Original Article

Computerized Assessment of Articulating Paper Occlusal Adjustment for Implant Crowns Restoring Modification Spaces of Kennedy Class II Cases

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Abstract

Objective: The study was conducted to evaluate the effectiveness of articulating paper-guided occlusal equilibration for single implant crowns used to restore the modification space anterior to the second premolar as a pier abutment in mandibular Kennedy class II cases using T-Scan.

Subjects and methods: Eighteen patients had lower Kennedy class II with a second premolar as a pier abutment, removable partial dentures (RPD) were constructed after restoring the modification spaces with implant-supported screw-retained metal-ceramic crowns. The occlusal contacts on the implant crowns were marked using articulating paper, standardized photographs were taken to compare with T-scan recordings, and the percentage of force applied to the implant abutment crowns (POFI) and contralateral teeth (POFT) was evaluated using T-Scan before and after the adjustments. The data were analyzed using the paired t-test and the student t-test, while regression analysis was carried out for assessing the frequency of matchings and non-matchings between the paper marks and the T-scan.

Results: The POFI values were decreased, and the POFT values were increased, after articulating paper occlusal adjustments however, the changes were not significant for the natural teeth. The correlation coefficient between the most apparent paper marks and the number of red columns presented in T-scan recordings indicated a fair correlation.

Conclusion: Choosing forceful tooth contacts utilizing paper marking’s appearance as a guide is, at best not evidence-based, and at worst, highly error-prone, however, for clinical correlation, occlusal accuracy in such cases will not suffer if more readily feasible and simpler ways are employed to guide occlusal equilibration.

Keywords: Computerized occlusal analysis, T-scan, articulating paper, Dental implant occlusion, implant-supported crowns.

Introduction

Dental implants, as a helpful adjunct of prosthodontics, may have a key role in partial denture retention as well as stability and support, although not a routine treatment modality, a few strategically placed dental implants combined with the remaining dentition can help to achieve a more favorable RPD design, in cases where fixed rehabilitation is not possible. (1) Functional forces applied to the distal-extension bases create an axis of rotation around the most distal abutment teeth subjecting them to distal tipping, rotation, torque, and horizontal movement. When the most distal abutment is isolated, it will be subjected also to mesial tipping due to lack of mesial contact, promoting a fulcrum-like situation of mesiodistal torquing leading to rapid destruction of its supporting periodontium. (2, 3)
Different treatment modalities have been recommended to reduce harmful forces directed at pier abutments. One approach involves splinting of the pier abutment to the nearest tooth by a fixed partial denture.\(^2\)\(^,\)\(^3\) Restoring the modification space anterior to the pier abutment by an independent implant-supported crown also creates an intact dental arch anterior to the free end edentulous space; and it has been reported that this approach can completely eliminate the fulcrum-like situation associated with the pier abutment.\(^4\)

Dental implants are more susceptible to occlusal overloading issues in comparison to natural teeth owing to their deprivation of periodontium shock-absorbing function, and as they exhibit low proprioceptive feedback and low tactile sensitivity in the absence of periodontal mechanoreceptors, thus ideal implant occlusion is of paramount importance for oral function and prevention of implant-related complications. After rigid fixation of the dental implant is achieved, the health of the associated hard and soft tissues is dependent on the mechanical stress and strain from occlusal loading. Thus, a primary cause of peri-implantitis and bone loss around implants is the excessive force applied from unwanted occlusal contacts. Additionally, mechanical complications such as screw loosening and fractures, as well as prosthesis and implant fractures, may also occur from occlusal overload.\(^5\)

The concept of implant-protected occlusion (IPO) was developed by Dr Carl Misch for prosthetic rehabilitation with dental implants. The goal of IPO is to reduce the biomechanical stress on the implant interface and the prosthesis. The ideal occlusal scheme for an implant prosthesis is designed to control the stress on the implant system, provide a prosthetic and biologically acceptable implant interface, and maintain long-term stability of the marginal bone, soft tissue, and prosthesis. The IPO principles address several conditions to decrease stress on the implant system, including existing occlusion, implant body angle to occlusal load, cusp angle of implant crowns, occlusal table width, mutually protected articulation, cantilever or offset loads, crown contour, occlusal contact position, and timing of occlusal contacts.\(^6\)

