CLINICAL RESEARCH

Influence of denture adhesives on occlusion and disocclusion times

Mohamed Hussein Abdelnabi, BDS, MSc, PhD, Amal Ali Swelem, BDS, MSc, PhD, and Ayman A. Al-Dharrab, BDS, MSc, MPhil, PhD

Growing use of adhesives by complete denture wearers is accounted for by the subjectively perceived enhancement in overall denture performance,\(^1\) even in well-made and well-fitting prostheses.\(^6\) Denture adhesives were found to improve the individuals’ mastication efficiency and their ability to manage their conventional dentures and to increase their comfort, confidence, and satisfaction with their prostheses\(^1\) and, hence, their overall quality of life.\(^2\) A number of objective methods have been implemented to demonstrate the effectiveness of denture adhesives in improving retention and stability,\(^6\) in decreasing denture dislodgement\(^13\) and movement during function,\(^16\) and in improving masticatory performance and occlusal force.\(^7\) It is only logical to assume that all these enhancements are either indicative of or attributable to the denture’s overall occlusal contact simultaneity. However, to date, dental publications lack clinical studies that objectively assess the occlusal balance and occlusal contact simultaneity of complete dentures with and without adhesives.

Intraoral clinical assessment of occlusal contact simultaneity, however, is challenging when using conventional methods. It includes the use of articulating paper, occlusal indicator wax, patient feedback, and

ABSTRACT

Statement of problem. The effectiveness of adhesives in enhancing several functional aspects of complete denture performance has been well established. The direct influence of adhesives on occlusal contact simultaneity has not yet been investigated.

Purpose. The purpose of this crossover clinical trial was to evaluate quantitatively the influence of adhesives on occlusal balance by recording timed occlusal contacts; namely occlusion time (OT) and disocclusion time during right (DT-right) and left (DT-left) excursions by using computerized occlusal analysis.

Material and methods. A crossover clinical trial was adopted. Assessments were carried out while participants (n=49) wore their dentures first without then with adhesives. Computerized occlusal analysis using the T-Scan III system was conducted to perform baseline computer-guided occlusal adjustment for conventionally fabricated dentures. Retention and stability assessment using the modified Kapur index and recording of OT and DT-right and DT-left values using the T-Scan III were subsequently carried out for all dentures, first without adhesives and then after application of adhesive. All T-Scan procedures were carried out by the same clinician. Wilcoxon signed-rank test was used to analyze the Kapur index scores and occlusal parameters (\(\alpha=.05\)).

Results. Stability and retention of conventional dentures ranged initially from good to very good. However, adhesive application resulted in significant improvement (\(P<.001\)) in stability and retention and a significant decrease in duration of all occlusal parameters (\(OT [P=.003]\), DT-right \(P=.003\), and DT-left \(P=.008\)).

Conclusions. Adhesives significantly decreased OT and DT durations in initially well-fitting complete dentures with fairly well balanced occlusion, and further enhanced denture stability and occlusal contact simultaneity. (J Prosthet Dent 2016;115:306-312)
Clinical Implications
Clinically acceptable stability and occlusal contact simultaneity can be achieved in well-fitting conventional complete dentures with fairly well-balanced occlusion; however, using denture adhesives could significantly enhance them.

subjective interpretation. These methods are straightforward and quick yet questionable, as none has demonstrated the ability to provide contact time sequence or quantify occlusal forces. Although articulating paper has been the most commonly used method, its marks are affected by occlusal morphology, patient occlusion quality, and the salivary impregnation of dental surfaces, which can diffuse the articulating paper ink and lead to false positives. Additionally, its marking repeatability is poor as it is subject to fragmentation and perforation during intercuspation. Articulating paper is an insufficient indicator of occlusal contact simultaneity because it cannot register contact force or time sequencing and because the size of the paper mark is only indicative of contact location and surface area and is an unreliable indicator of applied occlusal load.

The objective assessment of occlusal equilibration has been possible in recent years through computerized occlusal analysis. The T-Scan system was developed by Maness et al in 1987. The latest version (T-Scan III) provides a dynamic visual evaluation of a patient’s occlusion from initial tooth contact to maximum intercuspation. The system records relative force values, but it allows for objective quantitative evaluation of occlusal balance by recording timed occlusal contacts and by displaying numerical values for occlusion and disocclusion times.

