The Effect of Denture Adhesives on Denture Quality and Occlusal Force

ABSTRACT

Introduction: Complete dentures (CDs) have been associated with substantial problems regarding edentulous patient's function. Denture adhesives seem to be useful adjuncts to improving retention and stability. Methods: A clinical study was undertaken to investigate the effect of a denture adhesive (DA) on function in complete denture wearers along with the quality of their CDs. Thirty complete denture wearers participated in the study. The first phase of the experimental procedure comprised 3 groups of measurements performed at 3 distinct time points: the initial measurement (T1), a 2nd measurement after 15 days of DA daily application (T2), and a 3rd measurement following a 15-day washout period (T3). The second phase consisted of the follow-up measurements. The measurements included: recording of relative occlusal force (ROF), distribution of occlusal contacts (DOC) and center of force (COF) using the T-Scan 9.1 device and functional assessment of dentures using the FAD index. Results: The DA use induced a statistically significant increase in ROF (p-value=0.003) and decrease in COF (p-value<0.001) and DOC (p-value=0.001). The overall FAD score significantly improved (p-value<0.001). Conclusions: The use of the DA improved the occlusal force, the distribution of occlusal contacts as well as the qualitative characteristics of CDs.

Keywords

Denture Adhesives
Complete Denture Quality
Occlusal Force

Authors

Maria Georgiou *
(DDS, MSc)

Olga Naka *
(DDS, MClinDent, PhD, Assistant Professor)

Vassiliki Anastassiadou *
(DDS, MSc, PhD, Professor)

Argirios Pissiotis *
(DDS, MSc, PhD, Professor)

Address for Correspondence

Olga Naka *

Email: naka@dent.auth.gr

* *Aristotle University of Thessaloniki, Faculty of Health Sciences, School of Dentistry, 54124, Thessaloniki, Greece*

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INTRODUCTION

Advances in dentistry, improvement of living conditions, patients' education, awareness, and motivation have led to an increased number of people that preserve their natural teeth for longer in life. Nevertheless, a considerable number of older adults suffer from edentulism, while conventional complete dentures (CDs) remain the main treatment modality to restore function, aesthetics, and comfort.[1] Complete dentures have been associated with substantial problems regarding edentulous patient's masticatory efficiency and satisfaction. Also, adaptation to complete dentures maybe difficult even if they are constructed according to accepted protocols.[2]

Retention and stability are considered critical technical requirements for a functionally successful rehabilitation with CDs.[3] Other frequently used criteria for the functional assessment of dentures are chewing capacity, vertical occlusal dimension, occlusion, and speech.[4,5] Denture adhesives (DAs) have proven to be useful adjuncts to improving retention, stability, and function.[6] In the presence of saliva, DAs swell from 50 to 150% by volume, filling the gaps between the denture and the underlying tissues.[7]. By increasing the adhesive and cohesive properties and the viscosity of the intermediary film of saliva, DAs provide an interface, allowing retentive forces to be transmitted.[8,9] Due to the chemical and physical reactions that take place, a significant improvement in retention and stability of maxillary CDs during chewing, swallowing, and speaking has been observed with

the use of DAs both in well- and poor fitting dentures.[10] When properly used, DAs may increase patient's occlusal force and improve the subjective chewing ability, while they provide psychological benefits to their users, higher rates of satisfaction and overall increased quality of life.[11] Apart from the increase of maximum occlusal force, DAs improve the occlusal force distribution over the denture bearing area, enhance the masticatory performance and decrease the number and duration of chewing cycles for the comminution of food.[12-14] By reducing the denture dislodgement, the masticatory function is improved, allowing the denture wearers to have a balanced diet and enjoy an active social life. [6,15-17]

Various recognized objective methods have been used to evaluate the effectiveness of denture adhesives. These include the Kapur index, the measurement of occlusal force needed to dislodge a denture using gnathodynamometers or gnathometers, evaluation of masticatory performance through sieve tests, electromyography, kinesiography, etc.[6,9,18-20] Methodology limitations and flaws though jeopardize the reliability and the generalization of their results.

Clinical studies assessing the effect of DAs on occlusal balance and occlusal contact simultaneity are very rare in the dental literature. The evaluation of occlusal contact simultaneity with conventional occlusal indicators such as articulating paper and shim stock foils, have been combined with the patient's occlusal "feel" feedback.[21] However, none of these methods can record the time sequence of occlusal contacts or quantify the occlusal contact forces. Articulating paper, which is the most popular occlusal indicator cannot measure occlusal load since no scientific correlation between the amount of force applied per contact and paper mark size or mark appearance characteristics (depth of color) has been found.[22] T-Scan digital occlusal device constitutes an objective instrument for the evaluation of occlusal equilibration. A major advantage of this system is that it combines qualitative information regarding the topography and distribution of occlusal contacts with quantitative information relative to occlusal load, time sequence of tooth contacts and right and left balance. More specifically, T-Scan provides a dynamic visual recording of the sequence of occlusal contacts from the initial tooth contact until maximum intercuspation in the form of a real-time movie and an accurate evaluation of relative occlusal force per tooth contact in highly repeatable fashion.[21,23-24]

Although occlusal force constitutes an important indicator of the functional status of the masticatory system,[25] the effect of DAs on masticatory/ occlusal force in combination with the effect of DAs on the distribution and balance of occlusal contacts in complete denture wearers has not been studied in the literature. Furthermore, there are no studies exploring the effect of DAs on the overall quality of CDs using a specialized for this purpose index.

