REVIEW ARTICLE

Influence of T-scan System on Occlusion Correction of Implant Supported Prostheses: A Systematic Review

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Abstract

Aim: To systematically evaluate the literature evidence regarding the suitability of the T-scan occlusal system for implant supported prostheses.

Materials and methods: A thorough bibliographic search was conducted on PubMed, Google Scholar, Cochrane library, Web of Science, EMBASE, and Scopus to collect relevant articles published from January 1, 2008 to August 30, 2021, using a combination of the following words: "T-scan," "Implant supported prostheses," and "dental implant" according to the PRISMA guidelines for the focused research question constructed using the PICO criteria. Randomized control trials, prospective studies, retrospective studies on the use of T-scan system in implant-supported prostheses reported in English language were included in the study.

Results: This review consisted of 17 studies and 359 patients rehabilitated with 1,126 implants. In 3 studies, removable types of prostheses were given over implants, and in 14 studies, fixed types of prostheses were given. Nine studies determined the percentage of occlusal force magnitude and occlusion time sequence. Three studies measured the localization of the occlusion center. T-scan was used in two studies to measure the amount of gingival crevicular fluid after occlusal adjustment. The follow-up period ranged from 6 months to 2 years or more.

Conclusion: T-scan proved with better results than other occlusal analysis indicators in terms of occlusion measurement, clinical execution, quantify the location and contact timing, and occlusion in 3D with more precision.

Clinical significance: T-scan occlusal analysis system is widely used in dentistry and there is an increase in the number of studies, so a systematic review evaluating and comparing results is warranted.

Keywords: Dental implants, Occlusion, Restorations, T-scan.

The Journal of Contemporary Dental Practice (2022): 10.5005/jp-journals-10024-3288

Introduction

Occlusion is the principal concern of prosthetic and restorative dentistry. Occlusal interferences are injurious functional problems that become apparent after the treatment of the prosthesis. To register the occlusal-articulation relationship, various types of occlusion analyzers are used. They are broadly divided into qualitative and quantitative occlusion analyzers. Qualitative analyzers are high-spot indicator, articulating film, metallic shim stock film, articulating silk, and articulating paper. These analyzers are the most commonly used materials for registering the occlusion due to their lower cost and ease of use. The limitations of these analyzers are that only the localization of the occlusal contact points is possible, the occlusal contact sequence cannot be registered, intraorally they should be used only once, and prior to testing, the teeth should be dried. Quantitative indicators are the T-scan 10 occlusal analysis system, occlusal sonography, pressure-sensitive films, and virtual technology. The T-scan 10 system gives a precise method of assessing the sequence of time and occlusal contact force magnitude by converting qualitative data into quantitative parameters. It also increases the patient's confidence by displaying it on a digital display.[1]

In contrast to the natural teeth, osseointegrated implants lack a periodontal ligament, which provides proprioception as well as shock-absorbing capacity. The literature has revealed that it is difficult to control implant occlusion since dental implants react biomechanically in an alternate fashion to occlusal stress. The clinical success and occlusal stress dispersion of dental implant restorations can be effectively accomplished by reducing large cantilevers and heavy and premature contacts.[2]

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How to cite this article: Aradya A, Nagarajagowda RSK, Basavaraju RM, *et al*. Influence of T-scan System on Occlusion Correction of Implant Supported Prostheses: A Systematic Review. J Contemp Dent Pract 2022;23(1):105–117.

Source of support: Nil

Conflict of interest: None

The longevity of successful dental implants depends on understanding the possible occlusal stresses and basic prosthodontic occlusal concepts. Overloaded dental implants exhibit screw loosening, abutment and prosthesis fracture, and possible implant fracture.[3] However, controlling implant occlusion within the physiologic limits of the fixture environment influences long-term implant success. This may also give potential answers for managing complications identified with implant occlusion.[4]

The complete objective measure of occlusal loading at discrete contact points makes the T-scan 10 system an optimal methodology for the analysis of the dispersion of biting pressure within dental arches. No systematic review has been carried out on occlusal

measurement, clinical execution in different types of dental implant restorations with the use of T-scan system. Clinical research needs to be assessed to confirm the T-scan concepts validity in various implant restorations. The aim was to make an arsenal of the current writing to plot the effect of T-scan system on occlusal measurement, clinical execution, and to analyze and discuss the intricacies to give clinicians accommodating thoughts in the dynamic cycle of situation where this usage of T-scan 10 is significant in different types of implant-supported prostheses.

Methodology

Materials and Methods

This systematic review was conducted as per the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines.[5] A review methodology was set up by following the recommendations of the *Cochrane Handbook for Systematic Reviews of Interventions*.[6]

Focused Question-PICOS

The focused question was the utilization of T-scan occlusion analysis system in dental implant patients.

Does T-scan system (I) clinical performance (C) result in better precise localization of occlusal center, occlusal force, occlusal contact time, and qualitative and quantitative evaluation of occlusal adjustment and selective polishing outcomes (O) in various implant restorations (P) using randomized control trials, controlled clinical trials, prospective studies, retrospective studies (S)? (Table 1)

Search Strategy

A thorough bibliographic search was conducted in the electronic database National Library of Medicine, MEDLINE/PubMed, Google Scholar, Cochrane library, Web of Science, EMBASE, and Scopus to collect relevant articles published from January 1, 2008 to August 30, 2021. The search included only English language articles. The PRISMA statement guidelines with predetermined search methodology were used (Table 1). Furthermore, a hand search was performed in the reference sections of the studies included (cross-referencing). The following search terms were used for literature searches (((((T-scan [All Fields] AND ("dental implants" [MeSH Terms] OR ("dental" [All Fields] AND "implants" [All Fields]) OR "dental implants" [All Fields]), T-scan [All Fields] AND fixed [All Fields] AND implant [All Fields] AND restoration [All Fields], T-scan [All Fields] AND implant [All Fields] AND supported [All Fields] AND ("denture, overlay" [MeSH Terms] OR ("denture" [All Fields] AND "overlay" [All Fields]) OR "overlay, T-scan [All Fields] AND implant [All Fields] AND supported [All Fields] AND ("denture, partial, removable" [MeSH Terms] OR ("denture" [All Fields] AND "partial" [All Fields] AND "removable" [All Fields]) OR "removable partial denture" [All Fields] OR ("removable" [All Fields] AND "partial" [All Fields] AND "denture" [All Fields])).

