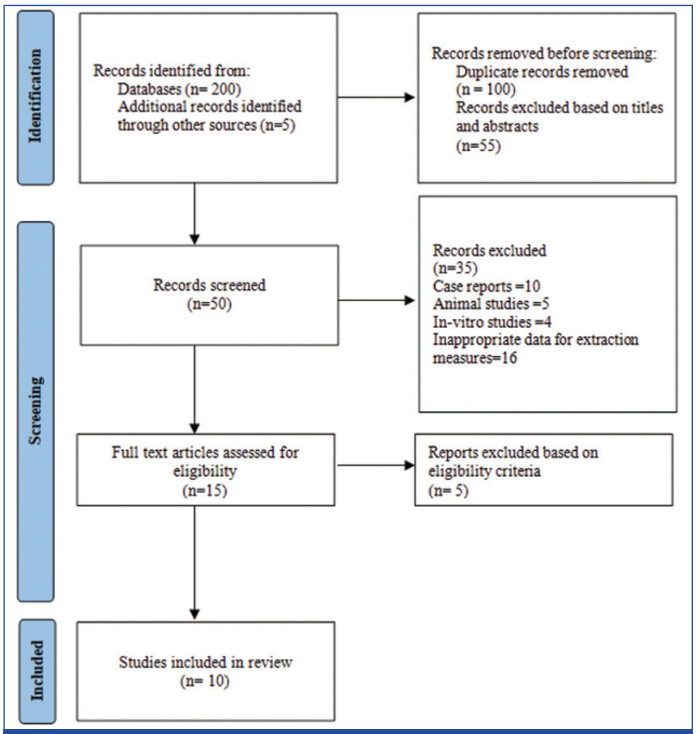
- Animal studies, in-vitro studies.
- Case reports and case series.
- Narrative review.
- Articles with incomplete data.

Information Sources

Electronic databases: The MEDLINE database via PubMed, Google Scholar, and Scopus were searched for studies reporting the use of T-scan in TMJ disorders to check the DT and patient-related outcomes. The search was performed from January 1991 to November 2022.

Search Strategy: The search was conducted separately by two reviewers (PU and SD). Boolean operators, keywords, and controlled terms {Medical Subject Headings (MeSH)} were combined whenever possible. Relevant keywords with Boolean operators were also used to search articles. A comprehensive description of the search strategy is provided in [Table/Fig-1].

Study Selection: Two researchers independently conducted the initial screening of the title and abstract based on the inclusion criteria after eliminating duplicate records. In cases of discrepancies, a third reviewer facilitated a consensus discussion to resolve them. Inter-reviewer agreement was measured using Cohen's kappa, which was calculated to be 0.85. The PRISMA flowchart in [Table/Fig-2] summarises the study selection process in detail. Subsequently, the selected studies underwent validity assessment and data extraction.



[Table/Fig-2]: PRISMA flow diagram showing the inclusion and exclusion of studies.

Data Extraction

Data extraction was independently performed by two reviewers who were blinded to each other. A third review author was consulted to resolve disagreements. The collected data was entered into the piloted data extraction sheet. Primary information extracted from the selected articles includes demographic details such as author, publication year, and country of study. Participant information encompasses study design, characteristics of the study population, and the total number of patients involved. The intervention highlighted in the studies focussed on the utilisation of T-Scan technology.

The outcomes under scrutiny include VAS scores for pain assessment, improvements in symptoms associated with TMDs, DT, and the overall study results and conclusions.

Risk of bias within studies and quality assessment: The risk of bias was assessed by two independent reviewers for non randomised studies included in the review. Discrepancies were resolved through discussion and consultation with a third reviewer using the Newcastle-Ottawa scale (NOS) [25]. Intervention and outcome measures for this study are presented in [Table/Fig-3] based on selected references [14,19,20-24,26-30]. This structured data extraction provides a comprehensive overview of the studies, aiding in understanding the relationships between demographic factors, participant characteristics, intervention methods, and reported outcomes in the context of TMDs and T-Scan technology.

