

# International Journal of Dental Science and Innovative Research (IJDSIR)

# IJDSIR : Dental Publication Service Available Online at: www.ijdsir.com

Volume - 4, Issue - 6, November - 2021, Page No. : 292 - 306

Comparison of occlusal calibration between efficiency of articulating paper versus t-scan in evaluating occlusal force and occlusal contact points in patients undergoing dental treatment: A systematic review

<sup>1</sup>Aman Merchant, Department of Prosthodontics, Saveetha dental college and hospital, Saveetha institute of medical and technical science, Saveetha University Chennai, India

<sup>2</sup>Deepak Nallaswamy, Department of Prosthodontics, Saveetha dental college and hospital, Saveetha institute of medical and technical science, Saveetha University, Chennai, India

<sup>3</sup>Marina M., Department of Prosthodontics, Saveetha dental college and hospital, Saveetha institute of medical and technical science, Saveetha University, Chennai.

**Corresponding Author:** Deepak Nallaswamy, Department of Prosthodontics, Saveetha dental college and hospital, Saveetha institute of medical and technical science, Saveetha University, Chennai, India

**Citation of this Article:** Aman Merchant, Deepak Nallaswamy, Marina M., "Comparison Of Occlusal Calibration Between Efficiency Of Articulating Paper Versus T-Scan In Evaluating Occlusal Force And Occlusal Contact Points In Patients Undergoing Dental Treatment: A Systematic Review", IJDSIR- November - 2021, Vol. – 4, Issue - 6, P. No. 292 – 306.

**Copyright:** © 2021, Aman Merchant, et al. This is an open access journal and article distributed under the terms of the creative commons attribution noncommercial License. Which allows others to remix, tweak, and build upon the work non commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

Type of Publication: Review Article

**Conflicts of Interest: Nil** 

# Abstract

This systematic review was conducted to compare the efficiency of articulating paper and T-scan<sup>TM</sup> to detect the occlusal force and premature contact in patients undergoing prosthetic dental treatment. A search questionnaire was formulated using PICO to compare the efficiency of articulating paper and T-scan<sup>TM</sup> and a comprehensive search was initiated in PubMed Central, Medline Cochrane and Google Scholar databases were searched for the literature published single 1965s. Randomised control trials, clinical studies and case control studies were included. Due to the lack of clinical evidence, In-vitro studies were independently analysed to avoid diluting the homogeneity of the study.

2 studies were included on the basis of inclusion criteria. They compared the sensitivity of T scan and articulating paper in determining the potential premature contacts. The clinical evidence points to no significant difference between the T-scan and articulating paper in detecting premature contacts. However, 4 in-vitro studies that exclusively analyzed the force equilibration with T-scan appear to support the clinical value of T- can. There are no detailed clinical studies evaluating force equilibration and their impact on the longevity of the prosthesis.

Hence more number of clinical studies with longerfollow up is required to establish the benefits of T- scan.Keywords: Articulating Paper, Occlusal Contacts, T-

scan, premature contacts, force calibration.

### Introduction

Gradual tooth wear is a normal phenomenon which takes place throughout life (1). Some people have a tendency to apply excessive occlusal force which leads to more causing pulpal pathology, occlusal tooth wear disharmony, esthetic disfigurement and impaired function (2). Restoration of a compromised dentition is a challenge which a dentist faces many times (3). The distribution of the forces should be taken into consideration as it will have a great impact on the longevity of the dentition(4). Uneven distribution of force results in trauma from occlusion (5) and periodontal problems (6). It happens due to occlusal interferences (7) and excessive height of the occlusal restoration (8) (9). Occlusal interference is any tooth contact that inhibits the remaining occluding surfaces from achieving stable and harmonious contacts (10). There are many indicators which help to evaluate the occlusal interferences (11). They can further be classified into quantitative indicators and qualitative indicators.

### **Quantitative indicators**

- Articulating paper
- Articulating silk
- Articulating film
- Metallic shim stock film
- High spot indicator

# **Qualitative indicators**

- T-Scan occlusal analysis system
- Virtual dental patient

The most commonly used occlusal indicator which most of the practitioners use is articulating paper (12). Articulating papers are available in different widths and thicknesses with dyes impregnated in them (13) (13,14). The articulating paper mainly consists of a colouring agent and a bonding agent.(15) When occlusal contact

takes place, the colouring agent is expelled from the articulating paper and the bonding agent helps the tooth to retain the colour which helps to reduce the occlusal interferences. The principle behind articulating paper is the relation between size and colour depth of the marking (16). It is believed that darker marking indicates heavy occlusal force and lighter marking indicates lesser occlusal force (17). This leads to a lot of errors in contact force level as the size and colour of the mark does not indicate the intensity of occlusal force. Also, it cannot be used repeatedly as the colouring agent inside the articulating paper fades (18). Another disadvantage of the articulating paper is that it does not give any idea about contact timing and duration (19). Saliva also contributes to the errors in recording contacts with the articulating paper, hence a dry field has to be maintained while using an articulating paper.

