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Average Force Applied for Individual Tooth in All Ceramic Restoration

Rajmonda Halili[1] Alban Shabani[2] Lumturie Asllani[3] Sebahate Hamiti Alidema[4]

[1] Department of Prosthodontics, AAB College, Pristina, Kosovo
[2] Department of Maxillofacial Surgery, Dental School, University of Prishtina "Hasan Prishtina", Pristina, Kosovo
[3] Department of Periodontology, UBT College, Pristina Kosovo
[4] Department of Prosthodontics Alma Mater Europaea, Campus College Rezonanca, Pristina, Kosovo

Address for correspondence Sebahate Hamiti Alidema, PhD, Department of Prosthodontics Alma Mater Europaea, Campus College Rezonanca, 10000 Pristina Kosovo (e-mail: sebih@hotmail.com).

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Abstract

Objectives Occlusion plays an important role in the retention and stability of dental restorations. Aim of this study was to analyze occlusal loading detected on dental elements in patients with unilateral partial edentulism—class III Kennedy, before and immediately after prosthetic treatment with a zirconia-based bridge in maximal intercuspation position with the help of electronic system T-scan III.

Materials and Methods The research sample consisted of a total of 60 patients who, based on the preset selection criteria, were divided into two groups: control group with 30 (100%) patients with intact dentition (Gr1) and study group with 30 (100%) patients with unilateral partial edentulism—class III Kennedy, analyzed before prosthetic treatment (Gr2) and immediately after prosthetic treatment with a zirconia-based bridge (Gr3).

Results In Gr1, the highest average force applied for individual tooth had the tooth numbers: 17–14.6 ± 9.9%, 26–11.9 ± 6.8%, and 27–11.7 ± 6.8%. The lowest average value was registered for the teeth number 22–1.4 ± 1.3%, 12–1.9 ± 3.8%, and 13–2.9 ± 2.7%. In the group Gr2, the highest average force applied for individual tooth had the tooth numbers: 17–12.9 ± 35.6 and 21–9.6 ± 13.9%, whereas the lowest in teeth 24–2.7 ± 5.2 and 27–3.4 ± 6.8. In Gr3, the highest average force applied for individual tooth had the tooth numbers: 17–11.8 ± 15.4 and 14–9.8 ± 10.9%, whereas the lowest in the tooth 22–2.1 ± 2.6.

Conclusion This study demonstrated that all patients with the loss of teeth showed occlusal discrepancies and functional disharmony. During the delivery of zirconia restorations in the future a careful analysis of occlusal contacts should be performed. T-scan III technology reduces the subjective interpretation of occlusal analysis data allowing records and measures the contacts between the teeth.

Keywords
- occlusal force
- occlusion
- T-scan III

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Introduction

The operative dentist must design restorations with harmonies and smooth occlusion, so that the clinical stresses that are created must always be below the fatigue limit of the restorative material.[1] For the effective prosthetic treatment of edentulous patients, correct occlusal relationships are important.[2,3] Furthermore, occlusion plays an important role in the retention and stability of dental restorations. Occlusal force distributions as a result of normal occlusion affect the masticatory system's harmoniously functional relationships. Through analyzing the occlusal form of initial occlusal contact and bite force, force change of the teeth, the destructive occlusal stress contact can be eliminated, so that we can solve the problematic of bite unbalance.[4,5] The parameters of T-scan system embrace the percentage of occlusal force distribution that can provide a reference for analyzing immediate direct occlusal conditions.[5] As reported by a study, maximum clenching forces of the masticatory muscles recorded by the T-scan system were located in centric occlusion at the third molars in a dentition of 32 teeth. The greater bite force in the posterior dental arch may also be reliant on the increased occlusal contact number of posterior teeth loaded during the biting action.[3,6] Another study found that free-end posterior teeth bear a greater biting force.[7] Tooth loss can destabilize static occlusion, maximum intercuspation; therefore, if one of the teeth of antagonist jaw interferes with equal contact, it can cause damage to teeth of dental arch with tooth loss, because, they will absorb excessive forces.[3,7] Premature contacts on the ceramic restorations must be eliminated; otherwise ceramic restoration will broke because of the high occlusal pressure of premature contacts.[8] The aim of this study was to detect and compare occlusal loading on dental elements in patients with intact teeth and patients with partial edentulism (Class III Kennedy before and after prosthetic treatment with a zirconia-based bridge) in the maximal intercuspation position with the help of electronic system T-scan III.