Thus, the aim of the current prospective clinical study was to investigate the effect of denture adhesives on function (Relative Occlusal Force, Center of Force and Distribution of Occlusal Contacts) and complete denture quality.

MATERIALS AND METHODS

The study has been carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans and was approved by the Ethical Committee of the School of Dentistry, Aristotle University of Thessaloniki (No. 25/3-2-2017).

This prospective clinical study was conducted on 30 edentulous participants (16 males and 14 females) aged from 48 to 81 years (mean age: 66.6, SD: 8.02). Fifty individuals were initially assessed for participation. Participants were selected based on a random generated system, so that each member of the population had an equal chance of selection to be part of the study. Screening included thorough extraoral and intraoral examination, while predefined eligibility criteria were followed. The choice of the participants was determined by the following inclusion criteria: completely edentulous adults in both arches with previous or no experience of conventional CDs, in good health, receptive and mentally agile (normal cognitive mental state) with normal alveolar ridge volume and skeletal Class I. Individuals with masticatory system dysfunction, functional limitations (i.e., limited manual skills), wearing immediate dentures or overdentures, with burning mouth syndrome, xerostomia, pathological conditions in the oral cavity, history of allergic sensitivity to DAs or intolerance to CDs were excluded. Participants were classified as Class I and II, according to the Prosthodontic Diagnostic Index (PDI) criteria,[26] as participants classified as Class III were not suitable candidates for the undergraduate clinic, where the study took place. Their cognitive mental state was evaluated using the Mini Mental State Examination-MMSE questionnaire.[27]

All participants were given detailed information about the procedure and provided informed consent. The construction of their complete dentures was held at the undergraduate clinic of the Department of Prosthodontics, following a standard protocol. Anatomic acrylic teeth were used (SR Orthotyp PE, Ivoclar Vivadent Schaan Lichtenstein) and a bilaterally balanced occlusal scheme was established. A clinical remounting procedure was carried out to verify and refine occlusal contacts. A 30-day period was allowed to elapse before the initiation of the experimental procedure as it was considered necessary for adjustments and functional adaptation to the new dentures.[6,16,19] After the adaptation period and once the participants were free of lesions (sore spots/tissue injuries) and complaints, the experimental procedure commenced. The measurements during the experimental procedure were performed by the main investigator who was calibrated to develop an acceptable degree of intra-examiner consistency.

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A cream type of Denture Adhesive was used (Fixodent Pro Original; Procter & Gamble) that was easily applied and removed by the patient. Additionally, its fine texture could not affect the occlusal position and vertical dimension of the denture. It contains calcium/zinc PVM/MA (adhesive agent), cellulose gum (binding agent), mineral oil (suspending and levigating agent) petrolatum, silica (thickener), colorants, flavoring agents, and sodium saccharin (sweetener). The daily amount of zinc absorbed from that specific denture adhesive is approximately 4-6 mg when used 2 to 3 times per day while the recommended allowance for zinc is 11 mg per day for men and 8 mg per day for women. The application of the cream improved the cohesive and adhesive properties as well as the viscosity characteristics of the saliva intermediary film and eliminated possible voids in the interfacial space of the denture with the underlying tissues.

The experimental protocol was conducted in two phases and is illustrated in detail in Figure 1. The first phase of the experiment included 3 groups of measurements performed at 3 distinct time points (0, 15, and 30 days).

The initial group of measurements (T1) included recording of relative occlusal force (ROF), distribution of occlusal contacts (DOC) and center of force (COF) using the device T-Scan Novus with 9.1 Software (Teckscan, Inc. South Boston, MA, USA), and assessment of the denture quality using the FAD index.[5] More specifically, the T-Scan recordings included a baseline recording (T1a) without DA (Treatment 0) and a second recording (T1b) after the application of the DA (Treatment 1). The functional assessment of dentures included a baseline recording of the qualitative characteristics of dentures without DA (T1a-Treatment 0) and a second evaluation after the application of the DA (T1b- Treatment 1). Three strips of 1cm of DA cream were applied at three points of the impression surface of the dentures (front, posterior right, posterior left). Participants were then instructed to use the DA daily for 16 hours for the next 15-days. Fresh DA cream was applied every 8 hours. To ensure the standardization of the application of DA and the maintenance and cleaning of CDs, verbal explanations and written instructions were given.