Occlusion time (OT) is the time from the first contact of occluding teeth to maximum intercuspation, and disocclusion time (DT) is the time from maximum intercuspation to complete disocclusion during lateral movement. The clinical goal is to reach maximum intercuspation in less than 0.2 second and disocclude all posterior teeth in less than 0.4 second. The shorter the OT, the less time required to contact all teeth and the fewer the prematurities as the patient closes into maximum intercuspation, indicating occlusal contact simultaneity and equilibration. Shorter DT (less than 0.5 second) has shown to decrease contractile muscle activity significantly to near resting state values during mandibular excursions and decrease the stress on the temporomandibular joints (TMJs).

The T-Scan system was found to be considerably accurate and reliable and has been implemented in different clinical dental applications, including complete denture prosthodontics. However, studies using computerized occlusal analysis with complete denture wearers mostly used earlier versions of the system. Of those studies, only 1 investigated both OT and DT in complete denture wearers. Published dental studies that implemented the recently introduced T-scan III system with complete dentures are scarce. To the best of these authors’ knowledge, only 1 published clinical study used the T-Scan III to perform computer-guided occlusal-corrective adjustments to improve the occlusal balance of complete dentures by using the center of force concept.

To date, no published data are available for the definite impact of denture adhesives on occlusal contact simultaneity. The purpose of the current study was to quantitatively and objectively assess the influence of denture adhesives on occlusal parameters, namely OT and DT, in complete denture wearers using the T-Scan III computerized occlusal analysis system. The null hypothesis of this study was that denture adhesives had no significant effect on occlusion and disocclusion times.

MATERIAL AND METHODS
A crossover clinical trial was adopted. The assessment was carried out with conventional complete dentures (without adhesives) and then with the same dentures after adhesive application. The study sample included 49 completely edentulous participants, 37 men and 13 women (47 to 62 years of age, with an average of 55.1 years of age) selected from the Department of Oral and Maxillofacial Prosthodontics at King Abdulaziz University, Faculty of Dentistry. Power analysis was conducted using software (G*Power, v. 3.0.10; University of Kiel). Use of an alpha value of .05, a sample size of 49 was found to yield a power of 0.9. All participants were given detailed information about the investigation and gave written informed consent for their participation. The study protocol was reviewed and approved by the Faculty Research Ethical Committee.

All participants had an Angle class I jaw relationship with no history of temporomandibular disorders. Their edentulous conditions fell within classes I and II based on the prosthodontic diagnostic index (PDI) classification system for complete edentulism. Exclusion criteria were the presence of major medical problems or severe chronic diseases or any intraoral soft or hard tissue pathology.

New conventional maxillary and mandibular complete dentures were fabricated for all participants in a conventional manner. Elastomeric definitive impressions (Imprint II Garant; 3M ESPE) with border tracing were made in custom trays. Maxillomandibular records were made using intraocclusal records and mounted on semiadjustable articulators (Hanau Wide-Vue articulator; Whip Mix Corp) using facebow (Hanau Spring-Bow; Whip Mix Corp), centric relation, and protrusive
records. The occlusal scheme was bilaterally balanced occlusion with 20-degree artificial teeth (Trubyte IPN; Dentsply Intl). Laboratory remounting was carried out to correct occlusal changes due to processing errors. The necessary intraoral clinical adjustments were then carried out in a conventional manner on the day of denture insertion and continued throughout the first week until participants were free from any discomfort from their dentures. Clinical remounting procedures were then carried out 2 weeks later to refine occlusal contacts after denture settling. Before any occlusal parameter recording, computer-guided occlusal adjustment procedures were carried out on all conventional dentures as a baseline measure. Participants were allowed to use their conventional dentures for 2 weeks and then recalled for the OT and DT recording procedures. In the same appointment, the retention and stability of the conventional dentures were assessed intraorally by a single experienced examiner (M.H.A.) using the modified Kapur criteria (Olshan modification)\(^\text{30}\) (Table 1).

Participants were then left without their dentures for 2 weeks (washout period)\(^\text{22,53}\) before adhesive application. Paste denture adhesive (Corega; Stafford-Miller Ltd) was used in this study. The amount and application of adhesive followed manufacturer’s recommendations and were demonstrated to the participants after giving them all necessary instructions. Participants were asked to use the denture adhesive for 2 weeks and then recalled for the second OT and DT recording procedures that were carried out while the participants wore their adhesive-retained dentures. The same examiner (M.H.A.) reassessed the retention and stability of the adhesive-retained dentures.