Due to all these shortcomings, other indicators were brought into use which was below the thickness perception level of most of the patients. One of them was the T-scan<sup>TM</sup> ??. The T-scan<sup>TM</sup> occlusal analysis system was developed by Professor William L Mannes in the year 1987 after which it evolved over a period of 30 years(20). The first commercially available T-scan<sup>TM</sup> was T scan<sup>TM</sup> I in 1984, followed by T-scan<sup>TM</sup> II for Windows in 1995 to T-Scan<sup>TM</sup> III (software versions 5, 6, and 7) in 2004, with the development of Turbo recording in 2008, to the latest version in 2014 known as T-Scan<sup>TM</sup> 8 (Tekscan Inc. South Boston, MA, USA ). It is a computerized system which contains a hand-held device with a flat U-shaped pressure measuring sensor and computer software. The sensor is an electronically-charged thin film centre which is enclosed by a Mylar case and which can acquire 256 levels of occlusal contact relative force as a patient intercuspation, or makes excursive movements across its

recording surface. The main application of the sensor is to register the occlusal force. It analyses the occlusal force quantitatively and records the biting force on individual teeth. It records the occlusal contacts sequentially in terms of time and the force which is associated with the occlusal contact. The sensor foil is 60um thick consisting of an X-Y coordinate system. It has 1500 receptor points made of conductive ink which are highly sensitive and which are subjected to elastic deformation. When the patient bites on the sensor, because of the force applied the particles come to get closer to each other. This results in reduction of the electrical resistance which is recorded quantitatively. (21), (22) Graphical interface is used by the software to showcase the features which will help to analyse the occlusal contact. It is similar to the toolbar icon used in Windows (23) The T-scan<sup>TM</sup> sensors are available in two sizes: the smaller size can be used in arches which are 58mm wide and 51mm deep and the larger sensor is used in arches which are 66mm wide and 61mm (24). It has certain limitations like the thinnest sensor is 0.1mm which is thicker than the articulating paper. Also, while recording the force from a sharp cusp, the entire force is concentrated on a small area which may damage the sensor.

Very few studies are done which compares the efficiency of articulating paper against T-scan<sup>TM</sup> in evaluating occlusal force and occlusal contact. Hence this systematic review is an effort to compare the efficiency of T-scan<sup>TM</sup> in comparison to articulating paper in occlusal analysis.

# Aim

The aim of the current review is to systematically analyse the scientific evidence of the past and present articles and studies showing the comparison between efficiency of articulating paper versus T-scan<sup>TM</sup> in

evaluating occlusal force and occlusal contacts in patients undergoing dental treatment.

## **Materials and Methods**

# **Structured Question**

The question that needs to be assessed in this review is-"Is the use of T-scan<sup>TM</sup> more effective than articulating papers in evaluating occlusal force and occlusal contacts in patients requiring dental treatment."

#### **PICO Analysis**

- **Population:** Patients undergoing dental treatment.
- Intervention: T-scan<sup>TM</sup>
- Comparison: Articulating paper
- **Outcome:** Occlusal force and occlusal contacts.

## **Searched Databases:**

- PubMed
- Cochrane
- Google scholar
- Medline
- Embase
- Science direct

No limitation regarding publication type and publication date was set.

# Hand Searching

The following journals were hand searched for articles on the subjects of interest to complete the review:

- The Journal of Prosthetic Dentistry
- Journal of Oral Rehabilitation
- Journal of Advanced Technologies and Techniques
- Journal of Medical Sciences
- Journal of Prosthetic and Restorative Dentistry
- Journal of Indian Prosthodontic Society
- European Journal of Prosthetic and Restorative Dentistry
- Journal of Advanced Prosthodontics

. . . . . . . . . . .

#### **Article Eligibility Criteria**

Inclusion Criteria

• In vivo studies

- Articles comparing between articulating papers and T-scan<sup>TM</sup>
- Review articles
- Case reports
- In-vitro studies

**Exclusion Criteria** 

# Search Strategy

The following search strategy was performed based on the search terms from pico.