Materials and Methods

This prospective comparative randomized clinical study was conducted in the private dental practice RA Dent Ferizaj, Kosovo, with prior approval from the Ethical Committee (NR-1061/19, 25.02.2021) of Dental Chamber of Kosovo. The research sample consisted of a total of 60 patients who, based on the preset selection criteria, were divided into two groups: Control group (CG) with 30 (100%) patients with intact dentition (Gr1) and study group (SG) with 30 (100%) patients with unilateral partial edentulism—class III Kennedy, analyzed before prosthetic treatment (Gr2) and immediately after prosthetic treatment with a zirconia-based bridge (Gr3).

The following inclusion criteria were taken into consideration during participant selection: normal occlusion and no missing teeth for CG, and partial edentulism (Kennedy class III) for SG. On the other hand, participants with temporomandibular disorders and patients with other systemic, congenital, and traumatic disorders affecting the jaw and chronic periodontal disease were excluded from this study.

For the measurements, the T-scan III—Computerized Occlusal Analysis System 7.0 (Tekscan Inc., South Boston, Massachusetts, United States) was used. The maximum intercuspation option was used for registration by selecting the IP-CO (Intercuspal Position - Centric Relation) option in the software menu with the following protocol: Patients asked to sit upright in a dental chair with the Frankfurt horizontal plane horizontal. The patients were informed for measurements and the nature of following work steps. The recording handle with the sensor and arch support was placed between the maxillary central incisors of the patient. The recording was initiated by pressed record start/stop button on the handle. The patient was asked to close the mouth till complete intercuspation was reached, without making any excursive movements, and waited for computer to "beep." When correct number of forces was collected, record stopped automatically. As a recording is complete, displayed Movie Window. All the subjects were examined clinically by the same trained dentist.

Statistical Analysis

The SPSS software package, version 22.0 for Windows, was used to process the research data. Qualitative series were analyzed by determining relationship coefficients, proportions, and rates, and were shown as absolute and relative numbers. Quantitative series were analyzed with measures of central tendency (average, median, minimum and maximum values), as well as with measures of dispersion (standard deviation). Two independent numerical variables with non-normal distribution of frequencies were compared with the Mann–Whitney U test. Paired-samples *t*-test was used for the analysis of two dependent numerical variables with normal frequency distribution, and Wilcoxon signed-rank test was used for those with non-normal distribution of frequencies. A two-sided analysis with a significance level of *p*-value less than 0.05 was used to determine the statistical significance.

Results

The average force applied to each individual tooth was analyzed individually for each group as well as between groups in three combinations as Gr1/Gr2, Gr1/Gr3, and Gr2/Gr3 (►**Table 1**). In Gr1, the highest average force applied for individual tooth had the tooth numbers: 17–14.6 ± 9.9%, 26–11.9 ± 6.8%, and 27–11.7 ± 6.8%. The lowest average value was registered for teeth number 22–1.4 ± 1.3%, 12–1.9 ± 3.8%, and 13–2.9 ± 2.7% (►**Table 1**).

In the group Gr2, the highest average force applied for individual tooth had the tooth numbers: 17–12.9 ± 35.6 and 21–9.6 ± 13.9%, whereas the lowest in teeth 24–2.7 ± 5.2 and 27–3.4 ± 6.8 (►**Table 1**).

In Gr3, the highest average force applied for individual tooth had the tooth numbers: 17–11.8 ± 15.4 and 14–9.8 ± 10.9%, whereas the lowest in the tooth 22–2.1 ± 2.6 (►**Table 1**).

When comparing Gr1/Gr2 for *p*-value less than 0.05, a significant difference was observed for average applied force

Table 1 Average force applied on each maxillary tooth calculated by the T-scan III system in subjects with intact dentitions (Gr 1), and patients before (Gr 2) and after (Gr 3) insertions of the zirconia-based bridges