Computerized occlusal analysis was conducted using the T-Scan system (T-Scan III v8; Tekscan Inc). The system uses a 100-µm-thick recording sensor (high-definition generation IV sensor; Tekscan Inc) (Fig. 1) that scanned in 0.003-second increments. The system was initially used to perform computer-guided occlusal adjustment for all dentures. It was then used to record occlusal parameters, namely, OT and DT, for dentures without and with denture adhesives. All scanning procedures were carried out by the same clinician (A.A.S.).

The size of the sensor (large or small) was chosen to suit the participant’s dental arch. Prior to any occlusal data acquisition and according to the manufacturer’s recommendation, a proper sensitivity range was established,\(^\text{35,54}\) and sensor conditioning procedures of 2 to 4 test closures\(^\text{29,38}\) were performed for each participant.

For all scanning procedures, participants were asked to sit in a relaxed upright position in the dental chair. The sensor was held consistently in the same position with respect to the teeth. It was aligned to be parallel to the occlusal plane and centered on the midline between the central incisors (Fig. 2).\(^\text{38}\) For each participant, the same sensor was used throughout the adjustment and recording procedures.

Before occlusal parameter recording, corrective occlusal adjustments were carried out using the center of force (COF) concept for each participant.\(^\text{30,56}\) Each participant was asked to firmly occlude into the sensor with their dentures until maximum intercuspation occurred, holding their teeth together for 1 to 3 seconds, and then disoccluding and reintercuspating into the sensor once again. Premature contacts were then specifically adjusted based on the overloaded contact locations displayed and demarcated within the system’s 2D (Fig. 3) and 3D (Fig. 4) force/view panes (through color coding and force values).

### Table 1. Modified Kapur index evaluation criteria (Olshan modification)

<table>
<thead>
<tr>
<th>Retention</th>
<th>Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 = Excellent: excellent resistance to vertical pull and lateral force</td>
<td>4 = Excellent: no rocking on supporting structures under pressure</td>
</tr>
<tr>
<td>4 = Very good: very good resistance to vertical pull and lateral force</td>
<td>3 = Good: very slight rocking on supporting structures under pressure</td>
</tr>
<tr>
<td>3 = Good: moderate resistance to vertical pull and lateral force</td>
<td>2 = Fair: sufficient stability; demonstrates slight rocking under pressure</td>
</tr>
<tr>
<td>2 = Fair: moderate resistance to vertical pull and little or no resistance to lateral force</td>
<td>1 = Poor: some stability; demonstrates moderate rocking under pressure</td>
</tr>
<tr>
<td>1 = Poor: slight resistance to vertical pull and little or no resistance to lateral force</td>
<td>0 = No stability: extreme rocking under pressure</td>
</tr>
<tr>
<td>0 = No retention: denture displaces itself</td>
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</tr>
</tbody>
</table>

Figure 1. T-Scan III high-definition Generation IV sensor.

Figure 2. Sensor held parallel to occlusal plane and centered at midline between central incisors.

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The corrective occlusal adjustment procedure was repeated until a reasonably centered, measurably balanced force distribution (50% ±2% on each side) was achieved in each denture (Figs. 5, 6).

Occlusal parameters (OT and DT) were recorded for the occlusally balanced dentures in each participant on 2 occasions: first without adhesives (conventional dentures) and second after adhesive application (adhesive-retained dentures). Participants were asked to occlude on the sensor in centric occlusion with normal pressure until maximum intercuspation, then hold their teeth together for a period of 1 to 3 seconds, start a right or left excursion from that completely intercuspated position, and then disocclude.38 This was repeated 4 times for the right excursion (DT-right) and 4 times for the left excursion (DT-left). Mean OT, DT-right, and DT-left were then calculated by taking the averages of the recordings.

Statistical analysis was performed with software (SPSS v.16.0 [IBM Corp] for Windows [Microsoft Corp]). Data were collected, tabulated, and presented as means, standard deviations, and medians. The Wilcoxon signed-rank test (α=.05) was used to compare the modified Kapur index scores (qualitative variables) of the same dentures with and without denture adhesives. The Kolmogorov-Smirnov test of normality was conducted for the OT, DT-right, and DT-left data. Most of the variables were not found to be normally distributed. Data were, therefore, statistically analyzed with the Wilcoxon signed-rank test (α=.05). Intraexaminer agreement was also determined for the Kapur index assessments and occlusal analysis recordings using Kappa statistics.

RESULTS

Kappa statistics revealed very good intraexaminer agreement for both denture retention stability assessments (0.83) and occlusal analysis recordings (0.79). Modified Kapur index scores revealed that the stability and retention of both the maxillary and mandibular conventional dentures ranged from good to very good, indicating that the conventional dentures fit well initially.