A study with scores ranging from 7-9 indicates a low risk of bias, while scores below three are assigned to studies with high bias, as shown in [Table/Fig-4] [14,19,20,23-30]. Bias assessment for randomised studies was conducted using the Cochrane tool. If studies did not meet two or more of the four criteria, the risk of bias for that study was considered high. Studies were classified into low, medium, and high-risk bias categories as presented in [Table/Fig-5] [28]. This assessment suggests that the study has a low risk of bias across multiple domains, indicating that the findings are likely to be reliable and trustworthy.

S. No.	Study	T-scan system used	Intervention	Outcomes measured	Pain	Disocclusion Time (DT)	Electromyography (EMG)
1	Kerstein RB and Wright NR [14] (1991)	The Electromyography (EMG) data was collected by Midas system with M4 Myoelectric Monitor (Davicon, Inc., Burlington, Mass.)	T-scan-guided ICAGD	Assessment of symptoms of MPDS and EMG analysis pre and post treatment	NA	Pre-treatment 1.39±0.57 Post-treatment to 0.40±0.71 (p=0.0001*)	Significant improvement in muscle (p<0.05)
2	Kerstein RB and Radke J [19] (2012)	T-Scan II (Tekscan Inc., S. Boston, MA)	T-scan-guided ICAGD	- Muscle activity bilateral masseter and anterior temporalis	NA	NA	Significant muscle activity reduction in muscles post treatment.
3	Kerstein RB et al., [20] (1997)	NA	T-scan-guided ICAGD	- DT - Frequency and intensity of symptoms of MPDS	Reduction in frequency and intensity of symptoms.	Pre-treatment 1.45±0.66 Post-treatment 0.36±0.11 Post-treatment (1 month) 0.36±0.12 Post-treatment(1 year) 0.43±0.15 (p=0.05*)	NA
4	Thumati P and Thumati RP [23] (2016)	T-Scan III	T-Scan guided Immediate Complete Anterior Guidance Development (ICAGD)	- Jaw pain - Jaw fatigue - Facial tension - Difficulty in chewing/eating - Clenching - Temporal headache - Neck pain - Morning jaw pain	Significant reduction in mean intensity and frequency of myofascial pain (p<0.05)	Pre-treatment 1.963±1.08 Post-treatment 0.396±0.077 Post-treatment (1 month) 0.358±0.077 Post-treatment (1 year) 0.3444±0.077 Post-treatment (3 year) 0.319±0.058	5
5	Thumati P et al., [24] (2014)	T-Scan III	T-Scan guided Immediate Complete Anterior Guidance Development (ICAGD)	- Morning jaw pain, jaw fatigue, facial tension, difficulty in eating or chewing, clenching difficulty, temporal headaches, and neck pain - DT	Changes in median intensity values Day 1 and day 8 (p<0.05) Day 1 and 1 month (p<0.05) Day 1 and 6 months (p<0.05) Day 1 and 1 year (p<0.05)	Pre-treatment 1.99±1.21 Post-treatment 0.40±0.10 Post-treatment(1 month) 0.36±0.10 Post-treatment (1 year) 0.35±0.10 (p=0.05*)	NA
6	Thumati P et al., [26] (2021)	T-Scan computerised occlusal analysis system synchronised to the BioPAC (BioEMG III™, BioRESEARCH Assoc. Inc. Brown Deer, WI USA) and (EMG) system	T-Scan guided Immediate Complete Anterior Guidance Development (ICAGD) /DTR	- Frequency, intensity, and pain were found between the pre- and the five-year post-DTR treatment	Pre-treatment 27.77±10.20 Post-treatment 3.33 ±2.66	NA	NA
7	Ignatius AV et al., [27] (2022)	T-Scan 8 system	T-Scan guided Immediate Complete Anterior Guidance Development (ICAGD).	- VAS - DT - Force distribution pattern - TMJ sounds and mouth opening	Pre-treatment 7.31±1.63 post-treatment (1 week) 1.58±1.58 Post-treatment (1 month) 0.34±0.62 (p=0.05*)	Pre-treatment 1.71±1.09 Post-treatment 0.11±0.03 (p=0.001*)	NA
8	Thumati P et al., [28] (2020)	The T-Scan 10 computerised occlusal analysis system (Tekscan, Inc. S. Boston, MA, USA)	T-Scan guided Immediate Complete Anterior Guidance Development (ICAGD)	- 5 self-assessment scales (BDI-II, pain scale, symptom frequency, functional restriction, frequency of pain symptoms)	Significant decrease in pain at one month.	NA	NA

