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Effect of T-scan Occlusal Analysis and Adjustment Versus Articulating Paper on Stresses Transmitted to Single Mandibular Implant Supported Prosthesis

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Abstract

AIM: The study aimed to compare two different methods for occlusal analysis and adjustment of implant-supported prostheses (computerized T-scan and articulating papers) regarding the stresses transmitted to the implants.

MATERIALS AND METHODS: Seven patients with completely edentulous mandible opposing dentate maxilla have been selected and four implants have been inserted. Two identical mandibular zirconia implant supported prostheses have been constructed for each patient. Occlusal analysis and adjustments have been done using T-scan for one prosthesis and using articulating papers for the other prosthesis. Two identical acrylic casts for the mandibular arch (with four implant analogs on each cast) have been constructed for each patient. The prostheses on their acrylic casts were applied to cyclic loading using chewing simulator of 250,000 cycle (1 year loading). Strain gauges have been installed mesial and distal to each implant (28 implants of T-scan group and 28 implants of articulating paper group) and strain gauge analysis was conducted using the universal testing machine upon the application of bilateral and unilateral load after cyclic loading. Data were collected, tabulated, and statistically analyzed.

RESULTS: Higher micro strain values were found around implants among articulating paper group than T-scan group and that difference was statistically insignificant under bilateral loading and statistically significant under unilateral loading.

CONCLUSION: T-scan allows better occlusal stresses distribution as it brings additional information regarding force intensity and occlusal timing resulting in less stresses transmitted around implants.

Introduction

Despite the evolutions of both computer-based treatment advances and modern age dental materials, we have not overcome the traditional methods that are routinely used to examine the occlusion. To date, many dental practitioners continue to favour the use of articulating paper for analysis of the occlusion [1], [2]. Despite that, many dental practitioners recognize the importance of the occlusion when fabricating a dental prosthesis; dentists continue to rely on patient "feel" statements regarding the nature of the perceived occlusal contact comfort level, as an indicator of treatment correctness.

Unlike natural dentition, dental implants do not have shock absorption and cannot adapt according to the need of occlusal forces due to absence of periodontal ligaments. Hence, anticipated occlusal and chewing forces need to be taken under consideration for any implant-supported prosthesis. In addition, potential parafunctional mandibular movements should be noted. That is why many authors consider T-Scan

occlusal analysis system is helpful to meet the needs of patients for reliable measurement of occlusal biting forces for implant-supported prostheses [3], [4].

Recently, The T-scan computerized occlusal analysis system has been used to visualize the occlusal contact locations and the relative force intensity to ensure even distribution of forces. This system overcomes the limitations of articulating paper. The repeated errors of incorrect occlusal contact selection can be minimized that happen from depending only on the use of dental articulating paper and patient feel.

Some authors published a review about the history of the dental materials used for recording static and dynamic occlusal contacts and they have found about 17 methods used in prosthodontics.

Occlusal analysis methods can be qualitative or quantitative.

Qualitative occlusal analysis methods (conventional non digital methods):

These methods are conventional methods based on a qualitative evaluation. They are used as occlusal indicators for making occlusal adjustments.

The most commonly used non-digital occlusal indicators are as follows:

Articulation papers and articulating foils: That leaves ink marks on the teeth where occlusal contacts exist.

Shim-stock foils

Which are tugged and pulled from between the teeth, to detect withdrawal resistance that supposedly indicates the presence of forceful tooth contacts.

Elastomeric impression materials

Which, when injected between opposing teeth to locate occlusal contacts are displaced completely where there is tooth contact.

Occlusal wax sheets

Which are softened and then imprinted by opposing teeth. Wax perforations or apparent wax thinness indicate occlusal contact, or near contact [5].

Quantitative occlusal analysis methods (Computerized occlusal analysis):

Quantitative occlusal analysis methods are computerized methods attempt to provide a quantitative evaluation of occlusal contact's pressure. They use digital sensors to get information that is elaborated with dedicated software. The result is an intuitive graphic that identifies the position of contacts and the corresponding occlusal pressure intensity [6].

