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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Significance of T-Scan™ in recording occlusion parameters in orthodontic patients

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SUMMARY

Introduction/Objective In orthodontics accurate records about occlusal aspects: contacts, forces, loads, the total load force and bilateral force distribution are essential. The aim of this prospective clinical study was to evaluate occlusal parameters in different malocclusions and normal occlusions using the T-Scan III Novus (Tekscan Inc., Boston, MA, USA).

Methods Group of 43 patients, was divided in three types of malocclusions (class I, II, III), normal occlusion. A multi-bite scan was registered, using T-Scan III Novus (Tekscan Inc.). Data was analyzed with T-Scan software v 10 (Tekscan Inc.). The total force on the first molars was analyzed, and average force percentage compared. For bilateral load distribution, we analyzed total forces in the first; fourth versus the second; third quadrant, for each malocclusion, average force was assessed and compared.

Results The first molar's occlusal load showed that tooth #26 was favored to bear the highest load of all first molars in class II, III, and normal occlusion. In class I malocclusion all molars had similar forces. The highest occlusion force mean on the right side was in class III, and at the left side in class II. The highest discrepancy was in class II, then class III, class I, and the lowest in the normal occlusion.

Conclusion Normal occlusion was the most equilibrated, with the best load distribution, lowest discrepancy and highest force values, while in other classes there was a need for load equilibration and similar force distribution throughout dental arches to minimize discrepancy between left and right side of the jaws.

Keywords: T-Scan; malocclusion; occlusal load

INTRODUCTION

The orthodontic therapeutic goal is to achieve an ideal alignment between the teeth in the dental arch and to allow even distribution of the generated forces during the act of mastication [1]. For instance, any premature occlusal contact can generate occlusal stress which leads to alterations in the tooth-supporting tissues, the masticatory muscles, and temporo-mandibular joint [1]. Occlusal articulation relations can be recorded using several occlusal analyzers. Articulating paper being the most used occlusal analyzer for determining contact points between the maxillary and mandibular arch. However, the paper can only record contact points and is unable to accurately quantify their intensity and/or determine the magnitude of the generated occlusal forces [1].

Clinicians use occlusal contact detection to identify the height of restorations, equilibrate occlusion [2], and to perform post-orthodontic adjustments [3, 4, 5]. However, these static indicators only mark the surface area of dental contact, and do not have the ability to assess the degree of occlusal force within the contact or quantify it is time variance. These methods are based on clinician's "subjective interpretation" combined with the patient's feeling and verbal feedback [6]. The correlation between the size of occlusal marking and the actual relative occlusal force contained within the marking is only 21%, if the largest paper mark on a tooth represents the most forceful contact, may result in wrong contact adjustment [7]. There is not enough scientific evidence that shows articulating paper can reproduce occlusal force, to justify its continued use as a diagnostic aid [8, 9].

Maness invented the T-Scan system for computer occlusal analysis in 1987 which allows real-time measurements of occlusal forces to be captured with intraoral sensor. The tool was upgraded over the years, with software and hardware modifications until current version of the system, known as T-Scan III Novus (Tekscan Inc., Boston, MA, USA). Graphical interface is supported by the T-Scan software v 10 (Tekscan Inc.) [8]. The program utilizes the data and displays it in full color 3D or 2D images. The resultant occlusal contacts are visualized as contours or cellular pictures on dental arch in 2D graphics. Moreover, the left and right sides can be displayed in distinct color codes (green on the left, red on the right), with the respective occlusal forces given underneath [9–12]. The dentition can also be divided into

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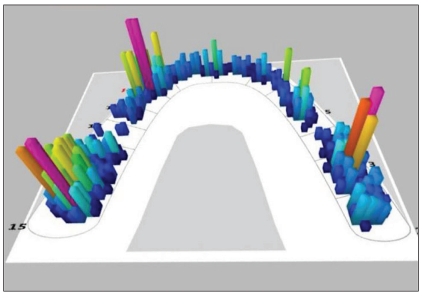