9	Thumati P et al., [29] (2019)	T-Scan™ III	T-Scan III guided Immediate Complete Anterior Guidance Development (ICAGD)	- VAS - Bilateral masseter and temporal muscle activity. - Relative bite force	Median symptom level after treatment (p=0.0003)	Right-side Pre-treatment 2.62±1.54 Post-treatment 0.34±0.27 Left-side Pre-treatment 2.70±1.71 Post-treatment 0.30±0.06	No Statistically significant difference in the EMG activity. (p=0.499)
10	Thumati P [30] (2015)	T-Scan III	T-Scan guided Immediate Complete Anterior Guidance Development (ICAGD)	- VAS	Reduction in pain in one week	NA	NA

[Table/Fig-3]: Intervention and outcome measures [14,19,20-24,26-30].

S. No.	Study ID	Selection				Comparability		Outcome			Total
		Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration of the outcome of interest was not present at the start of the study	Main factor	Additional factor	Assessment of outcome	Was followed-up long enough for the outcome to occur	Adequacy of follow-up	(9/9) 7-9 scores: Low risk. Between 4-6: Unclear risk. Below 3: high-risk.
1	Kerstein RB and Wright N [14] (1991)	0	0	*	*	*	0	*	0	0	4/9
2	Kerstein RB and Radke J [19] (2012)	*	*	*	*	*	0	*	0	0	6/9
3	Kerstein RB et al., [20] (1997)	0	0	*	*	*	0	*	*	*	6/9
4	Thumati P and Thumati RP [23] (2016)	*	*	*	*	*	0	*	*	*	8/9
5	Thumati P et al., [24] (2014)	*	*	*	*	*	0	*	*	*	8/9
6	Thumati P et al., [26] (2021)	*	*	*	*	*	0	*	*	*	8/9
7	Ignatius AV et al., [27] (2022)	0	0	*	*	*	0	*	0	0	4/9
8	Thumati P et al., [28] (2020)	*	*	*	*	*	0	*	0	0	6/9
9	Thumati P et al., [29] (2019)	*	*	*	*	*	0	*	0	0	6/9
10	Thumati P [30] (2015)	*	*	*	*	*	0	*	*	*	8/9

[Table/Fig-4]: Risk of bias assessment of studies included [14,19,20,23-30].
Risk of bias assessment for nonrandomised trials using New-castle Ottawa scale.
*denotes one score given for the signalling question under the respective domain.

Study	Domain	Bias Assessment	Rationale
Thumati P et al., 2020 [28]	Selection bias	Low	The study provided demographic characteristics of the sample population, minimising the risk of bias in participant selection.
	Performance bias	Low	No explicit information was provided to suggest bias in the implementation of interventions or procedures, indicating low risk of performance bias.
	Detection bias	Low	The study utilised objective measures and standardised assessments, reducing the likelihood of bias in outcome assessment.
	Attrition bias	Low	There is no indication of missing data or dropout rates, suggesting low risk of attrition bias.
	Reporting bias	Low	The study appears to have reported all relevant outcomes as described in the methods section, indicating low risk of reporting bias.
	Other bias	Low	No other sources of bias, such as conflicts of interest or funding sources were mentioned, suggesting low risk of other biases.