Table 1: Systematic search strategy (PICOS strategy)

Search strategy	
Domain	*Description*
Population	Implant restoration
Intervention	T-scan
Comparison	Clinical performance of T-scan
Outcome	• Precise localization of occlusal center, occlusal force, occlusal contact time • Qualitative and quantitative evaluation of occlusal adjustment and selective polishing
Study design	Randomized control trials, controlled clinical trials, prospective studies, retrospective studies

Selection Criteria

Inclusion Criteria

The inclusion criteria for selection of studies were (1) clinical trial (prospective or retrospective), randomized control studies reporting on utilization of the T-scan occlusion analysis system in dental implant patients; (2) case reports, pilot studies including the T-scan system in dental implant restoration.

Exclusion Criteria

The exclusion criteria included (1) articles that investigated the effectiveness of the T-scan occlusal framework in natural dentition, complete denture wearers, removable partial denture wearers, and patients with fixed restoration; (2) review articles; (3) *in vitro* or bench research studies including finite element analysis; (4) implant studies carried out on animal subjects; (5) duplicate studies; and (6) studies that did not have full text retrievable.

These studies were excluded because the T-scan occlusal system creates movies as the patient bites for dynamic playback and analysis.

Screening and Selection

The search and screening measure were carried out by two authors (AA, SS) (κ value = 0.83, which indicating near-perfect agreement between the two authors). At first, titles and abstracts were scanned followed by the full-text articles, which were then chosen and analyzed with careful and thorough reading based on the inclusion and exclusion criteria for future information extraction. Any disagreements between the authors regarding the selection or rejection of studies were resolved cautiously through thorough discussion.

Data Extraction and Quality Assessment

The data extraction procedure was carried out by the first author and then redefined by the second author. Data extraction was done independently from each full-text article that met the inclusion criteria; it is done in a standardized form in the electronic organization (Office Excel 2013 software, Microsoft Corporation). Information was classified under author/year, type of study, duration of the study, type of implant, type of restoration (fixed or removable implant restoration), sample size, and conclusion. These studies were classified according to study design and outcome variables.

Factors Assessed to Evaluate the Clinical Performance of T-scan

Precise localization of occlusal center, occlusal force, occlusal contact time, and qualitative and quantitative evaluation of occlusal adjustment and selective polishing.

The Newcastle–Ottawa scale was used to assess the methodological quality of the included prospective and retrospective studies (Table 2),[7] with the pertaining results narrated under the results section.

Results

Search and Selection

Selection criteria were based on the PRISMA statement flow chart (Flowchart 1). The database search (P) yielded 532 studies, of which

515 were excluded because they were irrelevant, duplicates, and data were unavailable. The remaining 17 full-text articles were evaluated for their eligibility and were included in the present systematic review (Flowchart 1) (Table 3).

Description of Included Studies

This review consisted of 17 studies listed in Table 3. Total data from 359 patients rehabilitated with 1,126 implants were included. Of the 17 studies, prospective study (7),[8–14] retrospective (3),[15–18] pilot studies (5),[19–22] and case reports (2)[23,24] types were there. In 3 studies, removable types of prostheses were given over implants,[12,15,22] and in the remaining 14 studies, fixed types of prostheses were given.[8–11,13,14,16–21,23,24] Of the 14 studies of fixed type prostheses, 7 studies had single fixed crowns over implants[8,9,14,16,17,21,24] and 7 studies had implant retained fixed prostheses in completely edentulous condition.[10,11,13,18,19,20,23] Nine studies determined the percentage of occlusal force magnitude and occlusion time sequence. Three studies measured the localization of the occlusion center. T-scan was used in two studies to measure the amount of gingival crevicular fluid after occlusal adjustment.[10,20] Six had a follow-up time of up to 6 months.[9,13,14,16,17,21] All five studies had a follow-up to 1 year.[10,11,12,20,22] Six had a long follow-up of 2 years or more.[8,14,15,18,19,23]

Table 2: Quality assessment of the prospective and retrospective studies using Newcastle–Ottawa scale[7]

Study	*Selection*	*Comparability*	*Outcome*
Luo et al.[8]	***	**	***
Madani et al.[9]	***	**	***
Roque et al.[16]	***	*	***
Yu et al.[17]	***	**	***
Viña-Almunia et al.[10]	***	*	***
Kabbua et al.[12]	***	**	***
Ma et al.[13]	***	**	***
Barrio et al.[14]	***	*	***
Khuder et al.[15]	***	**	***
Huang et al.[18]	***	*	***

Selection maximum score is * includes representativeness of the sample (*), sample size (*), nonrespondents (*), validated measurement tool (*). Comparability maximum score is ** includes study controls for the most important factor (*), study control for any additional factor (*). Outcome maximum score is *** includes independent blind assessment (*), record linkage (*), self-report (*)

Risk of Bias

The Newcastle–Ottawa scale was used to assess the methodological quality of the included prospective and retrospective studies (Table 2).[7] Six studies had overall score of 8 and four studies had overall score of 7. We considered high-quality studies as those achieved seven or more stars, medium quality studies with four to six stars, and poor quality studies with less than four stars.