Р	(Attrition) OR Attrited teeth) OR Abrasion) OR Abraded teeth) OR Erosion) OR Eroded
Search by inclusion (OR)	teeth) OR Abfraction) OR Abfracted teeth) OR Compromised teeth) OR Compromised
	dentition) OR Loss of vertical dimension) OR Collapsed vertical dimension) OR
	Collapsed bite) OR Establishing new bite) OR Full mouth rehabilitation) OR
	Malocclusion) OR Malaligned teeth) OR Incorrect centric relation) OR Compromised
	bite) OR Compromised occlusion) OR Incorrect vertical dimension) OR Bruxism) OR
	Clenching) OR Premature contacts) OR High points in occlusion) OR Patients requiring
	dental treatment))
AND	
Ι	(Occlusal indicators) OR T-scan) OR T-scan system) OR T- scan II) OR T-scan III) OR
Search by inclusion (OR)	Tekscan) OR Tekscan system) OR T-scan occlusal analyser) OR Tekscan occlusal
	analyser) OR Occlusal analyser) OR Digital occlusal analyser) OR Computerized occlusal
	analyser) OR Occlusal registration device) OR Occlusion registration device) OR
	Occlusion analysis system) OR Occlusal analysis system) OR Digital occlusal analysis
	system) OR Digital occlusion analysis system) OR Computerized Occlusal Analysis
	system) OR Computerized occlusion analysis system) OR Pressure indicator) OR Pressure
	indicating device) OR Force indicator) OR Force indicating device))
AND	
С	(Articulating paper) OR Articulating film) OR High point indicator) OR Occlusal
Search by inclusion (OR)	markers) OR Carbon marking paper))
AND	

0	(Bite force) OR Biting force) OR Occlusal load) OR Occlusion) OR Occlusal force) OR
Search by inclusion (OR)	Occlusal registration) OR Reliability) OR Validity) OR Occlusal adjustments) OR
	Accuracy) OR Intensity of occlusal contacts) OR Chewing efficiency) OR Biting strength)
	OR Food consistency) OR Occlusal force distribution) OR Masticatory force) OR
	Masticatory efficiency) OR Occlusal contact) OR Contact area) OR Occlusal contact area)
	OR Interceptive contacts) OR Contact point) OR Contact points) OR Dental occlusion)
	OR Occlusal function) OR Occlusion analysis) OR Occlusal analysis) OR Analysing the
	occlusion) OR Occlusal diagnosis) OR Diagnosing the occlusion) OR Mastication) OR
	Force percentage) OR patient comfort) OR Patient satisfaction) OR Occlusal correction)
	OR Correction of occlusion) OR Occlusal harmony)

# **Results and Discussion**

The above search strategy suggested 19 articles for evaluation. After hand search, we were not able to identify any more related articles and so the 19 articles were analysed independently by the two reviewers based on a standard checklist to determine the internal validity and the fulfillment of the inclusion criteria 1 study was excluded based on title and abstract and 1 was common in 2 database searches. Out of the remaining 17 studies, 15 were excluded based on the inclusion and exclusion criteria (Table x) of our interest and 2 were included on the basis of core data (Table 1). The 2 articles were reviewed and were consolidated as depicted in the flowchart. There was a disagreement between the two reviewers regarding the inclusion of 4 studies (cite them). Hence a third reviewer was invited to decide on these articles. Finally, all 4 of them were excluded since they did not evaluate the outcomes required for comparison.



Figure 1: Flowchart depicting the search methodology describing the total number of articles obtained, the ones excluded, inclusion of handpick articles and the total number of articles that were retrieved for analysis.

Page Z

Sn.	Author and Year	Study design	Reason for exclusion
1	Augusti D, 2015	Crossover clinical trial	Different intervention
2	Francova K, 2015	Crossover clinical trial	Different intervention
3	Harlurl SB, 2013	Prospective Cohorts	Difference in intervention and outcome measures
4	Venugopalan SK, 2012	Retrospective Cohorts	Different Intervention

Table 1: Table showing excluded studies (In-vitro studies table is separate)

5	Forrester SE, 2011	Prospective Cohorts	Difference in intervention and outcome measures
6	Kerstein RB, 2008	Literature review	Review is excluded
7	Forrester SE, 2009	Crossover clinical trial	Difference in intervention and outcome measures
8	Dimova M, 2012	Crossover clinical trial	No comparison between articulating paper and T-scan in results table
9	Reddy Chaitanya, 2019	Crossover clinical trial	No comparison between articulating paper and T-scan in results table
10	KS Vesma, 2017	Crossover clinical trial	No comparison between articulating paper and T-scan in results table
11	B Thanathorn Wong, 2017	Crossover clinical trial	No comparison between articulating paper and T-scan in results table

# **Data extraction**

The data of the selected studies was extracted using standardized abstraction tables. data extraction form. The articles were consolidated and general information was extracted (Table 2). Information extracted from each study included the following in one table as general characteristics of the study: 1) Author and year 2) Study design 3) Sample size 4) Groups 5) Types of statistical methods used 6) Outcome measures 7) Inference (Table 3). The general information was extracted for the in-vitro studies (Table 4) and the results and inference were given in a separate table (Table 5). The outcome variables of the extracted data from the studies were interpreted in detail. The level of evidence according to Oxford Centre for Evidence-Based Medicine 2011 was also tabulated (Table 6).