[Table/Fig-5]: Risk of bias assessment for RCT done using the Cochrane tool [28].

RESULTS

Study selection: Articles were selected as per the inclusion criteria by two independent reviewers. Following a thorough examination, a discussion was held during the selection process, and any discrepancies were resolved by a third reviewer. Ultimately, 10 articles were finalised for qualitative analysis. Studies were included from January 1991 to November 2022. All included studies were clinical studies involving patients [Table/Fig-6] [14,19,20,23,24,26-30]. Out of the 10 studies, one study was retrospective [26], while the other studies were prospective [14,19,20,23,24,27-30]. A study by Thumati P et al., (2020) was a randomised controlled trial [28]. Cumulative data from 527 patients was included in the present review. All studies involving patients had some or all symptoms related to TMD or myofascial pain. T-scan 8 [27], 10 [28], and T-scan III [19,23,24,29,30] were used in various included studies. Three studies [14,20,26] did not specify the T-scan used in their studies. Electromyographic analysis using BioEMG was employed in three studies [14,19,29]. VAS scores were evaluated by three studies [27,29,30]. DT pre- and post-occlusal equilibration was measured by T-scan in six studies [14,20,23,24,29]. The included studies aimed to study the effects of T-scan-guided ICAGD coronoplasty

S. No.	Study	Year	Region	Study design	Duration	No. of patients
1	Kerstein RB and Wright N [14]	1991	United States	Clinical study	NA	7
2	Kerstein RB and Radke J [19]	2012	United States	Clinical study	NA	45
3	Kerstein RB et al., [20]	1997	United States	Clinical study	6 months	25
4	Thumati P and Thumati RP [23]	2016	India	Single group interventional study	3 years	100
5	Thumati P et al., [24]	2014	India	Clinical study	1 year	51
6	Thumati P et al., [26]	2021	India	Retrospective study	5 years	30
7	Ignatius AV et al., [27]	2022	India	Prospective pilot study	1 month	15
8	Thumati P et al., [28]	2020	India	Randomised controlled trial	6 months	104
9	Thumati P et al., [29]	2019	India	Interventional study	NA	50
10	Thumati P [30]	2015	India	Clinical observational study	3 years	100

[Table/Fig-6]: Demography related to the included studies [14,19,20,23,24,26-30].

on the symptoms present in TMD or myofascial pain or to determine the relationship between DT and TMD symptoms. The available data was mostly qualitative and heterogeneous; therefore, a quantitative assessment of outcomes using meta-analysis was not performed.

Risk of bias within studies and quality assessment: Bias assessment was conducted using NOS for all studies [14,19,20,23,24,26-28,30] except for one randomised controlled study by Thumati P et al., (2019) [29]. Four studies among those included were categorised as low risk [23,24,26,30], while the remaining studies belonged to the moderate-risk category according to the Newcastle-Ottawa scale. The Thumati P et al., study (2019) [29] was identified as low risk as it fulfilled all four criteria of sequence generation, blinding, allocation concealment, and addressed outcome measures. [Table/Fig-7] displays the results and conclusions of the studies included in the systematic review.

DISCUSSION

The TMDs are a major cause of non-dental pain with a multifactorial aetiology [Table/Fig-7] [14,19,20,23,24,26-30]. These disorders mainly occur due to functional malocclusion rather than morphological malocclusion. Approximately 15-20% of adults are affected by TMDs [27]. Some authors have linked TMDs to factors like parafunctional habits [31], psychological factors [32], and postural factors [33], while others believe there is a strong association between TMD and malocclusion [13]. Diagnosis and management of these disorders always pose a challenge for clinicians, and an accurate diagnosis forms the foundation for appropriate treatment.