Clinical Performance of T-scan

A periodic occlusal adjustment of implant-supported prostheses is necessary to prevent potential overloading; however, T-scan allows the quantitative evaluation of assessment of occlusal changes in a subject to eliminate interfering variables. Clinical performance of T-scan improves implant restoration function significantly in terms of maximum occlusal contact force, tooth contact number without the impairment of force distribution, and had shown 100% success rate after 1 year. The oral function of the patients has been enhanced.

The details of the clinical performance of T-scan system have been mentioned in one of the columns in summary Table 3. The study[24] used the T-scan III system to analyze the postrehabilitation occlusal function of subjects treated with complex mandibular resection and subsequently rehabilitated with fibula osteoseptocutaneous flaps, dental implants, and fixed prostheses. In full mandibular reconstruction using dental implants, it seems easier to adjust the number of occlusal contact points and occlusal force by grinding the prosthesis, to avoid occlusal center asymmetry. Thus, the results of this study conclude that the occlusal center

Flowchart 1: PRISMA flow diagram of screening and selection process

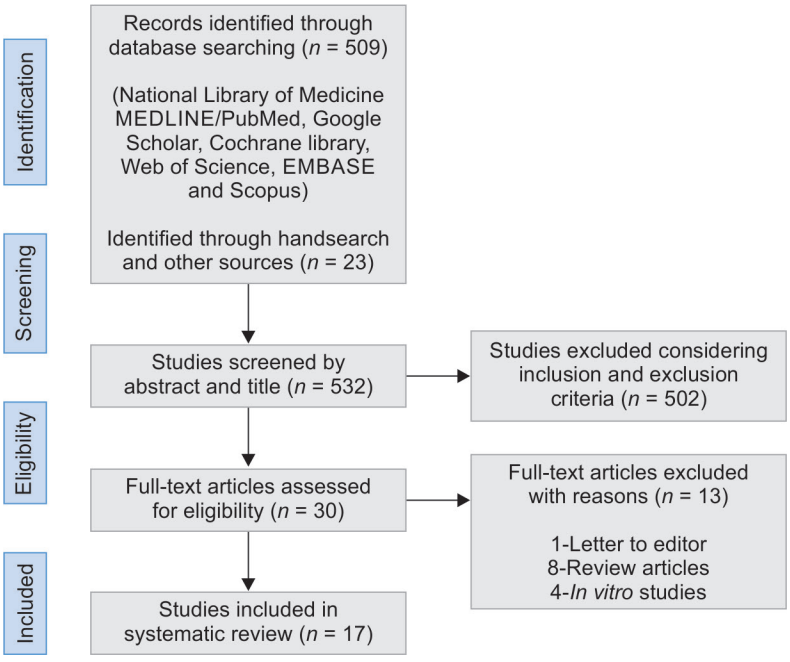

Table 3: Main characteristics of the studies

Sl. No.	*Study/year/ place of study*	*Study design*	*Sample size*	*Clinical situation*	*Implant type*	*Prostheses*	*Occlusal indicator*	*Follow-up*	*Results*	*Outcome*	*Limitations of the study*
1.	Liu et al., 2015[19] Taoyuan, Taiwan.	Pilot study	41 implants in 10 patients	Prosthetic reconstruction following mandibular resection	3i system	Fixed	T-scan III	49.25 months	Subjects with larger mandibular reconstructions and dental implants with fixed partial dentures demonstrated decreased average occlusal force assessed by T-scan system. The occlusal center and its asymmetrical degree are more reliable parameters.	• The T-scan system used to analyze the occlusal function has shown that measurements of the location of the occlusal center appeared more repeatable, and were less affected by additional factors.	Not mentioned
2.	Luo et al., 2020[8] Beijing, PR China.	Prospective study	37 implants in 33 patients	Partially edentulous patients who had received implant-supported single crowns in the posterior region	Not mentioned	Fixed	T-scan III	36 months	The occlusal force and occlusal contact time of implant prostheses changed significantly with time.	• The occlusion of implant prostheses changed over the 3-year follow-up period, which was mainly reflected in the increasing occlusal force and occlusal contact time of implant prostheses, which was assessed by the T-scan system. • The occlusion of implant prostheses should be carefully monitored during follow-up examinations, and occlusal adjustment should be considered when necessary.	The relative occlusal force (ROFs) of implant prostheses at 2-week follow-up range from 2 to 18%. This wide range of initial data may be related to the nonstandardized occlusal adjustment process at implant prosthesis delivery. In addition, the maximum occlusal force in the maximum intercuspal position (MIP) was used instead of the habitual occlusal force in this study. The occlusion of implant prostheses under the habitual occlusal force ay have differed. Participants who withdrew can also be a source of bias.
3.	Buduru et al., 2019[23] Cluj-Napoca, Romania.	Case report	8 implants in 1 patient	Completely edentulous maxillary arch and Kennedy's class I mandibular arch	Not mentioned	Fixed	T-scan™ Novus™	24 months	The results yielded by the T-scan device were different and they were also relevant for elucidating the cause of the symptomatology.	• Computerized T-scan analysis may provide additional extremely valuable information about force intensity, time of occurrence and much more precise localization. • Selective polishing was guided by the results of the T-scan analysis.	Not mentioned