The “timing” of occlusal contacts is extremely important to the force distribution when implants and teeth reside in the same arch because of inherent differences between teeth and implants. The goal of “timed” occlusal contacts is to account for the mobility differences between teeth and implants by delaying the implant occlusal contacts, so they receive minimal occlusal force until after the nearby natural teeth occlude and move within the PDL fibers. This will allow for an even distribution of occlusal load and the prevention of implant premature contacts and increased loads. First, due to the initial difference in vertical movement of the natural tooth and implant, the implant crown should have no contact with light biting force, then, after a greater occlusal force is applied equal contact between the implant crown and natural teeth should occur. The occlusal scheme that should be maintained for single implant restorations is mutually protected occlusion, no posterior occlusal contacts should be present during lateral and protrusive movements, as the forces are directed to the anterior teeth.\(^6\)\(^,\)\(^7\)

Articulating papers are used to detect high-force contacts, whereby the width, thickness, and dye type of the articulating paper leave a mark where contact exits. Articulating paper is a widely accepted occlusal indicator that supposedly locates forceful tooth contacts, despite that no scientific evidence shows ink spots measure differing occlusal force levels by their size or color depth. The clinical use of articulating paper relies on the unproven and non-scientific concepts that larger and darker marks are considered to be forceful contacts, while lighter marks and smaller marks supposedly indicate less forceful contacts.\(^8\)\(^,\)\(^9\)

Quantifiable Occlusal indicators have been developed to overcome the limitations and subjectivity of the static occlusal indicators, the T-Scan Computerized occlusal analysis
technology is superior in that T-Scan has the ability to record the very first contact of a tooth, relative force, and timing. The captured occlusal data is processed by the related software, and the outputs are displayed as two-dimensional and 3D illustrations. The percentages of applied forces per tooth are represented as bars and columns on the same tooth in graphical displays. Unlike conventional detection methods, “light contact” is interpreted from the T-scan in terms of both the percentage of bite force and the density of bite force with different colors. There is sufficient evidence that points out that the use of the T-Scan III system permits the application of the time-delayed loading concept on dental implants, by loading the natural teeth first with occlusion time (OT< 0.2s) followed by loading the implant restoration with OT< 0.4s (delay after the adjacent natural teeth). Sensitivity, reliability, and reproducibility are the major advantages of T-scan digital occlusal analysis. (9, 10, 11, 12, 13)

There are those who believe that articulating paper is effective to guide implant occlusion calibration and adjustment and still rely on it, (14, 15) however, several studies investigated the relationship between articulating mark size and the occlusal force levels contained within the same ink contacts using the T-Scan technology, and all showed that choosing high-force or low-force occlusal contacts by contact size and color depth was highly inaccurate and that using the quantifiable T-Scan occlusal analysis removed the inaccurate operator subjectivity from the contact selection decision-making process. (9,16, 17, 18, 19) Accordingly, this in vivo study was performed to verify whether the use of the articulating paper to calibrate the occlusal contacts of a single implant restoration is successful enough to fulfill the objectives of equilibrated implant-prosthetic occlusion according to the IPO concept or not, through the objective assessment of the changes in the percentage of biting force after articulating paper based adjustments by T-Scan computerized occlusal analysis, and by comparing articulating paper markings and T-scan recordings for occlusal points evaluation subjectively.

The null hypophysis was that: the occlusion of the implant-retained restoration that has been accepted as being optimal, based solely on articulating paper analysis, will not be disowned or repudiated by further investigation using the T-scan occlusal analyzer as a quantifying, non-subjective occlusal indicator.