The T-Scan device allows the recording of the force and timing of occlusal contacts and represents a development for achieving correct occlusion [7], [8]. For that reason, there is an argument between some authors that argue that the use of T-scan is the only reliable method for occlusion analysis and other authors which have considered articulating paper enough to achieve correct occlusion especially that using T-scan is very costly for a simple dental practice.

Thus, the aim of this study was to compare between two different methods for occlusal analysis and adjustment of implant-supported prostheses (articulating papers and T-scan) regarding stresses transmitted around the implants.

Materials and Methods

Study participant and ethics

Seven male patients with completely edentulous mandible opposing dentate maxilla have been selected. The trial was registered on ClinicalTrails.gov (NCT05051878). This research was approved by the Research ETHICS Committee, Faculty of Oral and Dental medicine, Ain Shams University and with code: FDASU-Rec ID051902. All patients were informed about the purpose and the period of the study. Each patient was informed about the clinical and laboratory procedures of this study, they agreed to take part in the study, informed their legal duties toward this study, and an informed consent was signed by the patients. All participants were informed about their legal rights for having implant-supported mandibular prosthesis at the end of this study. Guidelines were followed according to the ethical committee of the institution for clinical trials.

Pre-surgical protocol

Lower complete single denture was constructed. Lower primary impression was taken to obtain study cast. Then, special tray was constructed and secondary impression was taken and poured with dental stone to obtain master cast. Lower occlusion block was constructed. Face-bow [1] record was made to mount the upper cast on a semi-adjustable articulator [2] and centric occluding relation record was recorded at a predetermined vertical dimension and used to mount the mandibular cast. Protrusive record was recorded to adjust the horizontal condylar guidance of the articulator.

Modified cross-linked acrylic teeth were arranged following the mutually protected occlusion (canine guided) with anterior guidance to follow natural dentition to reduce masticatory muscle strength during off-center movements. Light-cured composite resin was added to the labial surface and incisal cusp tip edge of the lower canines, the articulator was moved laterally to create free gliding movements between the upper and lower canines on the working side and disocclusion between all the other teeth.

The trial denture was tried in the patient's mouth then the waxed up lower denture was flasked and processed into heat-cured acrylic resin [3].

Using the processed mandibular denture, dual CBCT scan protocol was applied. The first scan was done for the lower denture while the second scan for the patient wearing the lower denture and biting in centric occlusion. The two scans were superimposed onto each other guided by radiopaque composite markers added to the labial and lingual flanges of the lower denture on the software that allows virtual implant planning then stereolithographic surgical guide was constructed.

Surgical protocol

For each patient, using the 3D surgical guide, four implants [4] were inserted in canines and first molar positions (Figures 1-3).
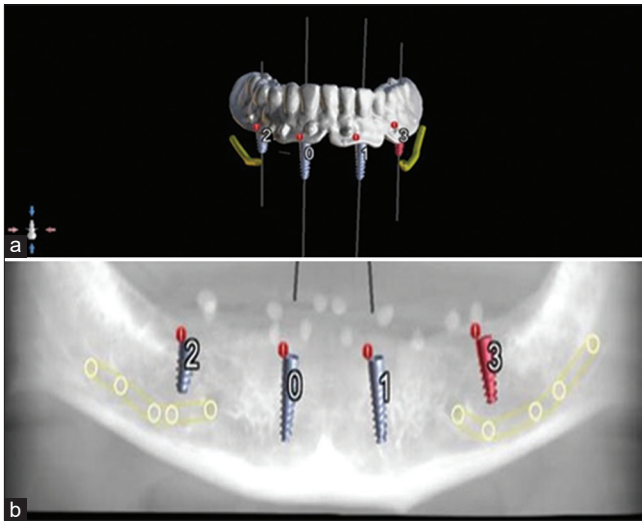
Figure 1: (a and b) Virtual implant planning

Figure 2: Surgical guide fixed on the mandibular arch by fixation screws

Figure 3: Healing abutments on the implants

Prosthetic protocol

Prosthetic loading started 3 months after implant placement. Open tray impression was taken and the impression was poured to obtain final stone cast [5].