4.	Madani et al., 2017[9] Mashhad, Islamic Republic of Iran.	Prospective study	21 implants in 21 patients	Single implant in posterior region of maxilla and mandible	(Biohorizons, Alabama, USA)	Fixed	T-scan III	6 months	There were significant differences between the POFI (percentage of force applied to the implant crowns) at 3- and 6-month follow-up. • A periodic occlusal adjustment of implant-supported prostheses is necessary to prevent potential overloading from the movement of opposing natural dentition.	• T-scan allows the quantitative evaluation of the assessment of occlusal changes in a subject to eliminate interfering variables. • One of the challenges in using T-scan is that it is time consuming and requires a skilled operator. • The intensity of occlusal contacts of implant-supported prostheses opposed by natural dentition gradually increased after prosthesis insertion. Placement of a single posterior implant-supported restoration decreased the percentage of occlusal force applied to the contralateral arch.	Assessed occlusion changes in implant-supported prostheses in a 6-month period. However, due to lack of patient cooperation, the study could not be continued for a longer period. Thus, randomized clinical trials are needed to assess the effect of occlusion changes on the implant surrounding marginal bone and the implant components.
5.	Roque et al., 2017[16] Boston, Massachu-setts.	Retrospective study	15 implants in 15 patients	Successfully osseointegrated single posterior dental implant in occlusion with natural dentition and adjacent natural dentition present.	Not mentioned	Fixed	T-scan III	6 months	When analyzing restora-tions by exact position, more posterior implant restorations decreased the occlusal pressure applied in anterior dentitions.	• Results of T-scan are quantifiable as percentages of the total load registered by the sensor and immediately exported to analysis software as opposed to manual photo occlusion or sub-jective analysis.	It only includes single edentulous spaces in the posterior dentition, and the data was analyzed at a static moment in time.

(Contd...)

Table 3: *(Contd...)*

Sl. No.	*Study/year/ place of study*	*Study design*	*Sample size*	*Clinical situation*	*Implant type*	*Prostheses*	*Occlusal indicator*	*Follow-up*	*Results*	*Outcome*	*Limitations of the study*
6.	Yu et al., 2020[17] Jinan, China.	Retrospective study	60 implants in 60 patients	• Fixed implant restoration in upper jaw facing natural dentition—20 patients • Upper jaw natural dentition opposing fixed implant restoration—20 patients • Upper jaw with removable partial denture opposing fixed implant restoration	Not mentioned	Fixed	T-scan 8.0	6 months	This study shows that in the fixed implant restoration of mandibular dentition, when the maxilla contains removable partial dentures, the occlusal time, the balance of left and right occlusal force and the offset of the center of occlusal force will be greater than those of the maxilla with fixed implant restoration and natural teeth column of patients.	T-scan reveals that when implant-supported fixed restoration at edentulous mandibular includes removable partial denture, the degree of occlusal instability and left and right asymmetry of occlusion center force are greater than with the natural dentition and implant-supported fixed denture at maxillary.	Not mentioned
7.	Viña-Almunia et al., 2020[10] Valencia, Spain.	Prospective clinical study	11 patient 14 implants in each patient	All the patients had bimaxillary implant-supported prostheses complete fixed ceramo-metallic prostheses supported by 8 in the upper maxillary and 6 in the mandible were selected	Phibo TSA® implants (Phibo Dental Solutions®, Impladent, Sentmenat, Barcelona, Spain)	Fixed	T-scan® III, Tesco	12 months	Implants with higher occlusal load presented higher IL-10 levels than control implants. It was also observed that occlusal adjustment diminished all the cytokines analyzed, in a short and medium period of time, in both test and control implants. Specifically, 2 months after occlusal adjustment, all the cytokines decreased significantly in both study and control implants, except TNF-α that decreased significantly at 12 months.	Study provides information of cytokines present in PICF of implants with different occlusal loading degrees. The results showed that peri-implant tissue health, at least in a subclinical level (cytokines in PICF), is related to occlusal loading. It is important to underline that at baseline, the included patients did not feel any discomfort at chewing or at occlusion. However, it was possible to discern between implants close and far away from the highest point of occlusal load thanks to the T-scan® III occlusal analysis system, a non-invasive method.	The sample met the strict inclusion criteria such as the homogeneity in the number of implants per patient, the type of rehabilitation, and the oral hygiene of the patients, but studies with larger number of patients are necessary. In order to reduce bias, the present study was performed with patients that had a very good oral hygiene with full-mouth plaque and full-mouth bleeding scores <25%. It would be interesting to analyze the effect of occlusion and clinical and subclinical parameters (cytokines in PICF) in patients with a peri-implant disease established. These would help to understand, together with clinical and radiological parameters, the influence of loading in the peri-implant tissues.