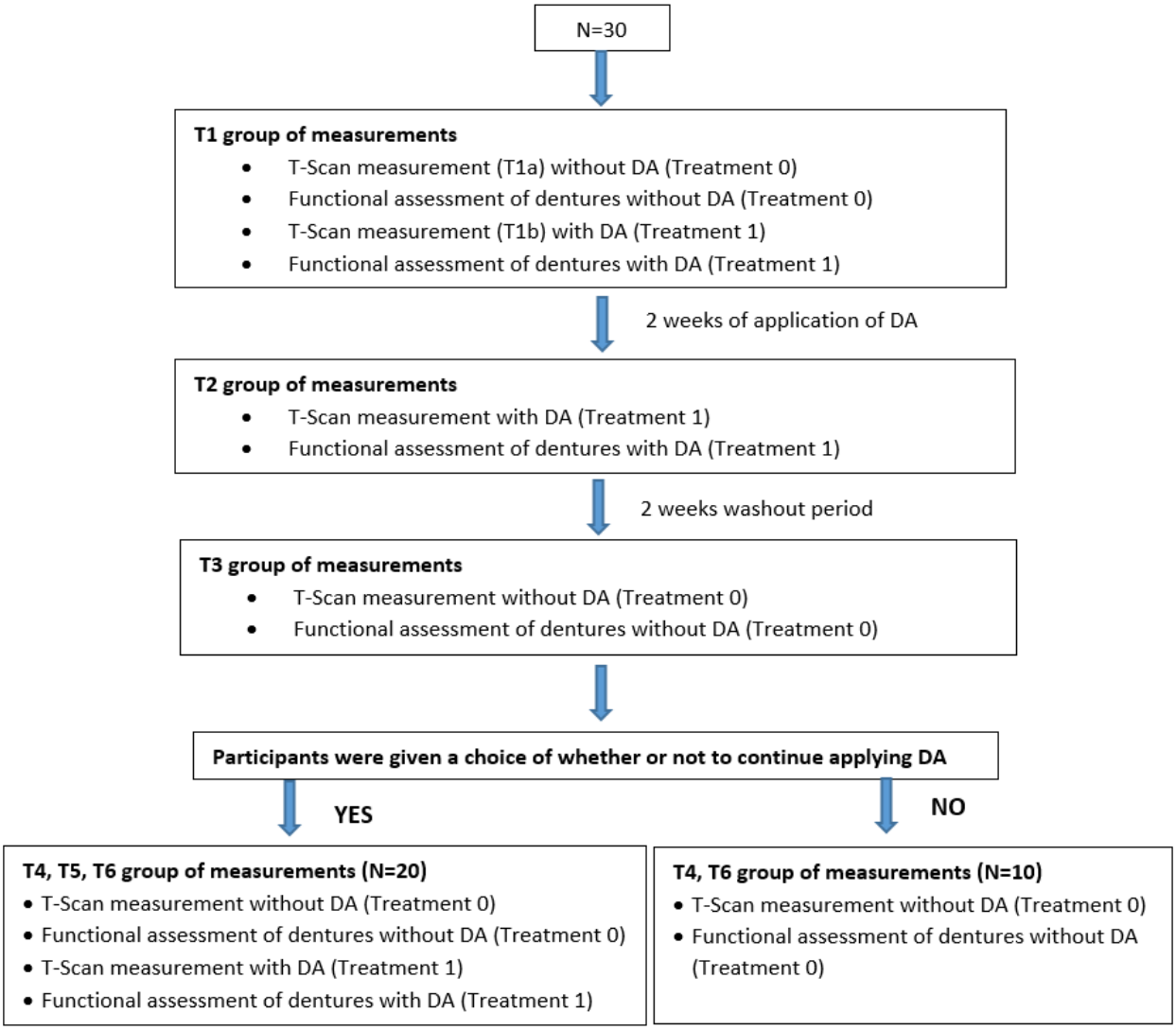

Figure 1: Experimental protocol.

The second group of measurements (T2) was conducted after 15 days of daily application of the DA cream and included T-Scan recording and evaluation of the quality of dentures with DA (Treatment 1). After 15 days of no intervention (washout period) the third group of measurements (T3) was performed, in which the same parameters were evaluated but without DA application (Treatment 0). Once the 3 groups of measurements were completed, the participants were given the right to choose whether they wanted to continue the use of DA or not. Twenty participants (20) decided to continue. The remaining 10 participants felt that the application of the DA was useless, or they wanted to adapt to the new situation by themselves without any additional adjunct.

The second phase consisted of the follow-up group of measurements. For the participants who chose the use of DA, the measurements were scheduled one month (T4) after the completion of the first phase, at 3 months (T5) and six months (T6) later. The group of measurements included: T-Scan recordings without (Treatment 0) and with DA (Treatment 1); functional assessment of dentures without (Treatment 0) and with DA (Treatment 1). For those who chose to end the use of DA, the follow-up measurements were scheduled one month (T4) after the completion of the first phase and at six months (T6). These measurements included: T-Scan recording and functional assessment of dentures without DA (Treatment 0) *(Figure 1)*.