Table 2: Showing the general information of all the included articles in the systematic review used in those studies.

Sn.	Author	Journal	University/	Country	Type of	Funding	Method 1	Method 2	Model	Articulators	Additional
	and	Name	Private		Study	source	(Type)	(Type)	Material	Used	Softwares
	Year		Practice						and		and
									Articulato		instrument
									rs used		s used
1	Gokhan	Journal	Ege	Izmir,	Non	Not	Not	Not	Not	Sam II	Not
	Oncag,	of	University	Turkey	randomized	mentioned	mentioned	mentioned	mentioned		mentioned
	2002	Medical			clinical trial						
		Sciences									

2	I.P	Med J	Command	Lucknow	Non	GOI	Articulating	T-scan III	Not	Not	Adobe
	Majithi	Armed	Military	, India	randomized	DGAFMS	paper		mentioned	mentioned	Photoshop
	a ,2014	Forces	Dental		clinical trial		(Products				CS4
			Centre				Dentaires SA				
							Vevey,				
							Switzerland)				

Table 3: Table showing the data extraction of all the included articles in the systematic review and outcome measures used in those studies.

Author and	Sample	Population	Group 1	Group 2	Type of	Outcome	Group 1	Group 2	Inference	Risk of
Year	size	Description			statistics	Measures	Results	Result		Bias
					used					
Gokhan	Cohort	9 girls and	SAM II	T-scan	Not	Number of	Before	Before	Group 1	Size of
Oncag et al,	Clinical	11 boys	Articulator +		mentioned	contacts	adjustment=	adjustment=	more	marking is
Journal of	trial	13-15 years	articulating				15.2±9.12	7.1±2.42	sensitive	subjective.
Medical	n=20	Received	paper.				After	After	than group 2	
Sciences		non-					adjustment=	adjustment=		
2002		extraction					19±11.25	9.2±3.67		
		orthodontic								
		treatment								
I.P Majithia	Cohort	Above 21	Normal	Maxillofa	Regression	Coincidence	Group	Group	Authors	There are
,2014	Clinical	years	Dentulous	cial	Analysis	rates	1=80%	2=87%	conclude T	no metrics
	trial	Complete	patients	trauma		between	coincidence	coincidence	scan is more	to validate
		set of		cases		articulating	between	between	reliable.	their
	n=30	permanent				paper and T-	Articulating	Articulating		claims.
		maxillary				scan in	paper and T-	paper and T-		
		and				evaluating	scan	scan		
		mandibular				number of				
		teeth				contacts.				

Table 4: Showing the general information of all the in vitro studies in the systematic review used in those studies.

. . . .

Sn.	Author	Journal	University/	Countr	Type of	Funding	Method 1	Method 2	Model Material	Articulators	Additional
	and Year	Name	Private	у	Study	Source	(Type)	(Type)	and Articulators	Used	Softwares
			Practice						used		and
											instruments
											used

1	Rod	Journal of	Private	Utah,	Invitro	Dennis	Accufilm	T-scan II	Dental	stone	Wide Vue	Not
	Andrus,	Advanced	Practice	United		Weir,	II- 23µm		Type III		articulator	mentioned
	2019	Dental		States		DDS, MA	(Parkell,N				(Waterpik,	
		Technologi		of		Certificate	YUSA)				Fort	
		es and		Americ		in	Shimstock				Collins,	
		Techniques		a		Prosthodo	foil- 8µm				USA)	
						ntics	(Coltene,					
						(monetary	Waldent,					
						help not	OH USA)					
						mentioned						
						)						
2	Ahmet	Journal of	Ege	Izmir,	Invitro	Not	Articulatin	Tekscan	Casts	were	Dentatus	Universal
	Saracoglu,	Prosthetic	University	Turkey		mentioned	g paper-		fabricated	from	(Hagersten,	testing
	2002	Dentistry					60 µm		acrylic	resin	Sweden)	machine
							Bausch		(Vertex:			(Autograph,
							Inc,		Dentimex	BV,		AG-50 Kng;
							Nashua,		Zeist, Holla	nd)		Shimadzu
							NH.					Co, Kyoto,
							Articulatin					Japan)
							g paper-					
							65 μm					
							Svedia					
							AB,					
							Enkoping,					
							Sweden.					
							Articulatin					
							g paper 8					
							µm, Hanel					
							GmbH					
3	Shravya	JMIR	Oxford	Banglo	In vitro	Oxford	Articulatin	T-scan III	Solid metal	die	Not	MOTIC
	Reddy,20	Biomedical	Dental	re,		Dental	g paper-				mentioned	Software
	18	Engineerin	College	India		College	40 μm					(Motic
		g					Bausch.					microscopy,
												Hong Kong)
												Adobe
												Photoshop
												CS4