Modern technology like T-scan has not only enabled accurate diagnosis of occlusal discrepancies but has also established a new approach for guidance during occlusal equilibration procedures in patients suffering from TMD [27]. This systematic review aimed to evaluate the effect of T-scan on the reduction of VAS scores of pain and improvement in the symptoms associated with TMD. Secondly, the review also aimed to evaluate the reduction in disocclusion, occlusion time, and occlusal interference analysis. Clinical trials, observational, and experimental studies were included in this review. All the studies were conducted on patients exhibiting symptoms of TMD or myofascial pain. They underwent treatment with digital equilibration using the ICAGD procedure, and the post-treatment effects were evaluated. ICAGD is a procedure where coronoplasty is performed using T-scan obtained endpoints, with the right and left DT set at <0.5 seconds duration [26]. Some studies reported subjective symptoms [19,26,30], while others reported the correlation to muscle activity using electromyographic analysis [14,19,29]. The reliability of using T-scan for occlusal contact distribution has been advocated by many authors over time [1,4,34]. The overall analysis of the studies depicted the usefulness and importance of the T-scan for identifying and correcting occlusal disharmonies using ICAGD

S. No.	Study	Year	Results	Conclusion
1	Kerstein RB and Wright N [14] (1991)	1991	A highly significant reduction in DT was observed after ICAGD. Muscle function almost returned to normal in all patients. EMG analysis revealed a reduction in contractile muscle activity	Chronic muscle activity is directly proportional to DT. Symptoms associated with MPDS may be directly related to muscle spasms and fatigue. ICAGD distributes the forces of occlusion evenly throughout the occlusal table.
2	Kerstein RB and Radke J [19] (2012)	2012	Highly significant reductions were found in all four muscles' activities	The ICAGD enameloplasty significantly reduces excursive muscle contractions after ICAGD treatment.
3	Kerstein RB et al., [20] (1997)	1997	The results suggest that shortening DT can induce remissions of many muscular myofascial pain symptoms.	Myofascial muscular symptoms were reduced in frequency and intensity after the treatment.
4	Thumati P and Thumati RP [23] (2016)	2016	A statistically significant change was observed from treatment day 1, and onwards through the three years of observational period. (p<0.05)	Relief of symptoms can be obtained in about a week to 10 days after treatment.
5	Thumati P et al., [24] (2014)	2014	The changes in DT and intensity of various symptoms were statistically significant (p<0.05)	The results of this study indicate that significant muscle activity level reductions may be observed with the treatment.
6	Thumati P et al., [26] (2021)	2021	Statistically significant reduction in intensity, frequency and pain scores after 5 years. (p<0.05).	When compared to other methods, T-Scan ICAGD/DTR therapy provided considerable long-term treatment and therapeutic advantages.
7	Ignatius AV et al., [27] (2022)	2022	Statistically significant reduction in the DT, i.e., from 1.71±1.09 pre-treatment to 0.11±0.03 post-treatment (p=0.001). -Statistically significant reduction in the VAS score (p=0.001).	Significant improvement in TMD symptoms was noted. The importance of the identification and correction of occlusal interferences was emphasised.
8	Thumati P et al., [28] (2020)	2020	A significant reduction in all five reported outcome parameters (p<0.00001).	All painful symptoms show dramatic improvement within weeks after treatment.
9	Thumati P et al., [29] (2019)	2019	- DTs were significantly reduced (p=0.001) - Post-treatment subjective symptoms (p=0.0003). - The EMG activity was significantly reduced after treatment (p<0.05).	The application of ICAGD reduced: DTs, myalgic symptoms, imbalance of forces during clenching, and amount of muscular effort during lateral excursions for TMD patients.
10	Thumati P [30] (2015)	2015	Chronic symptoms showed improvement in a week.	T-Scan guided occlusal equilibration provides relief from chronic symptoms in TMD patients

[Table/Fig-7]: Results and conclusions of the studies [14,19,20,23,24,26-30].

procedures. Additionally, it was observed that T-scan-guided occlusal correction procedures performed on patients with TMD or myofascial pain led to an improvement in symptoms over a week.