The parameters tested using the T-Scan device were the Relative Occlusal Force (ROF), the Distribution of Occlusal Contacts (DOC) and the Center of Force (COF). ROF is given in percentage and not in absolute values. DOC is calculated by subtracting the percentage of force of the one arch half from the other arch half (ROF left- ROF right or ROF right- ROF left). It is given in percentage too. COF illustrates the balance of the occlusion; it is represented on-screen by a red and white diamond (COF marker) in the 2D ForceView graph in relation to a dual elliptical target (COF target) which represents the ideal location of the center of force for any maximum intercuspation closure. The COF target is displayed on the screen by two "target" circles and a crosshair to denote the center "target" *(Figure 2)*. In order to codify the position of COF marker in relation to the target center 5 values were given to COF variable from "1" to "5". The score "1" was given when the COF marker was located at the crosshair (the center "target"), representing the perfect distribution of occlusal contacts. The score "5" was given when the COF marker was located at the border or beyond the outer ellipse *(Figure 3)*.

The evaluation of the quality of CDs was conducted using the Functional Assessment of Dentures 10-item dichotomous scale, known as FAD index. It was first developed by Corrigan *et al.* (2002)[28] and was later validated and translated in Greek by Anastassiadou *et al.* (2002) with high internal consistency and good intra- and inter-examiner agreement.[5] This

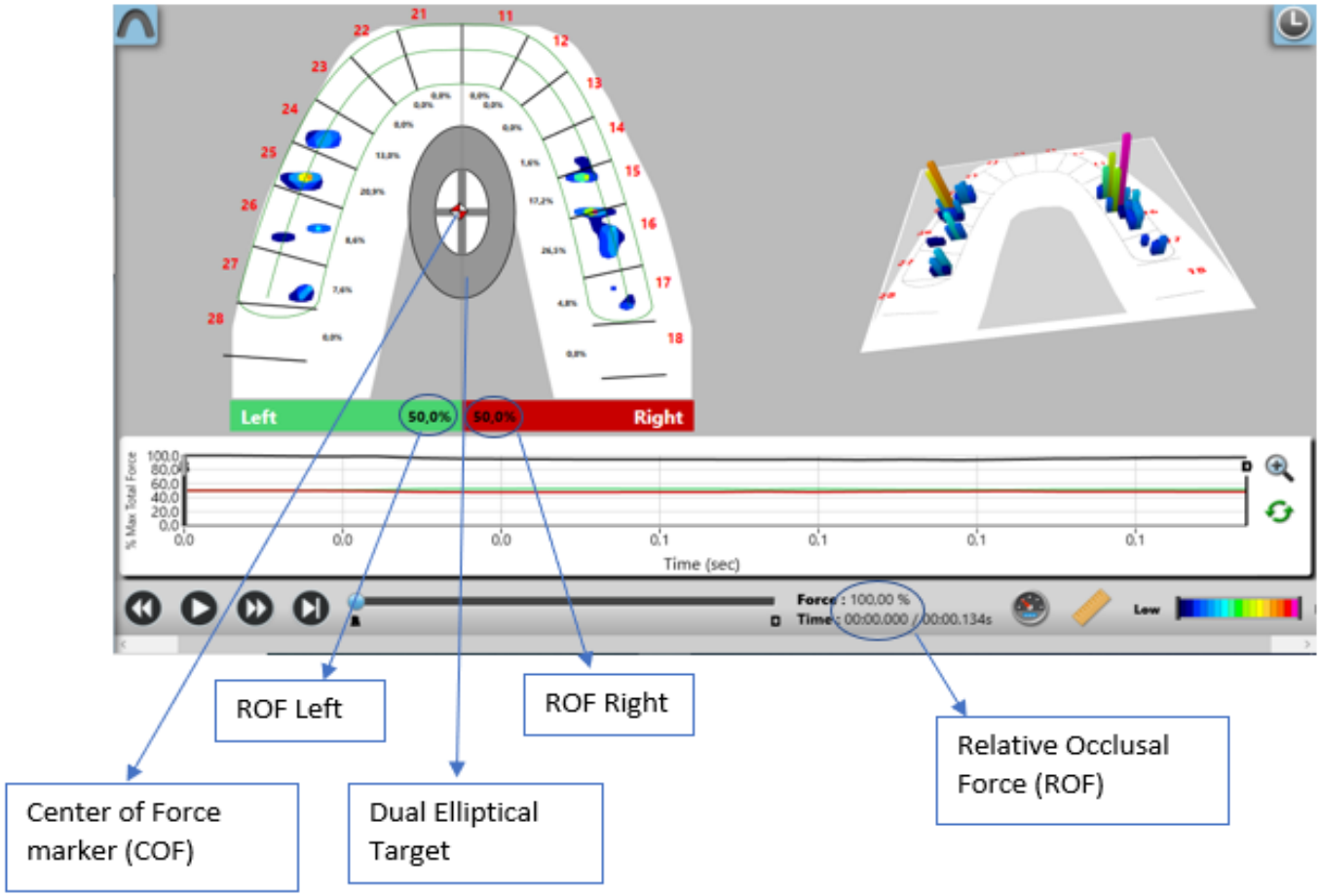

Figure 2: Graphical depiction of T-Scan data.