1												
	4	Inigo de	BioMed	University	Spain	In vitro	Gipuzkoa	Arti-fol 8	T-scan	Die Stone Type	Not	ATOS
		Prado,201	Research	of the			Provincial	μm		IV	mentioned	Compact
		8	Internationa	Basque			Council					Scan
			1	Country								Go!SCAN
												3D
												Geomagic
												studio 2014

Table 5: Table showing the data extraction of the in-vitro in the systematic review and outcome measures used in those studies.

Sn.	Author and Year	Sample size	Populatio Descriptio	n on	Group 1	Group 2	Type of statistics	Outcome Measures	Group 1 Results	Group 2 Results	Inference	Risk of Bias
							used			L.		
1	Rod	n=40	Casts	obtained	Articulati	T-scan	Paired	Force	Group 1	Group 2	Significantly	The
	Andrus,		from	patients	ng paper		sample t	distributi	=2.52±3.3	$=6.51\pm2.$	better	correspondi
	Journal of		with	Stable			test	on	1	88	occlusal	ng author is
	Advanced		Asympto	matic							force	a clinical
	Dental		occlusion	l							percentage	consultant
	Technolog		Equal nu	mber of							equality was	to the
	ies and		teeth bila	terally							obtained	company
	Technique										with T-scan	Tekscan,
	s 2019										than	Inc
											articulating	
											paper.	
2	Ahmet	n=30	Fully	dentate	Articulati	T-scan	2 way	Number		Group	Bausch	The
	Saracoglu,		maxillary	and	ng paper		ANOVA	of contact		2=8.0	Articulating	localization,
	Journal of		mandibul	ar				points	Group		paper	number and
	Prosthetic		dentate	casts			Kruskal		1=16.7		showed	distribution
	Dentistry		fabricated	l from			Wallis				higher	of contacts
	2002		acrylic re	sin			test				number of	was not
											contact	taken into
											points and	consideratio
											the T-scan	n.
											recorded	
											comparativel	
											y fewer	
											contact	
											points.	

- -

....

3	Shravya	Not	Dentulous	Articulati	T-scan	ANOVA	Area of	Group 1	Group 2	Size of	Subjectively
	Reddy,	mention	maxillary and	ng paper			contact	=159.67±2	=31.83±	articulating	defining
	JMIR	ed	mandibular die			Student t	with	8.22	1.60	paper is not a	and
	Biomedica					test	respect to			reliable	sketching
	1						force			predictor of	the
	Engineerin					Pearson				actual load	boundary of
	g 2018					correlati				whereas T-	the marked
						on				scan	area with
						coefficie				provides	MOTIC
						nt				more	software.
						method				predictable	False
										results of the	positive
										actual load.	markings
											due to
											smudging
											of the
											markings
4	Inigo de	n=11	Fully dentate	Articulati	T-scan	Shapiro	Number	Group 1 in	Group 2	Articulating	Errors
	Prado,		maxillary and	ng paper		Wilk test	of contact	lower	in lower	paper will	committed
	BioMed		mandibular casts				points	cast=24	cast=20.	bring more	in the
	Research						and		5	accuracy to	scanning of
	Internation						coinciden	Group 1 in	Group 2	the	dental
	al 2018						ce rates	upper	in upper	positioning	arches
								cast=26	cast=21	of occlusal	Prototyping
										contacts	and locating
								Coinciden	Coincide	while the T-	of dental
								ce rate in	nce rate	scan will	arches
								lower	in upper	show	Limitations
								arch=85.42	arch=80.	dynamic data	of
								%	77%	and changes	articulating
										in the	paper and
										contacts	T-scan
										during the	contact
										entire bite.	detecting
											systems

 $_{\text{Page}}301$ 

Table 6: CEBM level of evidence

Sn.	Study	Study design	CEBM level of evidence
1	Gokhan Oncag, 2002	Non randomized clinical trial	Level 3
2	I.P Majithia ,2014	Non randomized clinical trial	Level 3

Reliability and reproducibility of occlusal analysis is one of the most important things for a dentist in terms of dental treatment. The current literature which is describing the conventional occlusal indicator clearly indicates that some newer methods need to be used which is more reliable and accurate in providing information on both static and dynamic occlusal contacts (25). From the recent literature, it is evident that conventional occlusal indicators like the articulating paper give information only about the size and location of the premature contacts whereas the T-scan<sup>TM</sup> has the ability to quantify the timing as well as the force of occlusal contact (26).