VAS Score and Symptoms of TMD

Occlusal equilibration conducted with the assistance of a T-scan is effective in reducing TMD symptoms. ICAGD is one such technique that effectively reduces muscle activity [14]. Contacts during excursive movements can cause muscle spasms, fatigue, and pain. Teeth with unwanted interfering contacts act as pivots on the non working side, leading to shifting of the fulcrum from the TMJ and loss of contact of teeth on the working side. The altered lever system of the mandible causes a shift of the fulcrum to the non working side interference under the influence of the masticatory muscles. Both the joint and the teeth involved are subjected to excessive forces, potentially causing damage [3]. Coronoplasty performed to eliminate occlusal discrepancies allows for the establishment of a new, more favourable occlusal scheme for the muscles. The newly developed occlusal design helps reduce muscle activity, thereby decreasing lactic acid production and improving muscle function. Equilibration of contacts on the working and non working sides results in increased freedom in jaw movements [26].

Ignatius AV et al., assessed the VAS score for pain in the TMJ region before, 1-week post-treatment, and 1-month post-treatment for 15 patients. In this clinical trial, a significant reduction in VAS score was observed for pain in the TMJ region. These findings were consistent with a previous case study by Thumati P et al., in 2015, where the author assessed symptoms in 100 patients with myofacial pain [29]. The intensity of headaches in the temporal, masseter, and TMJ region, jaw fatigue, and night bruxism were some of the symptoms recorded on a visual ordinal scale. Similar findings were also noted by Thumati P et al., in 2019, Kerstein RB et al., in 2012, and Kerstein RB and Wright NR in 1997 [14]. EMG analysis was conducted in three studies, where a significant reduction in muscle activity was observed by Kerstein RB and Wright NR (1991) and Kerstein RB and Radke J [14,19]. However, one study by Thumati P et al., in 2019 failed to establish a significant difference in muscle activity before and after treatment [29].

Data on subjective symptoms were collected through questionnaires in five of the studies [20,23,24,26,28]. Thumati P et al., in 2019 evaluated 5 self-assessment scales (Beck Depression Inventory-II, Frequency of Pain Symptoms, Pain Scale, Functional Restriction, and Frequency of Symptoms) after one week of ICAGD treatment and observed a dramatic reduction in chronic muscular TMD symptoms [29]. Some authors noted that occlusal correction did not affect TMJ sounds [27,30], while one study by Kerstein RB and Wright NR in 1991 claimed that chronic crepitus was nearly eliminated in treated patients [14]. Improvement in mouth opening following the ICAGD procedure was observed in the results of Kerstein RB and Wright NR in 1991 and Ignatius AV et al., [14,27]. Thumati P et al., (2014) and Thumati P et al., (2019) assessed median pain intensity values and found significant results [24,29].

Force measurements by T-scan before and after treatment were calculated by Thumati P et al., in 2019, and a significant difference between the absolute percentage of force during forceful clenching was observed ($p=0.0002$) in patients with specific myalgias [29]. The alleviation of symptoms greatly influences the quality of life in symptomatic TMD patients. Follow-up of patients treated with occlusal therapy showed that there was no reversal of symptoms post-treatment [27,30].

Digital analysis of occlusion is an important and effective tool for the identification of these occlusal disturbances, and T-scan offers effective assessment of such contacts. It also provides information about the force distribution pattern. Computer-analysed digital equilibration procedures are only possible because of the time-measuring capacity of the T-scan [24].

Disocclusion Time (DT) can be quantitatively measured by T-scan. T-scan-guided procedures help avoid the subjective errors that can occur when assessing the end result [24]. The aim of the ICAGD protocol was to reduce the DT to 0.4 seconds or less. The difference between occlusal equilibration and Disocclusion Time Reduction (DTR) was described by Kerstein RB and Wright NR in 1991 [14].