The mandibular denture was sprayed with titanium oxide spray [6] and scanned with desktop extra-oral scanner (Figure 4). Scan abutments [7] were screwed on the implant analogs in the stone cast. Then, the transfer abutments were scanned with desktop extra-oral scanner [8]. Within the computer software [9], a prosthesis conforming to the mandibular denture was designed (Figure 5). Then, a prepolymerized PMMA [10] prosthesis was milled by computer-aided milled (CAM) [11] to be used to check passive fit, extensions, and pressure areas.

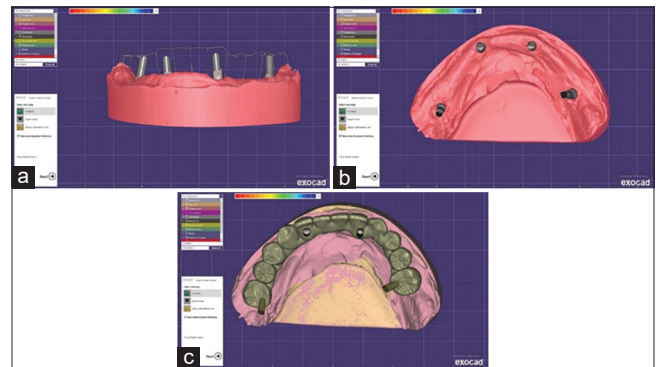Figure 4: Scanning of the lower denture on desktop scanner

Figure 5: (a-c) Planning and designing of the prosthesis on software

Occlusion was checked for correct centric occluding relation and anterior and lateral guidance. The PMMA prostheses were rescanned after finishing the necessary adjustments and another two PMMA were milled for occlusal adjustments as occlusal adjustments of PMMA are much easier than zirconia (Figures 6 and 7).

Occlusal adjustment

The patient received two prostheses: The first prosthesis was occlusally adjusted according to articulating paper occlusal analysis. The second prosthesis was occlusally adjusted according to T-scan occlusal analysis.

For the first prosthesis: Occlusion of PMMA was adjusted to follow mutually protected occlusion
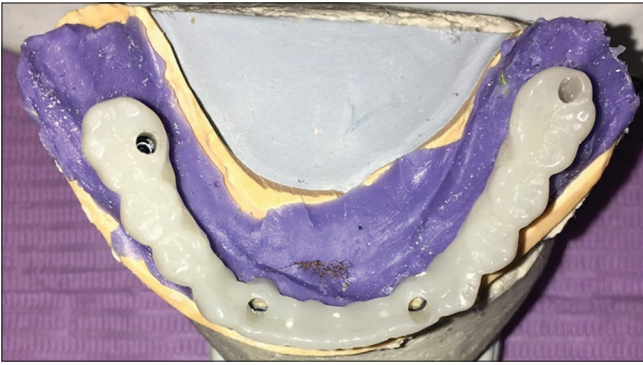
Figure 6: PMMA prototype on the stone cast

Figure 7: Two identical PMMA

(canine guided) with anterior guidance according to articulating paper analysis. Sequential use of articulating paper [12] has been done. Dryness to obtain a dry field to get obvious markings was done during articulating paper use. First, 65 micron horse-shoe articulating paper was used and the patient asked to bite (open and close) in centric many times repeatedly and heavy contacts have been removed. Then, 12 micron artifoil has been used in the same manner (Figure 8). After adjustments, the PMMA prosthesis was rescanned and final monolithic Zirconia prosthesis [13] was

manufactured. The zirconia prosthesis was screwed to the implants intraorally and final minimal occlusal adjustments were done guided by the sequential use of articulating paper in the same manner with the PMMA.

For the second prosthesis: Occlusion of PMMA was adjusted to mutually protected occlusion (canine guided) with anterior guidance according to T-scan [14] occlusal analysis. A periodontal probe was used to measure the width of the maxillary central incisor to determine the proper size of the sensor. The sensor was supported by the fork and connected to the T-scan hand piece which in turn was connected to the computer via USB cable, the main window of the software was opened to insert new patient data.