Subjects and Methods

This investigation was conducted in the prosthodontic department, faculty of dentistry, Ain shams university. The design of this study was approved by the ethics committee of the faculty of dentistry, at Ain shams university. Prior to an individual subject’s participation, each subject was given instructions that explained the study protocol, and had the opportunity to ask questions about the protocol, so as to accept or reject their participation in the study and informed consent was obtained from all participants.

Sample size calculation was performed using G*Power version 3.1.9.7 (20) based on the results of a previous study. (9) A power analysis was designed to have adequate power to apply a two-sided statistical test of the null hypothesis that there is no difference between the tested items. By adopting an alpha level of (0.05) and a beta of (0.2), i.e., power =80% and an effect size (d) of (1.20) calculated based on the results of a previous study (9). The predicted sample size (n) was (18).

A total of eighteen partially edentulous patients were selected from the out-patients clinic to share in this study, according to the following criteria that were verified by clinical and radiographic examinations: Patients had lower unilateral distal extension edentulous space (Kennedy class II) with a second premolar as pier abutment opposing dentate or
partially dentate maxillary arch. Patients had substantial bone height and width at the modification space anterior to the pier abutment to accommodate a standard size implant, patients exhibiting mutually protected occlusion. The remaining teeth are free from any periodontal disease, have adequate bony support, are free from mobility, and exhibit cusp-marginal ridge occlusal arrangement. The following patients were excluded: patients having edentulous space opposite to the prospective implant site, patients with parafunctional habits, temporomandibular joint, and neuromuscular disorders, Smokers, and patients receiving or undergoing radiotherapy or chemotherapy or having a systemic disease that affects osseointegration.

The patients’ diagnostic casts were mounted on a fixed condylar path articulator using a tentative centric jaw relation record for evaluation of the occlusal relationship of the remaining teeth, detecting the presence of any over-erupted or tilted teeth that may require occlusal adjustments, evaluation of the inter-arch distance at the posterior region, assessment of available crown height space at the prospective implant site and evaluation of the ridge relationship. All the required occlusal equilibration was executed before commencing the restorative treatment phase.

For all patients' surgical installation of the implants was performed under strict aseptic conditions, and delayed loading protocol was followed, each implant was restored by an independent screw-retained metal-ceramic crown.

At the insertion appointment, and before implant-crown placement, an 8 μm shim stock was held intraorally using forceps, the patient was asked to occlude into the strip in maximum intercuspation position, and the ability to hold the strip between opposing teeth on the contralateral side indicated the presence of occlusal contacts, then the implant abutment screw was tightened, and the crown was intraorally validated regarding the marginal fit, and esthetics including emergence profile, shape, shade, and embrasures. Free interproximal contact with the adjacent tooth was verified (slight snap when dental floss passes the contact point).

The occlusion was assessed again by the shim stock, to recognize whether the patients could still hold the strip between opposing teeth (indicating the absence of implant restoration occlusal interference), or not (indicating premature contact on the implant crown), in this case, an articulating paper was used to identify the location of occlusal interferences on the implant crown.

Patients were seated upright in the dental chair. Single-sided Mylar-based articulation paper strips (Accufilm, Parkell, Inc.Edgewood, NY, USA) were used. (Fig.1) The articulating paper was held intraorally with forceps while the subjects tapped their teeth together firmly through the articulation paper 5 times in succession. Each subject was instructed to attempt to generate their perceived maximum occlusal force while tapping through the articulation strips.

![Fig. (1): Accufilm articulating paper.](image)

Standardized intraoral photographs for articulating paper markings were taken by skilled photographers using a digital camera and an intraoral mirror for interpretation of light and heavy contacts based on the size and intensity or appearance characteristics of the marks (subjectively and by the same
personnel), for later comparison to the occlusal force data obtained from the same subject’s T-Scan III multi-bite recordings. All photographs were taken with a digital SLR camera (Canon, 5D mark IV, Canon Inc, USA) in manual mode, with a fixed focal length of 100 mm, an aperture of F 29, and a shutter speed of 1/125 second. A ring flash provided a consistent light source. The camera sat on a tripod placed 100 cm away from an intraoral mirror that was positioned parallel to the maxillary teeth, with the dental chair consistently set upright and maximum vertically down. This procedure repeatedly aligned the photographic mirror with the camera, such that, the photographic technique used between all subjects was standardized. (9)