Groups		Average force applied for individual tooth—%															
		18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
Gr1	Mean	5.5	14.6	12.2	7.5	5.3	2.9	1.9	2.3	3.5	1.4	3.4	5.5	5.9	11.9	11.7	3.3
	SD	7.1	9.9	9.2	6.9	3.9	2.7	3.8	3.7	5.7	1.3	3.2	3.5	3.8	6.8	6.8	5.6
Gr2	Mean	5.9	12.9	9.9	5.7	4.4	5.4	8.5	5.0	9.6	7.2	4.9	2.7	5.2	7.1	3.4	5.0
	SD	14.3	35.6	19.9	11.5	8.9	9.9	16.4	8.3	13.0	12.4	8.1	5.2	16.3	15.3	6.8	12.5
Gr3	Mean	3.1	11.8	6.3	7.4	9.8	7.4	2.8	3.7	6.7	2.1	4.6	8.5	8.7	9.5	5.7	5.7
	SD	9.4	15.4	8.4	10.3	10.9	9.1	4.3	5.9	15.4	2.6	6.1	10.8	10.8	13.1	8.5	11.8
† Gr1/Gr2		$p = 0.055$	$p = 0.003^*$	$p = 0.001^*$	$p = 0.001^*$	$p = 0.001^*$	$p = 0.547$	$p = 0.228$	$p = 0.830$	$p = 0.488$	$p = 0.539$	$p = 0.154$	$p = 0.001^*$	$p = 0.001^*$	$p = 0.001^*$	$p = 0.001^*$	$p = 0.188$
†Gr1/Gr3		$p = 0.012^*$	$p = 0.712$	$p = 0.003^*$	$p = 0.093$	$p = 0.706$	$p = 0.228$	$p = 0.088$	$p = 0.037$	$p = 0.687$	$p = 0.251$	$p = 0.325$	$p = 0.303$	$p = 0.534$	$p = 0.012^*$	$p = 0.001^*$	$p = 0.478$
††Gr2/Gr3		$p = 0.213$	$p = 0.360$	$p = 0.709$	$p = 0.445$	$p = 0.024^*$	$p = 0.259$	$p = 0.114$	$p = 0.465$	$p = 0.144$	$p = 0.082$	$p = 0.770$	$p = 0.008^*$	$p = 0.019^*$	$p = 0.028^*$	$p = 0.236$	$p = 0.721$

Abbreviation: SD, standard deviation.
$^*p < 0.05$.

in teeth number 17 ($p = 0.003$), 16 ($p = 0.001$), 15 ($p = 0.001$), 14 ($p = 0.001$), 24 ($p = 0.001$), 25 ($p = 0.001$), 26 ($p = 0.001$), and 27 ($p = 0.001$) in favor of higher applied force in Gr1. For p-value more than 0.05, the intergroup comparison of the other dental elements from Gr1/Gr2 did not indicate a significant difference in terms of the average applied force for an individual tooth (►**Table 1**).

Comparison of Gr1/Gr3, for p-value less than 0.05, indicated a significant difference for average applied force in teeth number 18 ($p = 0.012$), 16 ($p = 0.003$), 26 ($p = 0.012$), and 27 ($p = 0.001$) in favor of higher applied force in Gr1. For p-value more than 0.05, intergroup comparison of the other dental elements from Gr1/Gr3 did not indicate a significant difference in terms of the average applied force for an individual tooth (►**Table 1**).

Intergroup comparison of Gr2/Gr3, for p-value less than 0.05, indicated a significant difference for the average applied force in teeth number 14 ($p = 0.024$), 24 ($p = 0.008$), 25 ($p = 0.019$), and 26 ($p = 0.028$) in favor of higher applied force in Gr3. For p-value more than 0.05, the intergroup comparison of the remaining dental elements from Gr2/Gr3 did not indicate a significant difference related to the average applied force for an individual tooth (►**Table 1**).

A descriptive analysis of teeth with maximum force (Max F10) was made. The minimum/maximum number of teeth carrying the maximum force (Max F10) was 1/5 teeth. In the three groups, Gr1/Gr2/Gr3, as carriers of maximum force, two or three teeth were most often present at the same time.

In Gr1, the most frequent carriers of maximum force (Max F10) were teeth number 17 and 16 that occurred in 56.7 versus 53.3% of the cases, respectively, and teeth 26 and 27 occurred in 40% of the cases (►**Table 2**).

In Gr2, the most common carriers of maximum force (Max F10) were teeth number 17, 16 in 23.3% of the cases, and 12 and 21 in 20% of the cases (►**Table 2**).

In Gr3, the most common carriers of maximum force (Max F10) were teeth 17 and 26 presented in 26.7% of the cases, and teeth 14 and 24 presented in 20 versus 23.3% of the cases, respectively (►**Table 2**).