The patient was asked to sit in an upright and relaxed position. The sensor was placed in the patient's mouth and oriented so that the center pointer of the support fork was between the two central incisors and the handle was parallel to the occlusal plane (Figure 9). The patient was instructed to close, and the teeth contact was observed on the screen. Record button on the handle was pressed to start recording. The patient was instructed to bite down normally on the sensor for 2 s and then opened slowly. When recording was completed, the real time window became a 2D movie window, which was divided to two colored boxes (red right side and green left side) around the mid-sagittal plane showing the difference in biting force intensity on both sides. A 3D movie window, graph window and graph zoom window, were also automatically opened for the current movie showing color coded traces that represent the forces applied on each tooth, the distribution of the forces along the arch and teeth under heavy contact and premature contact in each of the colored boxes in the 2D movie window. Teeth with premature contact were reduced guided by the data displayed on the 3D graph. The process was repeated until nearly the contact between posterior teeth is equal in intensity and distribution in both sides of the arch. The same process was done to adjust contact at protrusive and lateral eccentric movements. After

Figure 8: Occlusal adjustment using articulating paper

Figure 9: Occlusal adjustment using T-scan

adjustments, the PMMA prosthesis was rescanned and final monolithic Zirconia prosthesis was manufactured. The zirconia prosthesis was screwed to the implants intraorally and final minimal occlusal adjustments were done guided by the T-scan in the same manner with the PMMA (Figures 10 and 11).
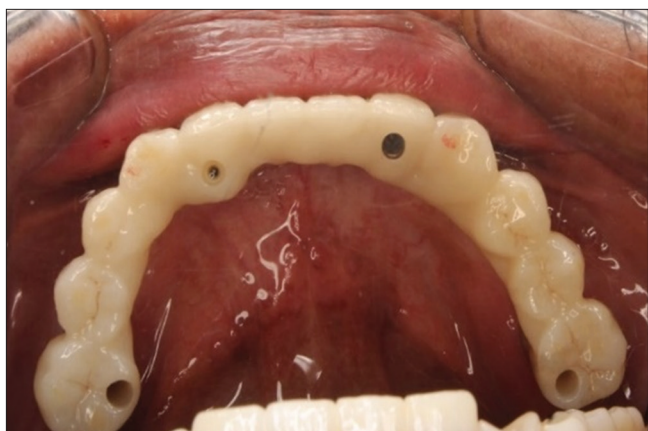

Figure 10: Two zirconia prostheses

Figure 11: Zirconia prosthesis screwed on implant intraorally

Duplication of acrylic models

The stone cast was duplicated to two acrylic casts using one of the zirconia prosthesis. The prosthesis was screwed on the implant analogues of the stone cast. Screw holes were blocked with Teflon to avoid impression material penetration to facilitate screw holes exposure. A stock tray has been perforated in front of screw holes. Silicone rubber base [15] has been used to make the impression. Screw holes were exposed to unscrew the prosthesis after the impression material has set and impression tray was removed. Dummy implants were screwed to the prosthesis in the impression.

The impression was poured with molten base plate wax [16] under mechanical vibration then left to harden. Cast in wax was processed to heat cured acrylic resin [17] model through flasking, wax elimination,

packing and curing using long cycle at 70°C for 9 h and left to bench cooling (Figure 12).
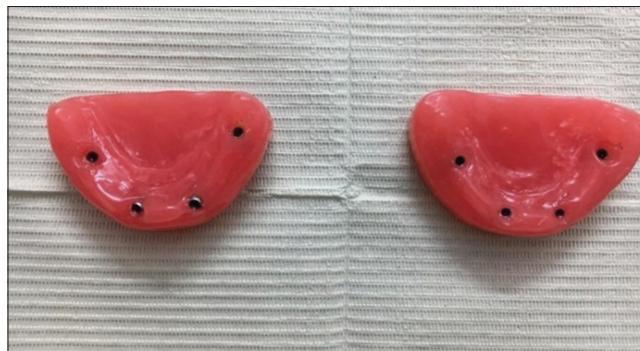

Figure 12: Two identical acrylic casts with dummy implants

New dummy implants with the same sizes were screwed to the prosthesis in the impression and another acrylic cast was poured in the same manner.