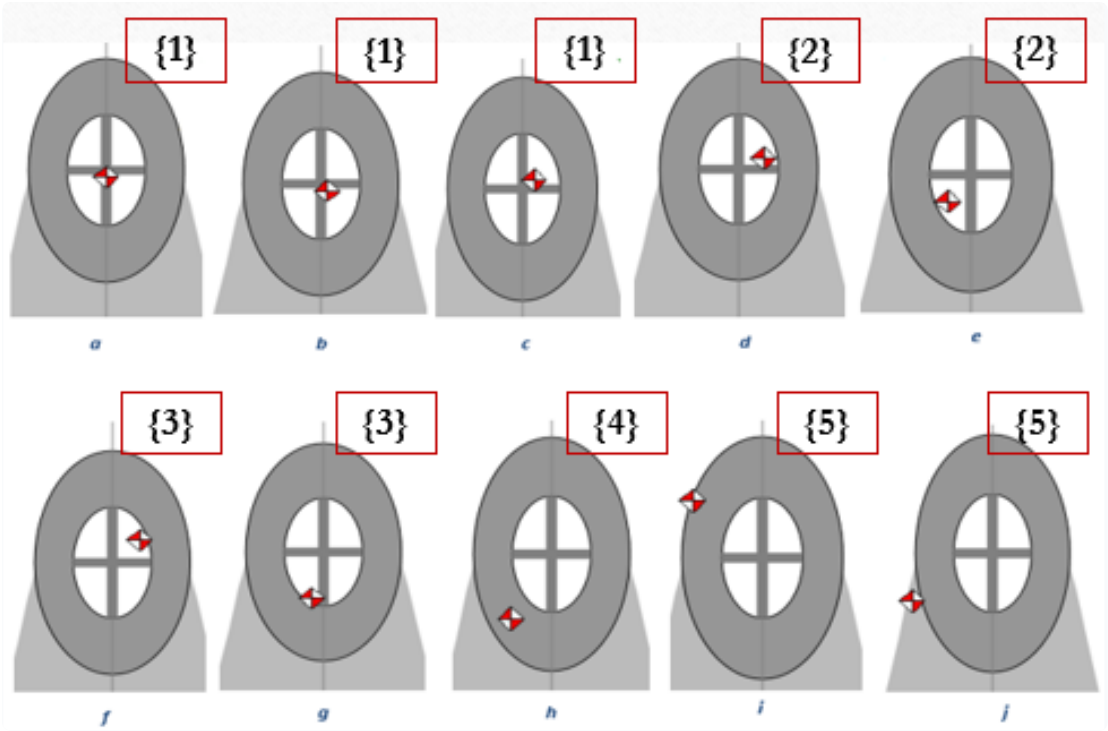

Figure 3: Topographic locations of COF marker.

instrument consists of ten functionally based criteria which describe particular clinical factors that are evaluated using specific intra-oral clinical assessments. The CDs were evaluated regarding the freeway space, occlusion, articulation, retention, and stability of maxillary dentures as well as stability of mandibular dentures *(Table 1*). Each parameter was scored dichotomously (0=unsatisfactory, 1=satisfactory). A final score for each set of CDs was obtained by the sum of all items. The higher the score the better the quality of the dentures.

STATISTICS

Statistical tests were conducted using IBM SPSS Statistics v.20.0 (SPSS Inc., Chicago, IL), at a significance level a=0.05. Descriptive statistics were performed in means and standard deviation (SD). The distribution of data was assessed using the Kolmogorov-Smirnov test. The intra-rater reliability for FAD index was evaluated using the Cohen's kappa coefficient utilizing repeated measures data at T1a, T2 and T3 measurements. The non-parametric paired sample Wilcoxon test was used for the comparison of ROF, COF, DOC, and FAD score variables between T1a (Baseline), T2 and T3 measurements (Phase 1), since no symmetrical data distribution was observed. The Friedman test was applied for the comparison of the aforementioned variables between the different time moments of Phase 2 for both groups of participants. The comparison of the variables between Treatment 0 and Treatment 1 at T1, T4, T5 and T6 time points was performed using either Paired sample t-test, where the data distribution was symmetrical or non-parametric paired sample Wilcoxon test.

Table 1. Functional Assessment of Dentures (FAD) Index

Functional Assessment of Dentures	
1. Freeway Space	Adequate= 1 Inadequate= 0
2. Occlusion	Balanced=1 Slide=0
3. Articulation	Minimal displacement=1 Excessive displacement= 0
4. Upper Retention **i. resistance to vertical pull**	Adequate resistance= 1 No resistance =0
5. Upper Retention **ii. tongue control, Incision test**	Tongue remains in the floor=1 Upper denture stabilized by tongue=0
6. Upper Stability **i. lateral displacement**	No=1 Yes=0
7. Upper Stability **ii. pronounced rocking**	No=1 Yes=0
8. Lower Stability **i. displacement**	Lower denture in place=1 Lower denture is noticeably displaced=0
9. Lower Stability **ii. pronounced movement**	No=1 Yes=0
10. Lower Stability **iii. antero-posterior movement**	No=1 Yes=0

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RESULTS

To evaluate the intrarater reliability, the intraclass correlation coefficient (ICC) and its 95%CI were calculated. An ICC value above 0.75 was considered as good and a value above 0.90 as excellent. The ICC value was 0.93 (95%CI from 0.84 to 0.96) indicating an excellent agreement between the two measurements taken by the same investigator.