Figure 1. 3D occlusal load interpretation

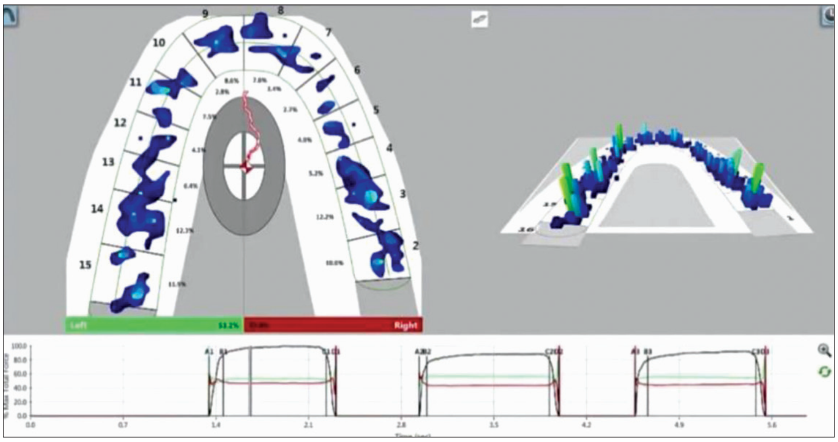

Figure 2. 2D occlusal load interpretation

two halves: anterior and posterior, dividing it in four study segments [13, 14] (Figures 1 and 2).

The aim of this prospective clinical study was to evaluate occlusal parameters in different malocclusions and normal occlusions using the T-Scan III Novus (Tekscan Inc.).

METHODS

This prospective clinical study was performed at Ras Al Khaimah college of dental sciences, Dubai, United Arab Emirates. The study was approved by the ethics committee of the School of Dental Medicine, University of Belgrade (No. 36/24)598 and it meets the criteria for medical research involving human subjects according to the ethical principles described in the Declaration of Helsinki. Study included 43 patients, with different types of malocclusions and normal occlusion, divided into four groups. Age range was 18–60 years old. All the subjects were given written consent.

Inclusion criteria: class I malocclusion (normal molar relationship, with crowding, misalignment of the teeth, rotations, cross-bites, and other alignment irregularities), class II malocclusion, class III malocclusion, normal occlusion. Exclusion criteria: patients with TMJ disorders, patients with severe malocclusion who require surgical treatment. Participants were assessed, a multi-bite scan was registered, using the T-Scan III Novus (Tekscan Inc.) for each patient to record the occlusal parameters.

Two variables were assessed:

1. NET discrepancies of forces generated at maximum intercuspation position between the left and the right side of the mouth.

2. the total average occlusal force of the first molars withstanding at maximum intercuspation position.

The patients were seated on the dental chair with the lower and upper half of the body positioned at an angle of 90º. Data acquisition using the T-Scan III Novus device (Tekscan Inc.) consisted of registering occlusal contacts with a sensor film, data transfer though a module called the 'handpiece' which is linked to a computer, with data processing software, to visualize the parameters on the computer screen (Figure 3).

Figure 3. T-Scan III Novus (Tekscan Inc.) handle and sensor film for load registration

Figure 4. T-Scan intraoral load registration

The recording sensor was inserted intraorally between the dental arches so that the central mark is positioned between the central incisors of a patient. Recording started with pressing the button on the handlebar; the patient was instructed to occlude firmly to complete intercuspation. A multi-bite scan was recorded for each subject consisting of three bites consequently, to minimize the possibility of an error. Values of the three readings were assessed for each patient. Nevertheless, the maximum intercuspation position – the B point interval, was also taken into consideration in this study (Figure 4).

Scan records were analyzed using the T-Scan III Novus software v 10 (Tekscan Inc.). The total force on the first molars was analyzed on each scan. For these selected teeth, an average force percentage was calculated and compared. For bilateral load distribution assessment, we analyzed the total forces in the first and fourth quadrant versus the second and third quadrant, for every patient and each malocclusion. Data was analyzed and average force for the right side (first : fourth quadrants) *vs.* left side (second : third quadrants) was assessed.

Data was processed using the IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA) software. Both descriptive and inferential statistics were used to describe the sample, identify differences in mean values between each tooth. The exact (and approximate) 95% confidence intervals, statistics test values, and p-values were reported. The p-value ($p < 0.05$) was defined as statistically significant.