In this systematic review, a total of 2 articles have been reviewed comparing articulating paper and T-scan<sup>TM</sup>. The included 2 studies are non-randomized clinical trials- (Gokhan Oncag, 2002), (I.P Majithia, 2014). The parameters included in the studies were the number of contact points and the coincidence rates between the two methods. A Meta-analysis could not be performed with the studies included as the outcome parameters in the included studies were different and the number of included articles was less. Both studies showed contrasting results. Although T-scan is shown to be a more efficient tool in evaluating the occlusal contacts and occlusal force in laboratory settings, one of the included studies concluded that articulating paper showed better results as compared to T-scan. The possible reason can be the subjective interpretation of the marks produced by the articulating paper. Another possible reason which can add onto the risk of bias is the diverse varieties in articulating paper. There are different types of articulating papers with different thickness. In the included articles, very few types of articulating paper are discussed. Hence, generalising the results can lead to bias. Due to contradictory results, more number of studies should be done to provide conclusive evidence.

Occlusal contacts play a vital role in masticatory apparatus. In the intercuspal position, there is the most amount of tooth contact which helps in maximum breakage of food(27). There is a strong association seen between the degree of intercuspal contacts and the chewing strokes (27–29). Also, proper intercuspation leads to a stable occlusion, otherwise which can cause temporomandibular disorders. Hence, the occlusal contacts form the basis of biodynamics in dental occlusion.

It has become necessary to measure the occlusal forces and contacts with T-scan<sup>TM</sup> to homogenize the force distribution between the left and right sides of the arch. Traditional methods such as articulating paper cannot quantify the force and cannot be a reliable aid in equilibrating occlusion as they are subjective (30,31). There are many studies which relate the size of the paper mark and the percentage of force (32). The size of the paper mark can vary according to the tooth morphology. Hence tooth morphology only gives information about the size of the paper mark size and not the percentage of force.

In-vitro studies were cited separately and not in the main table as in-vitro studies dilute the homogeneity of the study. There were 4 in vitro studies in the present study-(Rod Andrus, 2019), (Ahmet Saracoglu, 2002), (Shravya Reddy, 2018) and (Inigo de Prado, 2018). The parameters which were included in the present study were Force distribution, area with respect to force and number of contact points. 3 out of 4 studies concluded that T-scan is more reliable and efficient in evaluating occlusal force and occlusal contact. Although the invitro studies spoke in favour of the T-scan, it is important to verify the results with clinical trials.

Halperin (33) and Gazit (34) have concluded from their studies that there is no relation between characteristic of paper mark and occlusal force. Afrashtehfar and Qadeer (35) have reported that T-scan provides force which can be quantified and variations in time from the initial contact to maximum intercuspation. Bozhkova (36) reported that T-scan is an accurate tool to determine and evaluate the sequence of time and the magnitude of force of occlusal contacts by converting the qualitative data into quantitative data and displaying them digitally. There have been some studies which have discussed the limited use of T-scan. Harvey, Hatch and Osborne (21) have reported that sensors work precisely in recording occlusal interference not more than 2 or 3 times. After that, the precision is reduced. Patkyl(37) reported that the sensor of the T-scan was very variable and its resolution capacity was compromised due to the thickness of the sensor and limited flexibility. Yamamura and Takahashi (38) had doubts about the reliability of the sensor which will result in inaccurate recordings. On the contrary, Maness and Podoloff (20) and Reza and Neff (39) reported that the sensors of T-

scan have 100% precision level. Combadazou, Combelles and Cadenat (40) reported that T-scan is effective in occlusal diagnosis and follow-up. It has been reported by Patyk et al(37,41) that due to the flexibility of the T-scan sensors, there is a high possibility of uncontrolled shift of the mandible, which might give false results in terms of force dissipation. Although all these articles gave adequate information on the efficiency of articulating paper and T-scan<sup>TM</sup>, they had certain limitations. All these studies have been done with the older version of T-scan<sup>TM</sup> after which it has evolved over the period of years. All the studies which are included in this systematic review do not have adequate follow up. Hence, more number of studies should be done in patients with a longer follow up to evidently conclude the superiority of T-scan<sup>TM</sup> over articulating paper for evaluation of occlusal contacts and occlusal force.

# Conclusion

Based on the current evidence, it can be suggested that there is no significant improvement to recommend Tscan<sup>TM</sup> as the gold standard for occlusal analysis in comparison to articulating paper in occlusal analysis. Hence more number of clinical studies are required with longer follow up.