8.	Pellicer-Chover et al., 2014[20] Valencia, Spain.	Pilot study	11 patients 12 implants in each patient	Rehabilitation of both arches with implant-supported complete fixed ceramo-metallic prostheses.	Phibo TSA® implants	Fixed	T-scan® III	12 months	Before occlusal adjustment, study group implants presented higher volumes of crevicular fluid than control group implants, with statistically significant difference ($p = 0.002$). When results before and after occlusal adjustment were compared, a significant fall in crevicular fluid volume occurred in study group implants, resulting in almost equal volumes between the study and control groups after adjustment ($p = 0.011$).	Study group implants receiving higher occlusal loading presented significantly higher volumes of crevicular fluid than control implants. Crevicular fluid volumes were similar in both groups 2 and 12 months after occlusal adjustment by T-scan.	It may be concluded that implants subjected to higher occlusal forces presented significant increases in crevicular fluid volumes in comparison with implants subjected to lower occlusal loads. Two months after occlusal adjustment, when overloading had been eliminated, crevicular fluid volumes were similar in both groups. These values were stable at the 12-month follow-up. Further research is required with longer follow-up periods and larger sample sizes to confirm these results and better evaluate the influence of occlusal over-loading on peri-implant soft tissues.
9.	Zhou et al., 2021[21] Phatum Thani, Thailand.	Pilot study	32 implants in 30 patients	Single posterior dental implants opposing natural dentition	Not mentioned	Fixed	T-scan III	6 months	The occlusal force of implant-supported prostheses was significantly ($p = 0.000$) lower than those of the control natural teeth at the baseline, then no significant difference was found with that of the mesial teeth at 3 months, and finally it was significantly ($p = 0.000$) lower than that of the distal teeth at 6 months; meanwhile, it significantly ($p = 0.008$) increased by a mean of 2.04 times from 2 weeks to 3 months whereas no significant difference ($p = 0.900$) was found from 3 to 6 months.	• Bite force and masticatory ability can be improved with the immediate delivery of a single posterior implant restoration. T-scan in the study has shown that the bite force distributed on the implant prosthesis inevitably increases after placement of implant prostheses. A routine follow-up and occlusal evaluation by T-scan are strongly needed.	The potential bias from the small sample size and short-term follow-ups. The drop-out rate was 15.63% (5 lost from 32 subjects) at 3 months and 18.75% (6 drop-out from 32 subjects) at 6 months, respectively.

(Contd...)

Table 3: *(Contd...)*

Sl. No.	*Study/year/ place of study*	*Study design*	*Sample size*	*Clinical situation*	*Implant type*	*Prostheses*	*Occlusal indicator*	*Follow-up*	*Results*	*Outcome*	*Limitations of the study*
10.	Yu et al., 2021[11] Tainan, China.	A clinical, occlusal and bio-mechanical study	65 patients 6 implants in each patient	Edentulous mandibles who underwent fixed implant-supported restorations	Not mentioned	Fixed	T-scan III 8.0 version	12 months	Occlusal parameters indicated that the 1-piece design was superior for the masticatory system than the 3-piece design. Biomechanical analysis revealed the highest stress values in the posterior region of the 3-piece design.	Based on occlusal outcomes by T-scan, the 1-piece framework design might be the superior therapy for restoring an edentulous mandible.	The decision making process should be based primarily on long-term survival and complication rates.
11.	Kabbua et al., 2020[12] Chiang Mai, Thailand.	Prospective clinical study	31 patients 2 Mini implants in each patient	Completely edentulous patients who had complete dentures, had been used for 1 year	Not mentioned	Removable	T-scan 8, Software version 8.0.1, Tekscan, Inc., Boston, Massachusetts, USA	12 months	There was a significant difference between the MOF (Maximum Occlusal contact Force) before implant placement (84.14% ± 5.79) and after 1 year of function (89.77% ± 4.56), (p <0.05). There was a significant difference found between maximum occlusal contact force after 1 day of function (85.27% ± 5.92) and 1 year of function (89.77% ± 4.56) (p <0.05).	• Using T-scan computerized occlusal analysis, mini dental implants improve complete denture function significantly in terms of maximum occlusal contact force and tooth contact number without the impairment of force distribution and shown a 100% success rate after 1 year. The oral function of the patients has been enhanced.	The maximum occlusal contact force can be shown only in percent when compared to the other areas of the patient's occlusion, but it cannot show the numerical value of the force in Newton.
12.	Ohkubo et al., 2008[22] Yokohama, Japan.	*In vivo* pilot study	5 patients 2 implants in each patient	Missing bilateral (Kennedy's Class I) mandibular premolars and molars received implant supported removable partial denture	Brånemark TU MK III, Nobel Biocare	Removable	T-scan system	12 months	The implant-supported RPDs tended to have lower values for mean time and coefficient of variation of masticatory movement compared to the conventional removable partial dentures, except for the opening phase. The center of occlusal force of the ISRPD (implant-supported RPDs) tended to move more distally compared to the CRPD (conventional RPDs.).	• The T-scan has shown that the implant-supported RPDs had greater occlusal force than the conventional RPDs. • All the patients preferred implant supported RPDs for all criteria (comfort, chewing, retention, and stability).	Few subjects participated, and the ISRPDs were evaluated only at an early stage after denture insertion. Thus, the number of patients rehabilitated with ISRPDs should be increased in a subsequent study. In addition, a longitudinal study on ISRPDs is necessary in which the survival rate of the implant, the conditions of the terminal abutment teeth, and the edentulous ridge resorption are re-evaluated at various intervals.