The occlusion was assessed by a skilled operator using a T-Scan III computerized occlusal analysis system (Tekscan Inc., South Boston, MA, USA). (Fig.2) The recording sensor was placed intraorally between the dental arches to capture the real-time occlusal force and time-sequence data, the patients were asked to occlude the recording sensor with the maximum possible bite force for 1 to 2 seconds. This procedure was repeated three times, and the closure with maximum occlusal force was selected for analysis.

As soon as the recording was completed, the real-time window became a 2-D Movie window, which was divided into two equal-colored boxes (one green for the left side and one red for the right side) around the mid-sagittal plane showing the difference between the intensity of the biting forces on both sides. A 3-D Movie window, Graph window, and Graph Zoom window were also automatically opened for the current movie. The Graph and Graph Zoom windows contain color-coded “traces” representing forces applied, the distribution of the forces along the arch, teeth under heavy contact, and premature contact inside each of the colored boxes in the 2-D Movie window.

The acquired occlusal points analysis and force data recordings were saved to be compared later with the obtained digital photographs of the corresponding articulating paper markings of the same subject, to estimate subjectively the extent of compatibility or deviation between them, by matching the most manifesting paper marks to the number of red or orange columns in the 3D view graph widow of T-scan bite recordings. (Fig.3)

Occlusal contact was equilibrated in static and dynamic movement according to the IPO concept based solely on articulating paper analysis. The articulating paper was used to identify the location of occlusal interferences on the implant crown. Any premature contact was eliminated using fine and extra-fine diamond burs. A 19 µm articulating paper was used for initial implant occlusal adjustment in occlusion under light biting force, to obtain the clinically recognized “light contact”, the achieved light contact was confirmed by using the shim stock, it was held intraorally using forceps, the patient was asked to lightly occlude into the strip, the ability to hold the strip between opposing adjacent and contralateral teeth while easily withdrawn at the site of implant crown verified adequate occlusal adjustment.

Fig. (2): T-Scan III computerized occlusal analysis.
After equilibration with light bite force, the patient was asked to tap his/her teeth through a new articulating paper strip with maximum occlusal force. The purpose of occlusion evaluation under heavy occlusal load was to ensure the contact points showed similar intensity on the implant crown and adjacent teeth. Again, the performed equilibration adequacy was verified by the similar “resistance feel” when pulling the Shim Stock out from opposing occluded teeth at the implant site and adjacent tooth. Finally, the excursive contacts on the implant crown were eliminated.

This study included 2 phases of T-scan occlusal parameters measurement, including before articulating paper-guided crown adjustments, and immediately after adjustments. The following T-scan occlusal parameters were recorded for each subject and saved for future data analysis; the percentage of applied occlusal forces displayed on the implant crown (POFI) and contralateral teeth (POFT). The relative accuracy or inaccuracy of the articulating paper-guided occlusal equilibration was evaluated by comparing the after-adjustment recordings to the baseline recordings obtained before the adjustments. The changes in the percentage of force applied to the implant crowns, and contralateral teeth after performing the occlusal adjustments were calculated and tabulated for statistical analysis. After obtaining all data and whenever T-scan evaluation revealed the need for further occlusal adjustment, it certainly was performed.

Data analysis was accomplished by placing the T-scan relative occlusal force distribution data side-by-side with the counterpart photograph of the articulating paper marks and examining how frequently the largest, the most prominent observed paper marks describe the most forceful contact as indicated by the red, and orange columns in the T-Scan 3-D graph window. When the largest and most intense paper mark demonstrated the highest relative force on the same tooth in that quadrant, it was considered to be a “match”. When the tooth with the largest paper mark did not demonstrate the largest force on that same tooth, it was considered to be a “no-match”. This matching procedure was focused on the implant crown area. The “matches” and “no matches” were then tabulated for statistical analysis estimating the frequency of the matches to the no matches.