One of the two casts was marked with (T) later at its base to mark the cast that would be holding the T-scan adjusted prosthesis (Figure 13).
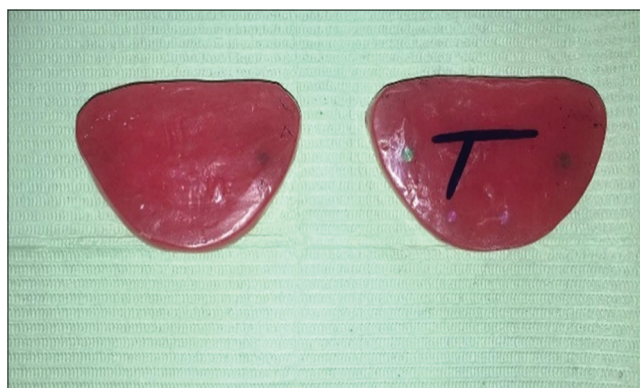

Figure 13: Marking the cast with t-scan prosthesis with letter (T)

Chewing simulation

The acrylic casts with the zirconia prosthesis were fixed to the chewing simulator. The specimen chamber was filled with artificial saliva (Figure 14).
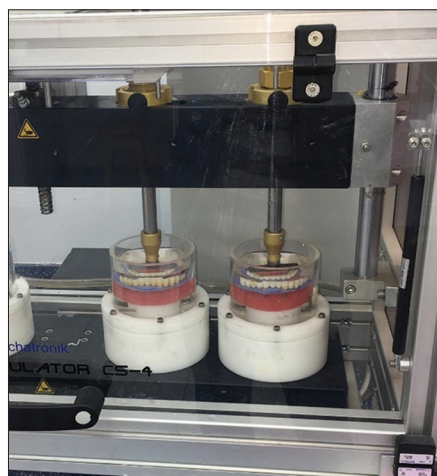

Figure 14: Prosthesis screwed on their acrylic casts and fixed to the Teflon holders in champers of the chewing simulator machine

The Chewing Simulator [18] was used to apply a dynamic cyclic loading bilaterally at load settings of 50 N and The software parameters were set at 60 mm/s speed, 3 mm vertical path, 0.7 mm horizontal path, and 1.6 Hz frequency. Each group was subjected to bi-axial cyclic loading for a total of 250,000 cycles (equivalent to 1 year loading).

Strain gauge installation

For each cast, grooves have been made 1 mm mesial and distal to each implant and strain gauges were installed in the grooves with delicate layer of cyanoacrylate base adhesive cement [19]. The strain gaugesv [20] used in this study had a length of 1 mm, width 2.4 mm and nominal resistance 120 Ohm connected to lead wires 100 cm in length (Figure 15).
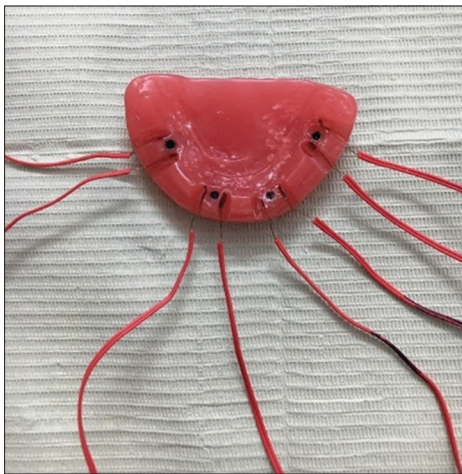