13.	Ma et al., 2016[13] Beijing, China.	Prospective study	13 patients 4 implants in each patient	All-on-4 rehabilitation	Not mentioned	Fixed	T-scan III	6 months	Maximum intercuspation: the left and right premolars took most of the occlusal force, namely (24, 25, 14, 15), the implants areas including the premolar and anterior teeth took of occlusal force. The left and right sides took the respective percentages.	At maximum intercuspation: the implant areas, including the premolar and anterior teeth, were the occlusal force centers; the force was concentrated in the areas (11, 12, 21, 22) at the protrusion position. The T-scan occlusal analysis system reveals multiformity in the lateral occlusal pattern.	Assessed occlusion changes in a 6 month period, thus randomized clinical trails are needed. The maximum occlusal contact force can be shown only in percent, but it cannot show the numerical value of the force in Newton.
14.	Cotruță et al., 2015[24] Bucharest, Romania.	Case report	3 implants in 3 patients	Three mandibular class III Kennedy edentulous male patients, all missing the first mandibular molar and all being prosthetically rehabilitated with an implant and a metal-ceramic crown.	Not mentioned	Fixed	T-scan II system	6 months	The analysis of occlusion with the T-scan II system in those three cases showed that the crowns were successfully integrated in the habitual occlusion.	This *in vivo* study demonstrated that with the help of the T-scan II system, the implant-prosthetic crown's occlusion was good enough to integrate it into the habitual occlusion of the patient. It has been shown that these methods, which are currently used in dental offices, can help the dentist correctly design the occlusion, if they are correctly and conscientiously used.	Not mentioned
15.	Prieto-Barrio et al., 2021[14] Catalonia, Spain.	Prospective study	16 implants in 14 patients	The implant-supported single crowns in molar and premolar regions	Not mentioned	Fixed	T-scan III	24 months	After 6 months and 2 years, no significant variations were observed in any region of the occlusal scheme assessments, including T-scan, using light or heavy clenching, and qualitative or quantitative occlusal contact assessment.	T-scan, using light or heavy clenching, and qualitative or quantitative occlusal contact assessment. The occlusal scheme did not vary at the intercuspal position 2 years after placing posterior implant-supported single crowns.	Studies with larger number of patients are necessary. It only includes single edentulous spaces in the posterior dentition.

(Contd...)

Table 3: *(Contd...)*

Sl. No.	*Study/ year/place of study*	*Study design*	*Sample size*	*Clinical situation*	*Implant type*	*Prostheses*	*Occlusal indicator*	*Follow-up*	*Results*	*Outcome*	*Limitations of the study*
16.	Khuder et al., 2017[15] Kuala Lumpur, Malaysia.	Prospective study	23 patients 2 implants in each patient	Maxillary and mandibular edentulous ridges. Mandibular implant overdenture	Not mentioned	Removable	T-scan III	24 months	The T-scan III digital occlusal system was used to record anterior and posterior percentage occlusal force (%OF) distributions. Depending on arch location, ridge resorption at various locations was associated with occlusal force distribution and/or treatment groups (implant prostheses or conventional complete dentures).	Ridge resorption at various locations was associated with occlusal force distribution, which was assessed by T-scan. In the edentulous maxilla, the anterior residual ridge resorption was significantly associated with relative occlusal force distribution; while in the posterior ridge, it was associated with the type of prostheses. Both occlusal and prostheses factors showed association with mandibular ridge resorption.	It was acknowledged that loading used in this study was only applied vertically and in the maximal intercuspal position without lateral movements. Meanwhile, the other occlusal parameters such as occlusal and disocclusal times, which were simultaneously recorded during occlusal analysis procedure, were not utilized in this study.
17.	Huang et al., 2020[18] Taiwan, China.	Retrospective clinical study	47 implants in 13 patients with oral cancer	Implant-supported prostheses in microvascular free fibular flaps in patients with oral cancer	Biomet 3i	Fixed	T-scan III	84 months	Increased length of the implant-supported prostheses compared with maxillary and mandibular dental arch length significantly impaired the maximal occlusal force ($p = 0.045$ and $p = 0.029$). The rehabilitated mandibular dental length should be as long as the maxillary arch length for optimum occlusal stress distribution.	Increasing the length of the reconstructed mandibular implant-supported prosthesis in the fibular flap will reduce the occlusal force measured by T-scan. The rehabilitated mandibular dental length should be as long as the maxillary arch for optimum occlusal stress distribution to maintain the peri-implant fibula bone level.	Determining how to decrease overloading and increase occlusal force by changing implant-supported prosthesis designs in patients with fibular reconstruction was the purpose of this research. However, peri-implant bone resorption in the MFF flap is a multifactorial outcome. In this research, all implants and prostheses were restricted to placement in the MFF flap. The prosthodontic prognosis may also have been affected by splinting the dental implants in the fibular flap when placed in the alveolar ridge. Further investigation is needed to determine whether splinting implant supported prostheses, the time of loading, or the osteotomy technique impacts the outcome of the treatment in this population.

and its asymmetrical degree are more reliable parameters than the occlusal force in occlusal function analysis using T-scan after mandibular reconstruction with implants.[24]

The T-scan III system can accurately identify occlusal force distribution and the sequence of occlusal time in implant prostheses. Madani et al.[9] evaluated the postinsertion posterior single-implant occlusion changes at 3- and 6-month intervals by using the T-scan computerized occlusal analysis system. Yu et al.[17]also reported that almost one-third of these changes occurred within the first 6 months after prostheses insertion. In the study done by Luo et al.,[8] T-scan has demonstrated that the occlusion forces and occlusion time experienced by implant prostheses designed to receive light occlusal contact which increased significantly not only in the first 3 months but also between 6 and 24 months after prosthesis delivery. This shows that even after reducing the diameter of implant prostheses and modifying the occlusal table, the occlusion of implant-supported fixed prostheses does not remain light indefinitely.[8]

Inference of the Study

In the studies reviewed for this article, T-scan system has been used to maintain the harmonious occlusion in implant retained and supported both removable and fixed prosthetic restorations and no apparent differences can be identified in the efficacy of implant-supported overdenture (ISOVD) and implant-supported fixed dental prostheses (ISFDP) in the light of this systematic review. This systematic review provided the effect of T-scan system on occlusal measurement, clinical execution, and to analyze and discuss the intricacies to give clinicians accommodating thoughts in the dynamic cycle of situation where this usage of T-scan 10 is significant in different types of implant restorations. Based on the studies analyzed in the systemic review, T-scan system can be successfully implemented in occlusion correction of implant-supported prostheses because computerized T-scan analysis may provide additional extremely valuable information about force intensity, time of occurrence, and much more precise localization.