Discussion

T-scan is a digital static and dynamic occlusion analysis system that records and measures the contacts between the teeth in terms of occlusal force and dynamics of occlusal ratios.[9] It can record relative forces on each tooth and modified or personalized note can be added to each scan in relation to data or patient.[10] Studies showed that T-scan system demonstrates good reproducibility in the premolar region and the molar region, but poor reproducibility in the anterior teeth region which indicates that it is not precise enough for determining the occlusal contact of anterior teeth.[11] In this study, by using T-scan, results showed that the highest average force applied for individual tooth in all groups had posterior teeth and this distribution is clearly expressed after bridge placement. Thereupon great significance in the occlusion analysis should include occlusal force.[12] T-scan III can detect occlusal interferences that are

Table 2 Distribution of maximum force in teeth by T-scan in groups

Groups	Teeth with maximum force (Max F10)															
	18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
Gr1 (*n*)	1	17	13	6	2	0	1	3	2	0	1	2	5	12	12	4
%	3.3	56.7	43.3	20.0	6.7	0.0	3.3	10.0	6.7	0.0	3.3	6.7	16.7	40.0	40.0	13.3
Gr2 (*n*)	4	7	6	2	4	3	6	3	6	5	5	4	1	4	3	5
%	13.3	23.3	20.0	6.7	13.3	10.0	20.0	10.0	20.0	16.7	16.7	13.3	3.3	13.3	10.0	16.7
Gr3 (*n*)	1	8	1	4	6	3	2	1	1	0	1	7	3	8	3	5
%	3.3	26.7	3.3	13.3	20.0	10.0	6.7	3.3	3.3	0.0	3.3	23.3	10.0	26.7	10.0	16.7

difficult to be recognized by the naked eye and cannot be fully detected by another method of occlusal detectors.[13] The number, location and size of all occlusal contacts, interferences if they exist, and the forces that is applied are important for the temporomandibular joints (TMJ) system. Occlusal force control on dental materials or natural teeth can then be measurably designed to ensure material or occlusal surface survival.[14,15] In a case subdivided by single implant and fixed bridge restorations, a study showed that occlusal force of the implanted tooth increased, but the occlusal force of the adjacent natural teeth has decreased; thus, the occlusal force of adjacent natural teeth showed a downward trend.[16] According to a study, Angle's class I had the highest number of contacts, contact area, and bite force distribution.[17] Angle's class I group had 73% of initial contacts in second molars and also there was a preference to right side in bite force distribution.[17] In this study, the distribution average force applied in teeth at Gr 1 varied between 1.4% in dense 22 and 14.6% in dense 17. At Gr2 3.4% in dense 27 and 35.6% in dense 17. At Gr3 2.1% in dense 22 and 15.4% in dense 17. This study indicated that maxillary right second molar had the highest average force in all groups. T-scan is used to guide the operator as to which tooth contact locations require occlusal adjustments.[18] In this study, in patients with intact teeth, the force applied in molars in the first group in comparison with the other two groups is higher. Moreover, by comparing Gr2 with Gr3, there was a significant difference for average applied force in teeth number 14, 24, 25, 26 in favor of higher applied force in Gr3. Based on the results obtained in this study, it can be stated with certainty that there were occlusal imbalances in the participants with class III Kennedy before the bridge placed.

Studies showed that analysis of occlusion only, without understanding the patient context, is not appropriate. Taking this into account, occlusal functions are considerably more adaptable than is conventionally believed.[19]

T-scan III system has the capacity to provide precise time and force sequencing information to objectively evaluate occlusal contacts enabling guide more accurate occlusal adjustment in prosthodontics.[20] Any interference to the normal occlusal contacts produces deviation during closure of maximum intercuspation, hinders smooth way to and from the intercuspation position, and increases the harmful occlusal forces on the bridges, which may lead to damaging effects on abutment tooth.[21]

A possible limitation of this study is the selective grinding of teeth in order to correct excessive occlusal contact force. Here we must emphasize the patient's reaction factors, where the teeth are often not allowed to erode. Another possible limit could be the individual difference in the way of biting. Furthermore, the surface of the sensor film does not always show uniform sensitivity.

Conclusion

This study demonstrated that all patients with the loss of teeth shows occlusal discrepancies and functional disharmony. During the delivery of zirconia restorations in the future, a careful analysis of occlusal contacts should be performed. T-scan III technology reduces the subjective interpretation of occlusal analysis data allowing records and measures the contacts between the teeth.

Authors' Contributions

All authors contributed correspondingly to this work. R.H. contributed to conception, design, data collection, analysis, interpretation of data, and writing manuscript. S.H., L.A., and A.S.H. contributed to the generating the data, analysis, interpretation of data, and critically revised the manuscript. All authors approved the final version of manuscript.

Ethical Committee

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethical Committee of Dental Chamber of Kosovo, Pristina, Kosovo (NR-1061/19, 25.02.2021).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data that support the findings of this study are available upon request from the corresponding author.

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Conflict of Interest
None declared.

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