A computerized file was created for each patient before and after occlusal equilibration including the tabulated baseline recordings of “matches” and “no matches”, and all the measured parameters (POFI, POFT).

The abutment and the crown were returned to the working model again and the restoration was sent back to the laboratory for glazing and extraoral cementation. For each subject the extraoral cemented intraorally screw-retained crown was fastened to the implant intraorally and tightened with the manual screw-driver, A peri-apical radiograph was taken to confirm the proper connection between the crown and the
implant platform, once fit has been verified it was tightened to the manufacturer’s recommended Torque value (25 Ncm) using the compatible driver in conjunction with the calibrated torque wrench. A small Teflon plug was placed in the abutment channel, then the screw access hole was plugged with composite resin to match the shade.

Removable partial dentures were constructed for all patients following the same procedures. The dentures were designed with a lingual bar as a major connector, a double Aker clasp on the first and second molars on the intact side; a gingivally approaching clasp (RPI) on the edentulous side second premolar, cingulum or occlusal rest was used as an indirect retainer on the intact side. (Fig.4)

**Fig. (4): Removable partial denture on cast.**

For the RPD, the heavy premature occlusal contacts in the centric position had been spotted by the articulating paper and correlated to the T-scan bite recording force and time data. Corrective occlusal adjustments were performed by grinding the premature spots selectively from the cusp tips and the central fossae. The procedure was repeated until the occlusal force was nearly equilibrated as confirmed by the T-scan force and time data.

Patients were educated and instructed on how to maintain good oral, denture, and implant hygiene and were scheduled for follow-up visits.

**Results**

Numerical data were explored for normality by inspecting the data distribution and calculating the mean using Kolmogrov-Smirnov and Shapiro-Wilk tests. Data revealed parametric distribution thus it was represented as mean and standard deviation. Statistical analysis was performed with IBM® SPSS® (SPSS Inc., IBM Corporation NY, USA) Statistical version 25 for Windows.

Comparison between the percentage of force to the implant crown before and after occlusal adjustment by using articulating paper was carried out using paired-T test, while comparison between the percentage of force to the implant crown and contralateral side (Dentate side) was carried out using independent-T test. The probability level of $P<0.05$ is considered statistically significant.

**Table (1):** Mean, standard division, and t-test of the percentage of force to the implant crown (POFI) and contralateral side (POFT) before and after occlusal adjustment

<table>
<thead>
<tr>
<th>Side</th>
<th>Before occlusal adjustment</th>
<th>After occlusal adjustment</th>
<th>Test value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side</td>
<td>No. = 10</td>
<td>No. = 18</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Implant crown (POFI)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56.93± 0.69</td>
<td>51.40 ± 0.64</td>
<td>2.32</td>
<td></td>
</tr>
<tr>
<td>Dentate side (POFT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43.50± 0.52</td>
<td>49.03± 0.55</td>
<td>6.53</td>
<td></td>
</tr>
<tr>
<td>Test value</td>
<td>8.892</td>
<td>1.145</td>
<td></td>
</tr>
</tbody>
</table>

The data obtained from Table (1) revealed that the mean value of the percentage of force to the implant crown POFI was (56.93, 51.40) before and after occlusal adjustment respectively which was found to be statistically significant as a p-value $P<0.05$. Regarding the contralateral side (Dentate side) the mean value
of the recorded POFT was (43.50, 49.03) before and after occlusal adjustment respectively which was found to be statistically significant \( P < 0.05 \).

Comparing the POFI and POFT the data obtained from table (1) revealed a significant \( P < 0.05 \) greater amount for the implant side before occlusal adjustment, however after occlusal adjustment although the POFI was greater than the POFT, the difference was found to be statistically insignificant \( P > 0.05 \)

Although a greater difference was detected after occlusal adjustment, statistical analysis of the data revealed an insignificant difference.