A sample size calculation was conducted after a preliminary assessment of the results from the first 15 participants. It was found that at least 20 participants were required to detect a significant difference between Treatment 0 and Treatment 1 (α=0.05; β=0.20). Considering possible losses and withdrawals, a group of 30 participants was estimated (G*Power 3.1; University of Kiel).

T-SCAN VARIABLES

Phase 1

Relative Occlusal Force significantly increased after the 15-day period of application of DA (T2) when compared to the baseline measurement (T1a) (p-value= 0.003). Between T2 and T3 measurements that followed the 15-day washout period a significant decrease of ROF was noted (p-value=0.004). Regarding the variable of Center of Force, there was a significant decrease, which means improvement of COF between T1a and T2 measurements (p-value <0.001). On the other hand, a significant increase in COF values was noted between T2 and T3 measurement (p-value=0.017). As for the Distribution of Occlusal Contacts (DOC), there was also a significant decrease (improvement) between T1a and T2 measurements (p-value=0.001), while a significant increase was noted between T2 and T3 measurements (p-value=0.03) *(Table 2)*.

Phase 2

For the 20 participants who chose to continue the use of DA, no statistically significant difference was noted between the follow up measurements (T4, T5, T6) that took place having applied DA (Treatment 1), compared to T2 measurement (Treatment 1) in any of the aforementioned variables (p-value=0.121 for ROF, p-value=0.577 for COF, p-value=0.603 for DOC). Similar results were observed for the 10 patients who chose to end the use of the DA. No statistically significant difference was observed comparing the follow up measurements (T4, T6) to T3 measurement (Treatment 0) (ROF p-value=0.753, COF p-value=0.678, DOC p-value=0.564).

Comparison between the T-Scan recordings (Treatment 0 vs Treatment 1) at T1, T4, T5, T6.

Statistically significant differences were noted between the two recordings at all time moments for the ROF values *(Table 3)*. Statistically significant differences were noted at T1, T4 and T5 time moments for the COF values *(Table 3)*. No statistically significant differences were observed for the DOC values *(Table 3)*, although there was a tendency for lower values (improvement) with DA.

Comparison between the measurements of "Treatment 0" between T1, T4, T5, T6 for the twenty participants.

The comparison between the measurements performed without DA (Treatment 0) for the twenty participants at T1, T4, T5 and T6 time points revealed no statistically significant differences regarding the ROF values despite the upward trend noted from T1 to T5 time points and the decrease of ROF between T5 and T6 time points (p-value=0.126) *(Table 4)*. As for the COF and DOC variables a significant decrease (improvement) was observed with time *(Table 4)*, however post-hoc tests revealed a statistically significant difference only between T1 and T6 time points for both variables (p-value=0.013 for COF, p-value=0.039 for DOC).

FUNCTIONAL ASSESSMENT OF DENTURES

The kappa values for the intra-rater reliability ranged between 0.81 and 0.86, indicating a very good agreement.

Table 2. Comparison of ROF, COF and DOC at T1a, T2, T3 (N=30).

	Baseline (T1α)/ Treatment 0	T2/Treatment 1	p-value	T3 /Treatment 0	p-value
	Mean ± SD	Mean ± SD		Mean ± SD	
ROF	89.37 ± 13.57	96.78 ± 3.82	0.003*	91.70±9.02	0.004*
COF	3.40 ± 1.30	2.43±1.19	<0.001*	3.17±1.23	0.017*
DOC	21.19 ± 14.55	11.75 ±7.96	0.001*	17.68 ± 12.84	0.030*

*statistically significant

Table 3. Comparison of ROF, COF, DOC (Treatment 0 vs Treatment 1) at T1, T4, T5, T6.

Time Moment	Treatment 0 Mean ± SD			Treatment 1 Mean ± SD			p-value		
	ROF	COF	DOC	ROF	COF	DOC	ROF	COF	DOC
T1 (N=30)	89.37±13.57	3.40±1.30	21.19± 13.57	96.10±4.64	2.73± 1.93	15.90± 13.54	<0.001*	0.011*	0.153
T4: 60 days (N=20)	94.25± 6.67	3.43±1.02	15.98± 13.03	97.03 ± 5.20	2.50± 1.10	10.12± 7.94	0.002*	0.047*	0.300
T5: 3 months (N=20)	97.25± 1.89	3.18±1.08	15.83 ± 8.75	98.34± 1.18	2.60± 1.27	13.68± 7.68	0.006*	0.024*	0.174
T6: 6 months (N=20)	95.52± 3.88	2.79±1.18	15.23 ± 9.13	98.08 ± 2.25	2.35 ± 1.42	11.27± 8.98	0.005*	0.189	0.181

*statistically significant

Table 4. Comparison of ROF, COF, DOC (Treatment 0) between T1, T4, T5, T6 (N=20.)