Figure 3. COF analysis preadjustment scan: 2D force/view shows COF marker located in left anterior of gray eclipse with unequal distribution between right (41.2%) and left (58.8%) sides. COF, center of force.

Figure 4. Pre-adjustment scan: 3D force/view shows premature contacts at particular areas, indicated by pink and red columns (representing higher intensity forces).

Figure 5. COF analysis postadjustment scan (after a series of clinical corrective guided occlusal adjustments): 2D force/view shows COF marker assuming midline position (located within white eclipse nearly at center) with right (49.4%) to left (50.6%) force balance approaching 50% bilaterally. COF, center of force.

Figure 6. Postadjustment scan: 3D force/view shows absence of high-intensity force columns and more favorable force distribution pattern.
Statistical analysis revealed significant improvement (P<.001) in the retention and stability of both dentures after adhesive application (Table 2). Mean values and standard deviations for OT, DT-right, and DT-left are presented in Table 3. Statistical analysis revealed a significant decrease in duration of all occlusal parameters with the adhesive-retained dentures compared with the conventional ones.

**DISCUSSION**

Results of the current study led to rejection of the null hypotheses. Application of denture adhesives significantly shortened OT and DT duration in complete denture wearers. OT and DT have been used by several researchers23,32-34,38,47-49 as occlusal evaluation parameters. These variables are considered definitive parameters in expressing and quantitatively evaluating the state of occlusal equilibration, regardless of the prosthesis type or occlusal scheme used.23,32 As mentioned earlier, these parameters represent the time lag obtained from occlusal contact recordings from the first premature contact to maximum intercuspal and from maximum intercuspation to complete disocclusion during lateral movement. As a result, shorter durations indicate stable occlusal balance of dentures on their residual ridges and the absence of premature contacts.23

To ensure valid and reliable results, several measures were considered. The study was designed as a cross-over clinical trial to exclude individual variations. Denture retention and stability were assessed by 1 examiner (M.H.A.). Similarly, all occlusal adjustments and occlusal parameter recordings were carried out by 1 clinician (A.A.S.). This was done to exclude interexaminer variations, as no studies have investigated operator influence on the values obtained from the scanning system.33 For all occlusal adjustment and recording procedures, participants were asked to sit in a relaxed upright position in the dental chair as an increasingly significant relationship between the sagittal plane head-neck posture and initial occlusal contacts has been reported for those over the age of 30.55 Sensors were individually held consistently in the same position38 to minimize sensor-positioning variability and assure stability during repeated closure. This ensured that the same sensing elements were repeatedly loaded by the same cusps in all records.31,38 According to the manufacturer, T-scan III sensors can be used up to 15 to 25 times while still retaining high standards of reliability. Accordingly, for each participant, the same sensor was used throughout the adjustment and recording procedures to eliminate any intersensor variability.

To make sure that the obtained results were due to the influence of denture adhesives exclusively, other factors that may negatively affect denture stability and hence occlusal balance were eliminated. Only participants with class I or II complete edentulous states (based on the PDI system), in which the residual ridge morphology and location of muscle attachments were favorable, were included in the current study. Two pre-recording measures, including the assessment of denture retention and stability using the modified Kapur scale and computer-guided occlusal adjustment using the T-Scan III center of force analysis30,50 were carried out. This was necessary to ensure a sound baseline for originally well-fitted dentures with fairly well-balanced occlusion and to avoid the influence of offset defective occlusal contacts and instability on the obtained results. Furthermore, to ensure that the “with” adhesive values were solely due to adhesive application and not due to participant adaptation to their dentures, a 2-week washout period was adopted.22,53 The participants were also asked to wear their conventional dentures for 2 weeks only given that denture adaptation requires 90 days.15

Results of the current study revealed a significant decrease in OT and DT times after the use of denture adhesives. The mean OT decreased significantly to 0.35 second, which approaches the recommended time of 0.2 second. Similarly, mean DT-right and DT-left values decreased significantly to 0.37 and 0.35 second, respectively, effectively achieving the recommended time of 0.4 second. To the best of these authors’ knowledge, no published studies have compared conventional and adhesive-retained dentures with regard to OT and DT. Thus direct comparison was not possible. However, these results indicate that adhesive application even to well-fitting, occlusally balanced dentures further improved