Figure 16: Applying bilateral force with T-shaped load applicator

Figure 15: Strain gauges installed mesial and distal to each dummy implant
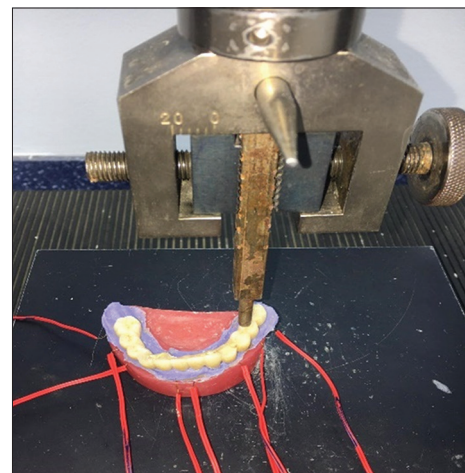
Figure 17: Applying unilateral force with chisel shaped on universal testing machine load applicator on universal testing machine

Load application

Universal Testing machine [21] was used for applying vertical static loads ranging between 0 and 100 Newton on the loading points bilaterally between the lower second premolar and the lower first molar and unilaterally on loading point between the right lower second premolar and first molar. A T-shaped load applicator was made to fit on the prosthesis bilaterally between the distal aspect of lower second premolar and mesial aspect of lower first molar (Figure 16), and a Chisel shaped load applicator was used to apply load unilaterally on the right side to represent the loaded side between second premolar and first molar (Figure 17).

For each prosthesis, the load applied was increased from 0 to 100 N at a constant rate of 0.5 mm/min. A four channel strain-meter was used to assess the microstrains induced by the load applied on the distal and mesial aspects of the implants.

Data were analyzed using the software (kyowa PCD-300A) and statistically analysed.

Statistical analysis methods

G*Power software for windows version 3.1.9.4 was used to calculate the sample size. Assuming a large effect size, a sample size of 28 implants in each group was calculated to have 95% power, α = 0.05, 1β = 0.95.

Statistical analysis was performed using the Statistical Package for the Social Sciences [22] version 26 for Windows. Mann-Whitney U-test was used to compare between two groups as data were not normally distributed. The significant level was set at p ≤ 0.05.

Results

Stress analysis during bilateral loading

Microstrains values induced mesial and distal to the implants during bilateral loading for each Group

are shown in (Table 1). Data are presented as mean, standard deviation (SD), and median values. Mann–Whitney U-test was used to compare between two groups. A probability level of p < 0.05 was considered statistically significant.

Table 1: Micro strains values induced mesial and distal to the implants during bilateral loading

Occlusion adjustment	Implants position	Implant side	Mean	SD	Median
T-scan	Canine	Mesial	51.79	19.159	50.00
		Distal	24.46	9.363	22.50
	Molar	Mesial	163.57	70.183	135.00
		Distal	356.96	291.615	230.00
Articulating paper	Canine	Mesial	48.04	4.159	47.50
		Distal	33.39	29.378	32.50
	Molar	Mesial	136.61	62.702	117.50
		Distal	576.25	459.026	447.50

The two groups were compared as shown in (Table 2) and (Figure 18). The mean rank of micro strains was found to be of lower value for T-scan group (114.46) than for articulating paper group (120.95) and the difference was found to be statistically non-significant p > 0.05.

Table 2: The mean rank and p-value of micro strains between both groups (bilateral loading)

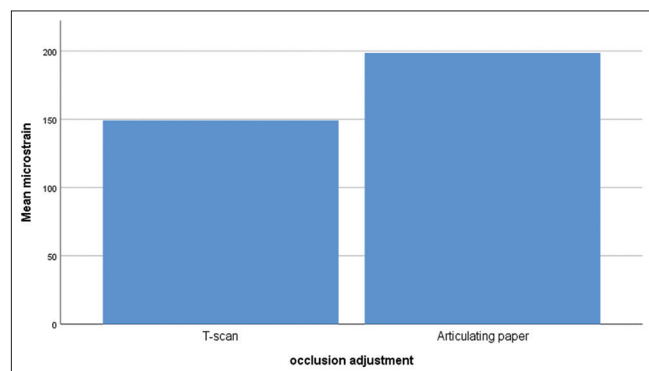| Occlusion adjustment	Mean rank	p-value
Microstrain		
T-scan	114.46	0.650
Articulating paper	120.95	

Figure 18: Bar chart of mean of microstrain under bilateral loading in both occlusion adjustment groups

Stress analysis during unilateral loading

Micro strains values induced mesial and distal to the implants during unilateral loading for each Group are shown in (Table 3). Data are presented as mean, SD and median values. Mann-Whitney U-test was used to compare between two groups. A probability level of p < 0.05 was considered statistically significant.