Discussion

New technologies and equipment are routinely introduced into dental practice. Ideally, clinicians should regard evidence-based dentistry as an essential guide in the planning of successful treatment. However, scientific evidence from well-controlled investigations into different aspects of prosthodontics, including the clinical performance of T-scan in dental implantology, is rarely available.

The T-scan 10 system gives an extremely precise method of determining and assessing the time sequence and force magnitude of occlusal contacts by converting qualitative data into quantitative parameters and displaying them digitally. Multiple corrections of imbalanced forces can be performed for every section of the dentition by using the T-scan 10 system. The tooth contact data are presented by demonstrating moments of time in the sagittal axis and transverse axis of the occlusal plane. The system is a significant clinical technique that eliminates a biased subjective evaluation of the occlusal and articular relations with respect to an operator.[25]

The T-scan framework has various clinical applications in dentistry. Occlusal adjustment is usually performed following orthognathic surgery, implant procedures, or dental prostheses, and these adjustments can be guided precisely by T-scan 10 occlusal analysis. The T-scan 10 can show premature contact and the load distribution on implant restoration, and provide measurable force and time information that ensures proper occlusal adjustment. In implant dentistry, the discovery of premature contacts allows early intervention to prevent future problems.[26] The T-scan 10 is the only tool to assess the force differences between the implanted restoration and the natural tooth in occlusion. Henceforth, it is strongly suggested in the field of implant dentistry in restoring implant occlusion.[27]

Liu et al. research study has shown that the T-scan III framework can be utilized as a measurement tool in clinical examinations, and the sensitivity setting can be adjusted to measure the occlusal force at various ranges.[19] T-scan results can be interpreted in proportion from the graphs of the software. For instance, the maximum occlusal contact force can be shown only in percent when compared with the other area of the patient occlusion. Kabbua et al. reported in his study that T-scan computerized occlusal analysis allows the mini dental implants to improve complete denture function significantly in terms of maximum occlusal contact force and tooth contact number without the impairment of force distribution and has shown a 100% success rate after 1 year.[12]

The Liu et al. in his study[19] used the T-scan III system to analyze the postrehabilitation occlusal function of subjects treated with complex mandibular resection and subsequently rehabilitated with fibula osteoseptocutaneous flaps, dental implants, and fixed prostheses. With the help of the T-scan system, it appears to be simpler to adjust the number of occlusal contact points and occlusal force by grinding the prosthesis, to avoid occlusal center asymmetry. Thus, the author has concluded that the occlusal center and its asymmetrical degree are more reliable parameters in occlusal function analysis by using the T-scan system in the case of mandibular reconstruction with implants.[19]

The T-scan III system can accurately identify occlusal force distribution and the sequence of occlusal time in implant prostheses.[28] Madani et al.[9] used the T-scan computerized occlusal analysis system to evaluate the postinsertion occlusion changes of posterior single-implant at 3- and 6-month intervals. In the study, he reported that the percentage of occlusal force applied to the contralateral arch was measured and a periodic occlusal adjustment of implant-supported prostheses was done using the T-scan system to prevent potential overloading from the movement of opposing natural dentition.

In the study done by Luo et al.,[8] T-scan has demonstrated that the occlusion forces and occlusion time experienced by implant prostheses designed to receive light occlusal contact increased significantly not only in the first 3 months but also between 6 and 24 months after prosthesis delivery. This shows that even after reducing the diameter of implant prostheses and modifying the occlusal table according to T-scan occlusal analysis, the occlusion of implant-supported fixed prostheses does remain light indefinitely.[8] The outcomes by Madani et al. and Luo et al. favored the T-scan system. This could be due to precise localization of the occlusal center, occlusal force, and occlusal contact time.

Zhou et al. reported in their study that while the occlusal force of single posterior implant restorations increased during the fourth phase post insertion observation period, it was still significantly less than that of distal teeth at half year follow-up, prompting to determine the periodontal status and bone loss rather than the value of bite force alone. Although, bite force is meaningful, a regular follow-up and occlusion assessment by T-scan were strongly recommended.[21] The study by Cotruță et al. concluded that the T-scan allows the clinician to load implants sequentially to maintain

balanced occlusal forces in single-implant restoration.[24] In their prospective study. Barrio et al. reported that in 2 years follow-up of posterior implant-supported single crowns, the occlusal scheme analyzed by the T-scan system did not vary at the intercuspal position.[14] These studies[14,21] favored the clinical performance of the T-scan system in single-implant restorations.

In their study on the rehabilitation of both arches with implant-supported complete fixed ceramo-metallic prostheses, the authors highlighted on the limitation of their study that the implants subjected to higher occlusal forces presented significant rises in crevicular fluid volumes in comparison with implants subjected to lower occlusal loads. Two months after occlusal adjustment by the T-scan system, elimination of overloading, and crevicular fluid volumes were similar in both groups. These values were stable even at the 12-month follow-up. Here peri-implant clinical parameters were analyzed in both implants before and 2 and 12 months after occlusal adjustment. Occlusal forces were registered with the T-scan® III and then occlusal adjustment was performed to distribute occlusal forces correctly. T-scan system aids in analyzing these peri-implant clinical parameters and point of higher occlusal load was determined only with the help of the T-scan®III.[20] Buduru et al. reported in their study that computerized T-scan analysis might provide additional extremely valuable data regarding force intensity, the moment of occurrence, and a much more precise localization.[23]