	Baseline (T1a)/ Treatment 0 Mean ± SD	T4/Treatment 0 Mean ± SD	T5/Treatment 0 Mean ± SD	T6/Treatment 0 Mean ± SD	p-value
ROF	91.42 ± 7.83	94.25 ± 6.67	97.25 ± 1.89	95.52 ± 3.88	0.126
COF	3.82±1.25	3.43±1.02	3.18±1.08	2.79±1.18	0.005*
DOC	25.22±15.47	15.98 ± 13.03	15.83 ± 8.75	15.23 ± 9.13	0.037*

*statistically significant

Phase 1

Between T1a and T2 measurements a statistically significant increase (improvement) of the total score of FAD index was noted (p-value<0.001), while a statistically significant decrease was observed between T2 and T3 measurements (p-value<0.001).

Investigating the effect of the DA on each FAD parameter individually (articulation, upper retention, upper stability, lower stability), a statistically significant difference was noted in the stability of the mandibular complete dentures. More specifically, a statistically significant increase (improvement) of the score was noted between T1a and T2 measurements (p-value<0.001), while a statistically significant decrease of the score was observed between T2 and T3 measurements (p-value<0.001). As for the parameters of articulation, upper stability and upper retention, although there was a tendency for increased (improved) values, no statistically significant differences were observed (p-values=0.317).

Phase 2

No statistically significant difference was observed in the total FAD score between the follow up measurements (T4, T5, T6) compared to T1b and T2 measurements (Treatment 1) (p-value=0.406). There were also no statistically significant differences in the scores of articulation, upper retention, upper stability (p-value=1.000) and lower stability (p-value=0.999). Similar were the results for the 10 participants who decided to end the DA use. No statistically significant difference was noted in the total FAD score between T4 and T6 measurements compared to T3 and T1a (Treatment 0) (p-value=0.307). Likewise, no statistically significant differences were observed in any of the aforementioned variables [articulation, upper retention (p-value=1.000), upper stability (p-value=0.999) and lower stability (p-value=0.119)].

Comparison between FAD scores (without and with DA) at T1, T4, T5 and T6.

The total FAD score was evaluated without DA (Treatment 0) and with DA (Treatment 1) at T1. The same strategy was followed for the 20 participants who continued the use of DA at

T4, T5 and T6. A statistically significant difference was noted in the total FAD score for each time moment (p-value<0.001).

As for the parameters of FAD index that were evaluated separately (articulation, upper retention & stability, lower stability), no statistically significant differences were observed in the scores of articulation (p-value=0.317 at each time point), upper retention (p-value=0.317 at each time point) and upper stability (p-value=0.317 at T1, p-value=0.157 at T4, p-value=0.084 at T5 and p-value=0.083 at T6). Regarding the stability of the lower denture, a statistically significant difference was noted only at T1 time point (p-value<0.001), while no statistically significant differences were noted at T4, T5, T6 time points (p-value=0.317 at each time point). Regarding the recordings of FAD overall score performed without DA (Treatment 0) at T1, T4, T5, T6 time points no statistically significant differences were observed with time (p-value=1.000).

DISCUSSION

The aim of the present study was to ascertain whether DAs can improve the occlusal force, the balance of occlusal contacts in complete denture wearers and the qualitative characteristics of complete dentures.

The participation of the patients reached the maximum rate of 100%. No dropouts were observed. All participants (N=30) completed the first phase of the experiment which consisted of a 15-day intervention period of daily application of a DA cream and a 15-day washout period of no intervention. According to the literature this 15-day intervention period is considered adequate to allow proprioceptive adaptation in relation to DA use during mastication, while the 15-day washout period allows proprioceptive memory deprogramming to occur.[6] The washout period was adopted to ensure that the "Treatment 1" values resulted solely from the application of the DA and not from the patients' adaptation to complete dentures.[14] Furthermore, a 30-day period was allowed to elapse for functional adaptation to the new dentures.

For the participants who selected to continue the application of DA the follow up group of measurements included two recordings of ROF, COF, DOC and FAD scores both without and with DA use.[20] The rationale behind these two measurements was to investigate whether the relative occlusal force, the distribution of occlusal contacts and the overall score of the quality of CDs presented any improvement with time even without DA. In other words, to investigate whether the improved results obtained by the usage of DAs could be maintained even in measurements performed without DAs.

The 15-day intervention period (DA application) led to a significant increase of Relative Occlusal Force. Moreover, from the comparison of the measurements without and with DA at T1, T4, T5 and T6 measurements, a consistent improvement of ROF values was noted at all time points, revealing the positive contribution of DAs. These results may be attributed to the mechanism of action of DAs, which increases the viscosity of the intermediary film of saliva between dentures and supporting tissues and optimizes its adhesive and cohesive properties. This results in a significant improvement in retention and stability and eventually, a significant increase of patient's occlusal force. Similarly, other studies investigating the effect of DAs on bite force also revealed a statistically significant increase. Notably, the recording device in those studies was a gnathometer.[15-16,19] As mentioned before, T-Scan device calculates the occlusal force values in percentages and not in absolute numbers, that's why the term of occlusal force is referred as "Relative Occlusal Force". Since the data obtained with the T-Scan device cannot be interpreted in terms of Newtons, a direct correlation with previous studies cannot be made. Nevertheless, literature has revealed that DAs undoubtedly improve the bite force and chewing efficiency.[15,29-30] As for the measurements performed without DA (Treatment 0) for the twenty participants who selected the use of DA during the follow up measurements, an upward trend was presented regarding the ROF values up to T5 time point (3 months), while the relative occlusal force decreased between T5 and T6 time points. However, no statistically significant difference was observed. After the application of DA ("Treatment 1" measurements) an even greater increase of ROF values was noted that led to statistically significant differences at all time points. This finding emphasizes the decisive role of DAs.