Table 3: Micro strains values induced mesial and distal to the implants during unilateral loading

Occlusion adjustment	Implant position	Mesial and distal	Mean	SD	Median
T-scan	Canine	M	27.50	23.999	22.50
		D	22.50	12.365	22.50
	Molars	M	183.93	182.685	140.00
		D	82.14	66.208	75.00
Articulating paper	Canine	M	17.14	6.712	20.00
		D	28.57	20.795	22.50
	Molars	M	285.71	300.978	132.50
		D	370.71	316.610	347.50

Comparing the two groups as shown in (Table 4) and (Figure 19). The mean rank of microstrains was found to be of lower value for T-scan group (23.34) than for articulating paper group (35.32) and the difference was found to be statistically significant p < 0.05.

Table 4: The mean rank and p-value of micro strains between both groups (unilateral loading)

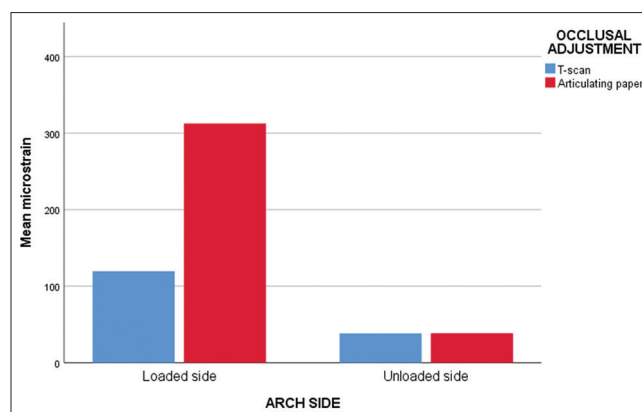| Occlusion adjustment	Mean rank	p-value
Microstrain		
T-scan	23.34	0.017
Articulating paper	35.32	

Figure 19: Bar chart of mean of microstrain under unilateral loading by loaded and unloaded arch sides by occlusal adjustment

Discussion

Fixed implant supported type of prosthesis was used in this study to avoid the effect of resiliency of the mucosa during occlusal analysis and occlusal adjustments [9]. To ensure standardization the two prostheses for each patient were CAM and the results compared only the different occlusal adjustments [10].

Occlusal adjustments were done on PMMA as it is easier and zirconia is more resistant than PMMA and to avoid surface flaws and micro-cracks that may be induced by grinding of the zirconia [11]. One of the zirconia prosthesis was used for duplication of the stone cast to ensure the duplication of the exact position and angulation of implants and to ensure the passive fit of the prostheses on the epoxy casts as it is on the stone cast [12].

The model was prepared from heat cure acrylic resin material which has appropriate modulus of elasticity and can stand the chewing simulation process [13].

Chewing simulators uses dynamic loading for producing cyclic fatigue that simulates masticatory function of humans [14]. These recent simulators can accurately reproduce mandibular movements in all planes and simulate all chewing movements after programming [15], [16]. The use of Glandosane artificial

saliva during chewing simulation was used in this study. As artificial saliva simulate the oral conditions [17]. All the strain gauges used in this study exhibited the same dimensions, resistance and gauge factors in order to obtain the same level of sensitivity to the applied load [18].

The use of bilateral posterior loading to simulate maximum intercuspation and unilateral posterior loading to simulate using one side as a working side like chewing activities that are usually carried out unilaterally as most patients use unilateral posterior loading during mastication and chewing [19].