Several studies have aimed to study the effect of prolonged DT. They have concluded that prolonged DT (>0.5 seconds) causes hyperactivity of the masticatory muscles during excursive movements. This hyperactivity manifests as clinical symptoms like pain, fatigue during chewing, facial tension, pain in the temporal area, neck pain, grinding of teeth, etc. [14,24,28,35-37]. The longer the DT, the greater the duration of posterior teeth contact during excursions. This creates compression in the periodontal membrane and causes flexion in the pulps of the teeth involved, which in turn activates the mechanoreceptors in the pulp and periodontal membrane, signaling the central nervous system and causing pain in the involved musculature [14,38].

The DT was evaluated in 6 studies [14,19,23,24,27,29]. Analysis of DT at various time intervals was found to be statistically significant in all the studies. Kerstein RB and Wright NR concluded that chronic muscle activity is directly proportional to DT [14]. The positive effect of reducing the DT remained unchanged after treatment [30]. Physiological resolution of occluso-muscular disorders can be accomplished using DTR and ICAGD procedures. These procedures can be as effective in reducing symptoms as other palliative treatment modalities like splints, medications, and cognitive behaviour therapy [28].

Limitations and Strengths

A limited number of studies with greater heterogeneity in terms of eligibility criteria, study type, outcomes assessed, and methodology were included in the present review. Most of the studies included were non randomised trials. There was a limited scope for meta-analysis due to a lack of homogeneous quantitative data. The present systematic review includes only the advantages of the T-scan for checking occlusal interferences but does not include other factors like cost and the limited long-term data available on it. Despite these limitations, the present review has assessed the effectiveness of T-scan technology in the identification of occlusal discrepancies. Additionally, the overall analysis showed that T-scan-guided occlusal equilibration successfully reduced the frequency and intensity of symptoms in patients suffering from TMD or myofascial pain.

Long-term therapeutic advantages make T-scan-guided occlusal equilibration in TMD patients a viable treatment modality. However, the results of this review should be interpreted with caution, as there is a need for more randomised trials with a significant sample population in the future to determine the certainty of the results of the present study.

Future Scope and Recommendations: Due to the limitations of the current investigation, well-designed RCTs with long-term follow-ups are required to validate the findings.

CONCLUSION(S)

The results obtained from this systematic review lead to the conclusion that T-scan technology can be successfully used in the precise identification and diagnosis of occlusal discrepancies in patients suffering from myofascial symptoms, thereby playing a crucial role in the management of TMD. The unique properties of T-scan, like real-time analysis, reproducibility, and patient education, play a crucial role in the management of TMDs. T-scan-guided procedures like ICAGD can further provide relief to patients by reducing the VAS score and enhancing the quality of life of patients suffering from chronic pain and muscular discomfort. The achievement of results in a short span with the long-term effectiveness of this treatment makes it an acceptable treatment alternative.

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PARTICULARS OF CONTRIBUTORS:
1. Postgraduate Student, Department of Prosthodontics, Crown and Bridge, Government Dental College and Hospital, Nagpur, Maharashtra, India.
2. Associate Professor, Department of Prosthodontics, Crown and Bridge, Government Dental College and Hospital, Nagpur, Maharashtra, India.
3. Professor and Head, Department of Prosthodontics, Crown and Bridge, Government Dental College and Hospital, Nagpur, Maharashtra, India.
4. Associate Professor, Department of Prosthodontics, Crown and BRIDGE, Government Dental College and Hospital, Nagpur, Maharashtra, India.
5. Postgraduate Student, Department of Prosthodontics, Crown and Bridge, Government Dental College and Hospital, Nagpur, Maharashtra, India.
6. Postgraduate Student, Department of Prosthodontics, Crown and Bridge, Government Dental College and Hospital, Nagpur, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Pooja Uchale,
Postgraduate Student, Department of Prosthodontics, Crown and Bridge,
Government Dental College and Hospital, Nagpur-440003, Maharashtra, India.
E-mail: poojauchale594@gmail.com

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