According to Yu et al.'s study,[17]opposing removable partial dentures leads to more occlusal contact time than the fixed implant and natural dentition of the upper jaw in implant-supported fixed restoration at edentulous mandible, and the displacement of the occlusal center point increases accordingly. The displacement of the occlusal force center point reflects the dynamic changes in the occlusal process, indicating that the occlusal force changes continuously with the occlusal contact from the mandibular position to the cusp interdigital position. Long displacement can reach the maximum bite force, and the bite is relatively unstable. With the fixed implant denture is repaired, special attention should be paid to removing early contact when adjusting the maxillary with removable partial denture, to ensure the stable contact of the median jaw during the occlusal process, and to reduce the occlusal contact time and the displacement of the occlusal center point.[17]

According to Yu et al.,[11] they reported in their study that based on occlusal outcomes by T-scan, the 1-piece framework design might be the superior therapy for restoring an edentulous mandible. Kabbua et al. in their study on the clinical evaluation of two mini dental implants-retained mandibular over dentures, they reported that using T-scan computerized occlusal analysis, denture function was significantly enhanced in terms of maximum occlusal contact force and tooth contact number without the impairment of force distribution, and even the oral function of the patients has improved.[12]

Khuder et al. reported in their study that in the case of implants retained over dentures, the ridge resorption at various locations was associated with occlusal force distribution, which was assessed by T-scan.[15] T-scan has shown that the implant-supported RPDs had greater occlusal force than the conventional RPDs. In comparison with the conventional RPDs, the center of occlusal force of the implant-supported RPDs was positioned distally. The implant-supported RPDs tended to have lower values for mean time and coefficient of variation of masticatory movement, except for the opening phase.[22]

At maximum intercuspation, the implant areas including the premolar and anterior teeth were the occlusal force centers; the force was concentrated in the areas (11, 12, 21, 22) at the protrusion position. The lateral occlusal pattern shows multiformity by the T-scan occlusal analysis system.[13] In their study, Viña-Almunia et al. reported that implants with higher occlusal loads presented a higher expression of IL-10 in peri-implant crevicular fluid. Occlusal adjustment with T-scan produced a decrease in the expression of all the analyzed cytokines.[10]

Pellicer-Chover et al. and Vina-Almunia et al. studies have shown the rise in gingival crevicular fluid due to increased occlusal overload. Later significantly, there was a change in the volume of gingival crevicular fluid after the occlusion adjustment by the T-scan system. These studies[10,15,20,21] favored the T-scan system's clinical performance because they were prompted to determine periodontal status and bone loss rather than the value of bite force alone.

Interestingly, several studies[12,13,17,21] showed comparable outcomes with measurement of force concentration area, displacement of occlusal center point, and force intensity with the help of the T-scan occlusal analysis system. Based on the results of this study, the majority of the studies were on fixed implant restoration. Few were on removable types of implant restoration, and additionally, these studies had an adequate follow-up period. As a result, the T-scan occlusal system is applicable to all types of implant restoration.

Advantages of T-scan

- Warning messages are given to the dental specialist for physiologic or nonphysiologic occlusion time as well as disclusion time.
- T-scan displayed more pinpoint precision in finding individual high-force contacts and excursive interferences.
- Relative occlusal force levels on individual teeth can be reported.
- T-scan is server-based, so regardless of which operatory PC is utilized, the database is saved on the server, and is open from any PC on the network quantify the location and tooth contact timing and occlusion in 3D.
- Untimely occlusal contacts are recognized in the dynamic occlusion rather than static.
- Forces distribution per tooth can be determined.
- T-scan system's recording process is unaffected by the saliva presence.[1]

Disadvantages of T-scan

- Impotence to quantify the definite force rate while assessing bite force is a significant disadvantage.
- It lacks reproducibility of data.
- T-scan is a decent device for evaluating the forces and bite dynamics, yet it cannot decide if the force comes from the maxillary or mandibular teeth as it simply records the force in between the teeth.[1]

Limitations of T-scan

- The T-scan sensors have the thickness of 0.1 mm which is as yet thicker than the articulating paper thickness because more thinner occlusal registration materials give more steady records of the contact points.
- There might be harm of the sensors to a sharp tooth cusp, if the forces are concentrated over a small region resulting in incorrect recording of the occlusal contact in the produced images.
- T-scan framework cannot reproduce the less than 0.6 mm occlusal interferences.
- Despite T-scan providing the percentage of force, it does not have the capacity to measure the absolute bite force.[1,12]

Strength of this Systematic Review

This review is based on a well-defined PICOS question and inclusion and exclusion criteria. Assessments of the included studies have done according to the Newcastle–Ottawa scale.

Limitations of this Systematic Review

Limitations of the study were the nonavailability of randomized controlled clinical trials (due to high investment costs for equipment) and the inclusion of literature in English only.

Future Directions

The studies included in this review are limited, and thus, the clinical relevance of the measured outcomes remains questionable. Some may suggest the use of T-scan in all fields of implant dentistry, but the potential benefits cannot be established yet. Well-designed RCTs with long-term follow-ups are required to substantiate the findings due to the present study limitations.

Conclusion

With the accessible evidence in the literature, it can be concluded that the T-scan system can be used as an effective occlusal analysis system in all types of implant restorations. Majority of the studies on fixed implant restoration used the T-scan system in achieving the harmonious occlusion. Results of this systematic review should be carefully interpreted in clinical practice. Occlusal correction with T-scan system was found to be more time efficient than traditional occlusal correction. T-scan can determine the high points, premature contacts, the regions of excessive loads, and the uneven force's concentration.

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