The concordance correlation coefficient measures variations in the linear relationship between two methods from the identity lines of two meaningful components: deviations in each measurement around the line (precision) and the distance between the identity line and the linear line (accuracy).

Table (2): Correlation between the red columns of the T-scan and articulating paper marks for premature contact.

<table>
<thead>
<tr>
<th>No.</th>
<th>Concordance correlation coefficient</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red columns of T-scan&amp; articulating paper marks</td>
<td>0.3662</td>
<td>-0.070 to 0.685</td>
</tr>
</tbody>
</table>

The data obtained from (table 2) According to Landis & Koch descriptions of estimates of the agreement are A coefficient of 0–0.20 slight agreement, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and 0.81–1 almost perfect agreement. The previous table shows that there was a statistically significant fair agreement between the red columns of the T-scan representing premature contact and the blue mark with articulating paper with a concordance correlation coefficient of 0.366 (-0.070 – 0.685).

**Fig. (5): the correlation between the number of red columns of the T-scan and blue marks of articulating paper on the implant crown.**

**Discussion**

Since the use of implant-supported single crowns has become a well-established and preferred approach to compensate for missing single teeth instead of preparing the sound structure of two intact teeth to receive FPD, in the present study the modification space bound by the lone-standing abutment was restored by an independent implant-supported crown. (6, 21)

The two-stage surgical protocol was followed as it has been established that obtaining soft-tissue coverage over the implant and maintaining a minimally loaded implant environment for 3 months reduces the bacterial infection, prevents apical migration of the oral epithelium along the body of the implant, allows time for proper osseointegration, and minimizes the risks related to early implant loading during bone remodeling. (22) The crown was fabricated with an occlusal screw access hole, allowing for the crown to have a stock abutment on the laboratory model, taking the mechanical advantage of screw retention; in addition, the extraoral cementation technique allowed easy and complete cement removal prior to intraoral placement. (23, 24)
Porcelain has become a material of choice for implant-supported fixed partial dentures (ISFPDs) due to its satisfactory aesthetics, ease of occlusal adjustments, and wear resistance. When comparing metal-ceramic to all-ceramic occlusal material, both were able to withstand loads. However, metal-ceramic can withstand higher strength loads. (25)

Despite the introduction of the T-scan occlusal analyzer technology, the majority of clinicians and dental colleges are still depending, to a great extent, on the articulating paper and the patient’s “feel” feedback for implant-prosthetic occlusion establishment. (19) In this study, we attempted to verify whether the sole use of the articulating paper to evaluate and equilibrate the occlusal contacts of a single implant restoration is successful enough to fulfill the objectives of the IPO concept. For this purpose, the T-Scan III system has been used as an objective method of post-adjustment evaluation of the implant-prosthetic occlusion because it provides a dynamic and comprehensive visual picture of the patient’s occlusion route. (17, 18) In addition the articulating paper markings which were subjectively evaluated to represent the most intensive contacts were compared and correlated to T-scan recordings for occlusal points evaluation, this was an effective way to accurately grasp the changes and correlations of the occlusal force distributed on the implants and the natural teeth by comparing the relative occlusal force values of those teeth in the T-scan recordings.

The null hypophysis for this study was thus accepted because the occlusion of the implant-retained restoration that has been adjusted based solely on articulating paper analysis was acceptable as revealed by further investigation using the T-scan occlusal analyzer, and also because the paper-mark versus T-scan relative force data analysis depicted a positive correlation.

This study runs on the same track as other studies that have been previously conducted to examine and assess the accuracy of the articulating paper in occlusion adjustment, particularly in the cases of implant restorations, (9, 18, 19, 26) as the occlusion of a single implant restoration should be designed to minimize the occlusal forces onto the implant and to ensure even force distribution to the adjacent natural teeth. (6)

The findings of this study are to some extent in accordance with the findings of other studies that previously attempted to correlate occlusal force to paper mark size. (9, 27, 28) It has been repeatedly shown that the characteristics of paper mark appearance do not describe the amount of occlusal force present on a given tooth.