Descriptive statistics was used to summarize the mean and standard deviation of each molar variables. One-way analysis of variance (ANOVA) was used to determine whether there are any significant differences in occlusion force means between groups. Post hoc was used to figure out which groups in the sample differ and to compare every mean with another.

RESULTS

Patient assessment:

At clinical assessment, the subjects were sorted out according to Angle's classification of malocclusion. In total, 14 subjects were diagnosed with class I malocclusion, eight subjects were diagnosed with class II malocclusion, nine subjects were diagnosed with class III malocclusion, and finally 12 subjects had no malocclusion (normal occlusion).

T-Scan III Novus data assessment:

The results in Table 1 display the mean values of occlusal force for each molar independently. The results showed that the highest occlusal force in the normal occlusion was noted in tooth (T) 26 of (B1, B2, B3), (B – point interval of maximal intercuspation), the mean of B1 was (14.8), B2 (14), and B3 (14.6). On the other hand, the readings of class I malocclusion were approximately close to one another, which ranged 9.4–12.5. Similarly in class II malocclusion, the values of T26 were the highest. B1, B2, and B3 had readings of mean values (11.6, 10, and 9.7) respectively. Finally, in regards of class III malocclusion, the readings of occlusion force of T26 and T36 were approximately the same, but they were higher compared to T16 and T46 (Table 1).

As the first molars are Angle's keys of the occlusion, they were of particular interest for this assessment. For purpose of this study, the analysis was narrowed to specific teeth: 16 – upper right first molar, 46 – lower right first molar, as opposed to each other they form an occlusal unit. As well as 26 – upper left first molar, 36 – lower left first molar on the opposite side of dental arch. Table 2. shows that the lowest occlusion force was noted in class II malocclusion between teeth 16 (5.7444 ± 5.98567) and 46 (3.0519 ± 4.18051). On the other hand, the highest occlusion force was noted in the normal occlusion between teeth

Table 1. Descriptive statistics for each molar by classification

Normal occlusion				
	T-16	T-26	T-36	T-46
B1	12.06	14.8	10.8	10.3
B2	10.68	14	11.7	8.9
B3	14.13	14.6	8.79	11.2
Class I malocclusion				
	T-16	T-26	T-36	T-46
B1	9.869	12.523	11	11
B2	10.692	11.783	10	10
B3	11.220	10.090	10	9.4
Class II malocclusion				
	T-16	T-26	T-36	T-46
B1	4.81	11.6	8.5	3.37
B2	5.06	10	6.8	4.82
B3	8.53	9.7	8.5	2.23
Class III malocclusion				
	T-16	T-26	T-36	T- 46
B1	9.712	12.51	12.17	7.21
B2	10.1	11.50	11.54	7.53
B3	7.875	10.87	11.55	6.28

T – tooth number; B – point interval maximal intercuspation

16 (13.5917 ± 10.50322) and 46 (14.4296 ± 5.79900). In regards of class I malocclusion, the occlusion force between teeth 16 and 46 was slightly higher compared to teeth 26 and 36. In contrast, the occlusion force in class III malocclusion of teeth 26 and 36 was higher than in 16 and 46. In total the highest values were noted at normal occlusion.

One-way analysis of variance (ANOVA) is used to determine differences in occlusion force mean values between groups. Table 3 shows the descriptive statistics of occlusion force by ANOVA. The highest occlusion force mean at the right side was reported in class III malocclusion (53.3019 ± 13.32165). While on the left side highest values were noted in class II (57.3854 ± 12.29782). The NET discrepancy indicates, that the highest value was noted in class II malocclusion, followed by class III

Table 2. Descriptive statistics of malocclusion as a group

Parameters	Class I malocclusion	Class II malocclusion	Class III malocclusion	Normal
16 (B1 + B2 + B3)	10.1267 ± 7.01293	5.7444 ± 5.98567	8.0815 ± 7.78995	13.5917 ± 10.50322
26 (B1 + B2 + B3)	9.8367 ± 7.48175	9.0074 ± 7.91359	10.4852 ± 14.45189	13.2944 ± 10.56608
36 (B1 + B2 + B3)	10.0333 ± 8.10563	6.7556 ± 6.40297	10.5519 ± 15.47594	9.5111 ± 7.91757
46 (B1 + B2 + B3)	9.9400 ± 6.07756	3.0519 ± 4.18051	7.5905 ± 8.31459	14.4296 ± 5.79900