The sample size was calculated by G*Power software for windows version 3.1.9.4 guide by a previous study and assuming a large effect size [20]. A sample size of 28 implants in each group was calculated to have 95% power, α = 0.05, 1β = 0.95.

In our study, we focused on evaluating the stresses transmitted to dental implants supporting the implant supported prosthesis as osseointegrated implants can be prone to occlusal overloading because of the absence of the periodontal ligaments and limited tactile sensitivity.

These results came with agreement with a study that aimed to digitally evaluate the static and dynamic occlusion of patients treated with both removable conventional complete dentures and implant-retained removable overdentures and to correlate two different methods of occlusal analysis. The distribution of the occlusal contacts in static and dynamic occlusion was compared by means of the digital method (T-Scan III) and the analog method (articulating paper) and the study came to a conclusion that the digital and analog methods showed a significant agreement and moderate correlation, irrespective of the type of complete denture. Also, they recommended that The T-Scan III digital system seems to be a consistent and reproducible method to analyze occlusion [21].

Another in vitro study was devised to determine whether a relationship exists between the occlusal load applied and the size of the markings produced from tooth contact when dental articulating paper and T-Scan are interposed alternatively. In that in vitro study, dentulous maxillary and mandibular dies were mounted on a metal jig and articulating paper and T-Scan sensor were placed alternatively between the casts. And they could not find a linear relationship between the applied load and the articulating paper mark area and concluded that the size of an articulating paper mark may not be a reliable predictor of the actual load content within the occlusal contact, whereas a T-Scan provides more predictable results of the actual load content within the occlusal contact [22].

Also, in our study, the mean stresses transmitted to the implants supporting the (articulating paper adjusted) prosthesis under unilateral loading were found to be more than the (T-scan adjusted) prosthesis and

that difference was found to be statistically significant. That could be explained as the T-scan could be more accurate to analyze and determine the interferences on various teeth contacts during lateral and horizontal movements as it presents more information as a video (movie) format about dynamic viewing of occlusion, timed analysis of force during various positions of teeth contact. Those results agreed with a study that was aimed to compare the effect of occlusal adjustment using T-scan III and articulating paper on the vertical bone height changes around dental implants supporting lower single fixed detachable hybrid prosthesis, it was found that there was increase in vertical bone loss both articulating paper and T-scan groups through-out the follow up period and on comparing the two groups there was a significant difference in the vertical bone height changes around the supporting implants after a follow up of 1 year where articulating paper group showed more vertical bone loss. It was concluded that the use of T-scan III device allow for better occlusal adjustment in case of implant supported lower single denture than articulating paper and resulting in less vertical bone loss around the supporting dental implants [23].

A review paper that discussed the role of T-scan in occlusal analysis concluded that the data that obtained from T-scan can be analyzed in three ways. It shows the duration and relative magnitude of all tooth contacts, it identifies disproportional loading forces and transient impact forces acting on specific teeth and it identifies active tooth contact occurring within the functional range of mandibular movement and the interaction between working and nonworking interferences [24].

A review article provided an insight to various occlusal indicators available in the clinical world of prosthetics has concluded that the qualitative recording materials (e.g articulating papers) can establish the location and number of contacts. These materials are primarily preferred because of their low cost and ease of application. As their marking ability is negatively affected by the presence of saliva, it is recommended that they can be used only once when used intraorally and that the teeth be dried prior to testing. The T-Scan system identifies the time and force characteristics of occlusal contacts, and hence, establishing true and measurable bilateral simultaneous occlusal contacts is a clinically attainable reality by using this system [25].

Conclusion

T-scan allows for better occlusal stresses distribution as it brings valuable information regarding force intensity and occlusal timing especially during eccentric movements and resulting in less stresses transmitted around implants than articulating paper.

The findings of this study are of major clinical relevance as it showed how articulating paper is still a reliable method for occlusal analysis and adjustment of implant supported prosthesis, when they are used correctly, during centric movements of the mandible but during eccentric movements of the mandible, T-scan is more accurate and allows better occlusal stress distribution.

Author Contributions

Methodology, resources, writing- Original draft, writing- review editing and visualization.

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