In this study, statistical analysis revealed that the subjective interpretation of the articulating paper heavy contact marks based on their size and intensity is fair correlated to the relative force data obtained from the T-scan occlusal analysis, (fig.6) this could be attributed to the fact that the antagonistic tooth morphology is likely the overriding factor in what forms the actual paper mark surface area; not the applied occlusal force, because small traces may result when a sharp surface opposes a flat surface, or contacts other pointy surfaces, conversely, when large flat surfaces oppose each other (like in areas of wear faceting) large marks are likely to appear because of the broad surface contact the opposing occlusal surfaces share. This can explain why a large mark can have a low force associated with it, and a small mark can have a much higher force associated with it. These findings have significant clinical implications because, if an operator assumes that the largest paper mark is representing the most occlusal force during an occlusal adjustment procedure, the operator will likely choose the wrong tooth to treat most of the time. (9)
The percentage of force applied to the implant crowns was significantly higher than that of the contralateral natural teeth before adjustments, which is considered occlusal overloading. Although the low causative relationship between the paper markings and the applied forces, this study revealed a significant decrease in the POFI values after performing the occlusal adjustments, this is probably attributed to the proper implementation of tools and techniques, standardized selection for articulating paper thickness and die type, and to the systematic approach in using the most suitable articulating paper and shim stock foil to its fullest purpose.\(^6, 8\)

In the present study, decreases in mean POFI values were accompanied by an increase in mean POFT values in the contralateral arch (table1), and in the light of the fact that “force distribution should be equal bilaterally and maximized on adjacent teeth”,\(^6\) this finding is affirmative of the adequacy of the performed occlusal adjustments and achievement of equitable bilateral force distribution, which validate the quiet effectiveness and undermine the oppressive criticism of using articulating paper in such simple cases, this is of clinical significance because many clinicians consider the increased chair time required to obtain a high-quality T-Scan recording for performing a computer-guided occlusal adjustment procedure, as a challenge. The T-scan learning curve involves choosing appropriate sensitivity settings, orally guiding the patient through the needed mandibular movements with the sensor interposed between their teeth, and observing the screen to follow the center of Force Trajectory as it moves around the T-Scan dental arch during patient data acquisition, which makes clinicians feel that operating the T-Scan with patients is time-consuming, technique sensitive and is not that cost-effective, consequently, they still prefer articulating papers in the clinical setting.\(^13, 19, 29\)

Although the increase in mean POFT values, the changes weren’t statistically significant, this may be due to the resiliency of the periodontal ligaments which permit tooth movement when patients apply heavy contact. The mean values of vertical displacement of natural teeth are 25 to 100 µm, while the range of axial movement of dental implants is approximately 3 to 5 µm, which could be enough to fog the resultant occlusal changes for the natural teeth.\(^5\)

Lastly, it’s worth mentioning that T-scan not only records the instantaneous occlusal contact, including the position, intensity, and distribution in the chewing cycle to the nearest 0.01 seconds dynamically but also objectively reflects the distribution and changes in the occlusal contact for each tooth and dental arch. Furthermore, the trajectory of the center of occlusal force (COF) obtained from a T-scan can assist in determining the dynamic change in the balanced occlusal force. This provides a quantitative, objective, and reliable method for the analysis of "dynamic" occlusion, so its use is highly recommended in wider prosthetic rehabilitation.\(^12, 13\)

**Conclusion:**

Choosing forceful tooth contacts utilizing paper marking’s appearance as a guide is, at best not evidence-based, and at worst, highly error-prone, however, for clinical correlation, occlusal accuracy in such cases (single implant-retained crowns) will not suffer if more readily feasible and simpler ways are employed to guide occlusal equilibration.

**Conflict of Interest:**

The authors declare no conflict of interest.

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This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

**Ethics:**
This study protocol was approved by the ethical committee of the faculty of dentistry- Ain Shams University on 16/11/2022, approval number: (FDASU.RecIR.112230)

References