Acknowledgement: We would like to acknowledge Saveetha dental college and hospital for providing complete patient details required for the study purpose and their constant help and support for this research.

# References

. . . . . . .

- Song M-Y, Park J-M, Park E-J. Full mouth rehabilitation of the patient with severely worn dentition: a case report. J Adv Prosthodont. 2010 Sep;2(3):106–10.
- 2. Turner KA, Missirlian DM. Restoration of the extremely worn dentition. J Prosthet Dent. 1984

Oct;52(4):467–74.

- Zou L, Cherukara G, Hao P, Seymour K, Samarawickrama DYD. Geometrics of tooth wear [Internet]. Vol. 266, Wear. 2009. p. 605–8. Available from: http://dx.doi.org/10.1016/j.wear.2008.04.062
- Duyck J, Van Oosterwyck H, Sloten JV, De Cooman M, Puers R, Naert I. Magnitude and distribution of occlusal forces on oral implants supporting fixed prostheses: an in vivo study [Internet]. Vol. 11, Clinical Oral Implants Research. 2000. p. 465–75. Available from: http://dx.doi.org/10.1034/j.1600-0501.2000.011005465.x
- Brandini DA, Trevisan CL, Panzarini SR, Pedrini D. Clinical evaluation of the association between noncarious cervical lesions and occlusal forces. J Prosthet Dent. 2012 Nov;108(5):298–303.
- Ishigaki S, Kurozumi T, Morishige E, Yatani H. Occlusal interference during mastication can cause pathological tooth mobility. J Periodontal Res. 2006 Jun;41(3):189–92.
- Korioth TW. Number and location of occlusal contacts in intercuspal position. J Prosthet Dent. 1990 Aug;64(2):206–10.
- Eliyas S, Martin N. The management of anterior tooth wear using gold palatal veneers in canine guidance. Br Dent J. 2013 Mar;214(6):291–7.
- Parker MW. The significance of occlusion in restorative dentistry. Dent Clin North Am. 1993 Jul;37(3):341–51.
- Agerberg G, Sandstro<sup>--</sup>m R. Frequency of occlusal interferences: A clinical study in teenagers and young adults [Internet]. Vol. 59, The Journal of Prosthetic Dentistry. 1988. p. 212–7. Available from: http://dx.doi.org/10.1016/0022-

3913(88)90017-0

- Sharma A, Rahul GR, Poduval ST, Shetty K, Gupta B, Rajora V. History of materials used for recording static and dynamic occlusal contact marks: a literature review. J Clin Exp Dent. 2013 Feb 1;5(1):e48–53.
- Qadeer S, Kerstein R, Kim RJY, Huh J-B, Shin S-W. Relationship between articulation paper mark size and percentage of force measured with computerized occlusal analysis. J Adv Prosthodont. 2012 Feb;4(1):7–12.
- Schelb E, Kaiser DA, Brukl CE. Thickness and marking characteristics of occlusal registration strips [Internet]. Vol. 54, The Journal of Prosthetic Dentistry. 1985. p. 122–6. Available from: http://dx.doi.org/10.1016/s0022-3913(85)80086-x
- Zuccari AG, Oshida Y, Okamura M, PaezCY, Moore BK. Bulge ductility of several occlusal contact measuring paper-based and plastic-based sheets. Biomed Mater Eng. 1997;7(4):265–70.
- Carey JP, Craig M, Kerstein RB, Radke J. Determining a relationship between applied occlusal load and articulating paper mark area. Open Dent J. 2007 Jul 23;1:1–7.
- Sutter BA. A digital poll of dentists testing the accuracy of paper mark subjective interpretation. Cranio. 2018 Nov;36(6):396–403.
- McNeill C. Science and Practice of Occlusion. Quintessence Publishing (IL); 1997. 538 p.
- Helms RB, Katona TR, Eckert GJ. Do occlusal contact detection products alter the occlusion? J Oral Rehabil. 2012 May;39(5):357–63.
- Kerstein RB. Time-Sequencing and Force-Mapping with Integrated Electromyography to Measure Occlusal Parameters [Internet]. Clinical Technologies. p. 895–916. Available from:

. . . . . . . .