### Table 2. Kapur index (Olshan modification) scores in conventional and adhesive-retained complete dentures (n=49)

<table>
<thead>
<tr>
<th>Denture response</th>
<th>I Conventional dentures Mean (±SD) Median</th>
<th>II Adhesive-retained dentures Mean (±SD) Median P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary denture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td>3.53 (0.50) 4.00</td>
<td>4.73 (0.45) 5.00</td>
</tr>
<tr>
<td>Stability</td>
<td>3.39 (0.53) 3.00</td>
<td>3.98 (0.38) 4.00</td>
</tr>
<tr>
<td>Mandibular denture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention</td>
<td>3.42 (0.67) 4.00</td>
<td>4.67 (0.47) 5.00</td>
</tr>
<tr>
<td>Stability</td>
<td>3.16 (0.72) 3.00</td>
<td>3.92 (0.45) 4.00</td>
</tr>
</tbody>
</table>

SD, Standard Deviation.*Wilcoxon signed rank test; highly significant at P<.001.

### Table 3. Occlusion and disocclusion times (seconds) in conventional and adhesive-retained complete dentures (n=49)

<table>
<thead>
<tr>
<th>Occlusion parameter</th>
<th>I Conventional dentures Mean (±SD) Median</th>
<th>II Adhesive-retained dentures Mean (±SD) Median P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>OT</td>
<td>0.48 (0.23) 0.35</td>
<td>0.35 (0.17) 0.03</td>
</tr>
<tr>
<td>DT-right</td>
<td>0.56 (0.34) 0.37</td>
<td>0.37 (0.32) 0.03</td>
</tr>
<tr>
<td>DT-left</td>
<td>0.54 (0.33) 0.35</td>
<td>0.35 (0.27) 0.08</td>
</tr>
</tbody>
</table>

DT, disocclusion time; OT, occlusion time; SD, standard deviation. *Calculated with Wilcoxon signed rank test; significant at P<.05.
the stability and occlusal simultaneity between the dentures. This could be attributed to their mechanism of action. Adhesives usually increase the contact and adaptation between the tissues and the denture and form a retentive force between the denture and oral mucosa by means of an intermediary film composed of a combination of the adhesive, saliva, and other oral fluids. This increases the amount of the denture seating surface in contact with the denture-bearing tissues, which increases the resistance of the prosthesis to dislodgement. Adhesives significantly increase the retention and stability of complete dentures, even for those that were initially well-fitting, as confirmed also by the findings of the current study. Consequently, adhesives reduce denture displacement and dislodgement during function. Adhesives were also found to reduce rotational denture movement and mastication time. Accordingly, adhesives help in the even distribution of occlusal forces across the denture-bearing area during function, thereby limiting local pressure points.

Therefore, the improved occlusal contact simultaneity achieved and possibly maintained by the use of adhesives may be attributed to the considerable reduction of premature contacts resulting from denture movement during function. The authors, however, emphasize the proper use of denture adhesives and the avoidance of their overuse or misuse. In their clinical study, Sierpinski et al. used the T-scan II occlusal analysis system and reported an average of 0.42 second for OT, 0.48 second for DT-right, and 0.45 second for DT-left for participants with new conventional complete dentures. In the current study, the mean OT, DT-right, and DT-left times recorded for conventional dentures were 0.48 second 0.56 second, and 0.54 second, respectively. Although the values are close, differences may be attributed to the different system versions and study designs. In another clinical study, Haralur used the T-Scan III system and reported an average of 0.69 second, 0.79 second, and 0.91 second for OT, DT-right, and DT-left times, respectively, in normal dentate individuals (n=50) with healthy TMJs. That study’s values were higher than those obtained in the current study. Those findings cannot be directly compared with the current findings because of the differences in dentition. However, those values could support the assumption that the results obtained with the conventional dentures in this study, although they do not represent the recommended values, still did not exceed the values obtained for natural dentitions with healthy TMJs. This implies that the values in the current research could still be considered within clinically acceptable limits, because all dentures were initially well-fitting with fairly well-balanced occlusion. These authors acknowledge that the current study did not cover all completely edentulous situations and was limited only to those with favorable denture-bearing conditions. The use of adhesives and their influence on occlusal parameters (OT and DT) in participants with fairly poor or unfavorable denture bearing conditions could be the scope of future research.

CONCLUSIONS

Within the limitations of the study design and given the specific patient population, the application of denture adhesives was found to significantly decrease OT and DT durations in initially well-fitting complete dentures with fairly balanced occlusion and further enhance denture stability and occlusal contact simultaneity.

REFERENCES

22. Per-Öliver Junior NM, Rodrigues LS, Mendonça Marin DO, Paleri AG, Pero AC, Compagnoni MA. Masticatory performance of complete denture