Furthermore, the variables of Center of Force and Distribution of Occlusal Contacts significantly decreased (improved) after the 15-day period of DA application. Lower values represent more balanced distribution of occlusal contacts. As the percentage difference between the two arch halves decreases, the distribution of occlusal contacts improves.[31] These results indicate that the use of DAs even in well-made and occlusally balanced complete dentures can favor a further improvement of stability and occlusal contact simultaneity. These positive outcomes may be attributed to the significantly reduced premature contacts, which occur due to the movement of CDs during function. DAs increase the area in contact between the denture base and the underlying tissues and consequently enhance the resistance to dislodgment of the CDs.[14]

A comparison was also carried out for the COF and DOC variables between the recordings without DA and the recordings with DA at T1, T4, T5 and T6 time points. For the COF values a statistically significant decrease (improvement) was noted at T1, T4 and T5 time points but not at T6 time point (six months later). Regarding the DOC variable although there was a tendency for lower (improved) values after the application of the DA, no statistically significant differences were noted. As for the comparison of COF and DOC values between the recordings performed without DA, a significant improvement was noted with time. However post-hoc tests revealed a statistically significant difference between T1 and T6 time points for both variables. The use of DAs can result in better stability and greater distribution of occlusal forces over the denture bearing tissues, eliminating the local pressure points.[30]

The comparison between the recordings of ROF, COF and DOC with DA one month after the completion of the first phase (T4), at three months (T5) and six months (T6) later revealed no statistically significant differences. This can be attributed to the fact that participants had already achieved the maximum levels of adaptability.[32] So, the improvement achieved using the DA at T2 time moment was maintained during the follow up measurements. In other words, the increased levels of Relative Occlusal Force and the improved occlusal contact simultaneity achieved after the 15-day intervention period remained stable.

The FAD index was implemented for the qualitative assessment of CDs. This instrument was proved to have good inter-examiner and intra-examiner repeatability and thus Internal Consistency.[5,28] All participants were provided with well-made conventional complete dentures satisfying all the necessary prosthodontic criteria including adequate freeway space, and balanced occlusion (occlusion according to FAD index is deemed unsatisfactory when there is a slide greater than 4 mm). Therefore, no statistically significant differences in technical characteristics such as freeway space or occlusion were expected, unlike the other quality characteristics (articulation, retention, and stability) that are subject to imponderable factors such as the residual ridge anatomy and the complicated muscle function.

The higher values for the FAD index noted at T2 measurement (after two weeks of DA application) led to a statistically significant improvement of the overall FAD score. On the other hand, the two-week washout period resulted in a statistically significant decrease (deterioration) of the score. The significant improvement in overall FAD score justifies the fact that DAs improve the retention and stability of CDs and reduce the mediolateral movement of the prostheses.[10,33] Consequently, individuals can develop greater occlusal force during mastication.[34] However, investigating the parameters of the index separately, a statistically significant difference was noted only in the stability of the lower dentures. Although the use of the DA had a positive effect on the retention and stability of the maxillary dentures no statistically significant difference was observed. Mandibular dentures are more frequently associated with poor stability and retention compared to maxillary dentures since the lower denture bearing area is approximately half to that in the upper jaw. Furthermore, the tongue and the movable floor of the mouth in the mandible compromise the establishment of the lingual border seal, thus minimizing denture retention and stability.[35-36] From the results of this study the DA had a pronounced effect on the stability of lower dentures compared to maxillary dentures.

For the participants who chose to continue the use of the DA during the second phase of the experiment, no statistically significant differences were observed between the measurements where the functional assessment of dentures was performed with DA. The beneficial effect of the DA on the overall score of the quality of dentures attained at T2 measurement remained stable at T4, T5, T6 time moments (Treatment 1) with no further improvement but no deterioration too.

The comparison of the FAD score without DA and with DA at T1, T4, T5 and T6 time moments revealed statistically significant difference at each time moment, underlining the positive impact of DA use on the quality of dentures. As for the parameter of stability of the lower denture a statistically significant difference was noted at T1 measurement, but not at T4, T5 and T6 measurements. These results imply that the use of the DA assisted the patients to adapt and enhance their skills for successful handling of the lower dentures. As there is a lack of similar studies investigating the effect of DAs on the quality of CDs using a normative scale based on specific prosthetic criteria, the results of this study cannot be compared with others.

CONCLUSIONS

The use of the Denture Adhesive induced a significant increase of Relative Occlusal Force of conventional complete denture wearers and improved the distribution of occlusal contacts and the overall quality score of complete dentures. For the participants who selected to continue the use of DA during the second phase of the experiment no further improvement was observed.

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DECLARATION OF COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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