- http://dx.doi.org/10.4018/978-1-60960-561-2.ch318
- Maness WL, Podoloff R. Distribution of occlusal contacts in maximum intercuspation. J Prosthet Dent. 1989 Aug;62(2):238–42.
- Harvey WL, Osborne JW, Hatch RA. A preliminary test of the replicability of a computerized occlusal analysis system [Internet]. Vol. 67, The Journal of Prosthetic Dentistry. 1992. p. 697–700. Available from: http://dx.doi.org/10.1016/0022-3913(92)90174-9
- Olivieri F, Kang K-H, Hirayama H, Maness WL. New method for analyzing complete denture occlusion using the center of force concept: A clinical report [Internet]. Vol. 80, The Journal of Prosthetic Dentistry. 1998. p. 519–23. Available from: http://dx.doi.org/10.1016/s0022-3913(98)70025-3
- Kerstein RB. Current applications of computerized occlusal analysis in dental medicine. Gen Dent. 2001 Sep;49(5):521–30.
- Kerstein RB, Lowe M, Harty M, Radke J. A force reproduction analysis of two recording sensors of a computerized occlusal analysis system. Cranio. 2006 Jan;24(1):15–24.
- Davies S, Al-Ani Z, Jeremiah H, Winston D, Smith P. Reliability of recording static and dynamic occlusal contact marks using transparent acetate sheet [Internet]. Vol. 94, The Journal of Prosthetic Dentistry. 2005. p. 458–61. Available from: http://dx.doi.org/10.1016/j.prosdent.2005.08.020
- Maness WL. Laboratory comparison of three occlusal registration methods for identification of induced interceptive contacts [Internet]. Vol. 65, The Journal of Prosthetic Dentistry. 1991. p. 483–7. Available from: http://dx.doi.org/10.1016/0022-3913(91)90284-4

- 27. Pameijer JHN, Glickman I, Roeber FW. Intraoral Occlusal Telemetry III. Tooth Contacts in Chewing, Swallowing and Bruxism [Internet]. Vol. 40, Journal of Periodontology. 1969. p. 253–8. Available from: http://dx.doi.org/10.1902/jop.1969.40.5.253
- Gibbs CH, Mahan PE, Lundeen HC, Brehnan K, Walsh EK, Sinkewiz SL, et al. Occlusal forces during chewing—Influences of biting strength and food consistency [Internet]. Vol. 46, The Journal of Prosthetic Dentistry. 1981. p. 561–7. Available from: http://dx.doi.org/10.1016/0022-3913(81)90247-x
- Ahlgren J, Öwall B. Muscular activity and chewing force: A polygraphic study of human mandibular movements [Internet]. Vol. 15, Archives of Oral Biology. 1970. p. 271–IN1. Available from: http://dx.doi.org/10.1016/0003-9969(70)90053-1
- Dawson PE. Evaluation, Diagnosis, and Treatment of Occlusal Problems. Mosby Incorporated; 1989.
  633 p.
- Kerstein RB, Neff PA. A Comparison of Traditional Occlusal Equilibration and Immediate Complete Anterior Guidance Development [Internet]. Vol. 11, CRANIO®. 1993. p. 126–40.
- 32. Saad MN, Weiner G, Ehrenberg D, Weiner S. Effects of load and indicator type upon occlusal contact markings. J Biomed Mater Res B Appl Biomater. 2008 Apr;85(1):18–22.
- Halperin GC, Halperin AR, Norling BK. Thickness, strength, and plastic deformation of occlusal registration strips. J Prosthet Dent. 1982 Nov;48(5):575–8.
- Gazit E, Fitzig S, Lieberman MA. Reproducibility of occlusal marking techniques. J Prosthet Dent. 1986 Apr;55(4):505–9.

- 35. Afrashtehfar KI, Qadeer S. Computerized occlusal analysis as an alternative occlusal indicator. Cranio. 2016 Jan;34(1):52–7.
- Bozhkova TP. The T-SCAN System in Evaluating Occlusal Contacts. Folia Med . 2016 Apr;58(2):122–30.
- Patyk A, Lotzmann U, Scherer C, Kobes LW. [Comparative analytic occlusal study of clinical use of T-scan systems]. ZWR. 1989 Sep;98(9):752–5.
- Yamamura M, Takahashi A, Aoki H, Takeuchi N, Endo Y, Tamaki K, et al. [A study on display and accuracy of occlusal contacts by means of T-Scan System]. Kanagawa Shigaku. 1990 Sep;25(2):236– 41.
- Reza Moini M, Neff PA. Reproducibility of occlusal contacts utilizing a computerized instrument. Quintessence Int. 1991 May;22(5):357– 60.
- Combadazou JC, Combelles R, Cadenat H. [The value of mandibular kinesiography and of T-scanning in the diagnosis and treatment of algo-dysfunctional syndrome of the temporomandibular joint]. Rev Stomatol Chir Maxillofac. 1990;91(2):86–91.
- Patyk A, Lotzmann U, Paula JM, Kobes LW. [Is the T-scan system a relevant diagnostic method for occlusal control?]. ZWR. 1989 Aug;98(8):686, 688, 693–4.
- WILLIAN, L. (1987). Computerized occlusal analysis: a new technology. Quintessence international, 18, 287-292.