B – point interval maximal intercuspation

Table 3. Descriptive statistics result by Analysis of Variance (ANOVA)

Parameters		N	Mean	Standard deviation	Standard error	95% confidence interval for mean		Minimum	Maximum	Significance #
						Lower bound	Upper bound			
Right	Normal	12	46.5423	9.74603	2.70306	40.6528	52.4318	27.60	61.63	p = 0.238
	Class I	14	44.7231	11.29099	3.01765	38.2039	51.2423	29.17	71.17	
	Class II	8	42.6146	12.29782	4.34794	32.3333	52.8958	26.67	60.23	
	Class III	9	53.3019	13.32165	4.44055	43.0619	63.5418	31.60	74.53	
Left	Normal	12	53.4577	9.74603	2.70306	47.5682	59.3472	38.37	72.40	p = 0 .238
	Class I	14	55.2615	11.27031	3.01212	48.7543	61.7688	28.83	70.83	
	Class II	8	57.3854	12.29782	4.34794	47.1042	67.6667	39.77	73.33	
	Class III	9	46.6981	13.32165	4.44055	36.4582	56.9381	25.47	68.40	
NET Discrepancy	Normal	12	15.1000	13.59180	3.76969	6.8866	23.3134	0.47	44.80	p = 0.544
	Class I	14	19.3766	14.97600	4.00250	10.7297	28.0234	2.47	42.33	
	Class II	8	24.7292	12.46588	4.40736	14.3074	35.1509	3.90	46.67	
	Class III	9	20.0556	17.50490	5.83497	6.6001	33.5110	1.00	49.07	

N – number of patients; #one way ANOVA

Table 4. Multiple comparison (post-hoc Tukey) of dependent variable

Dependent variable			Mean difference (I–J)	Standard error	Significance	95% confidence interval	
						Lower bound	Upper bound
Right	Normal	Class I	1.81923	4.42333	1.000	-10.4593	14.0978
		Class II	3.92772	5.16055	1.000	-10.3973	18.2527
		Class III	-6.75954	4.97991	1.000	-20.5831	7.0640
	Class I	Normal	-1.81923	4.42333	1.000	-14.0978	10.4593
		Class II	2.10849	5.08986	1.000	-12.0203	16.2373
		Class III	-8.57877	4.90661	0.528	-22.1989	5.0413
	Class II	Normal	-3.92772	5.16055	1.000	-18.2527	10.3973
		Class I	-2.10849	5.08986	1.000	-16.2373	12.0203
		Class III	-10.68727	5.58035	0.376	-26.1776	4.8030
	Class III	Normal	6.75954	4.97991	1.000	-7.0640	20.5831
		Class I	8.57877	4.90661	0.528	-5.0413	22.1989
		Class II	10.68727	5.58035	0.376	-4.8030	26.1776
Left	Normal	Class I	-1.80385	4.42079	1.000	-14.0754	10.4677
		Class II	-3.92772	5.15758	1.000	-18.2445	10.3890
		Class III	6.75954	4.97705	1.000	-7.0561	20.5752
	Class I	Normal	1.80385	4.42079	1.000	-10.4677	14.0754
		Class II	-2.12388	5.08693	1.000	-16.2445	11.9968
		Class III	8.56339	4.90379	0.531	-5.0489	22.1757
	Class II	Normal	3.92772	5.15758	1.000	-10.3890	18.2445
		Class I	2.12388	5.08693	1.000	-11.9968	16.2445
		Class III	10.68727	5.57714	0.375	-4.7941	26.1687
	Class III	Normal	-6.75954	4.97705	1.000	-20.5752	7.0561
		Class I	-8.56339	4.90379	0.531	-22.1757	5.0489
		Class II	-10.68727	5.57714	0.375	-26.1687	4.7941
NET Discrepancy	Normal	Class I	-4.27656	5.67110	1.000	-20.0188	11.4657
		Class II	-9.62917	6.61628	0.920	-27.9951	8.7367
		Class III	-4.95556	6.38468	1.000	-22.6786	12.7675
	Class I	Normal	4.27656	5.67110	1.000	-11.4657	20.0188
		Class II	-5.35261	6.52564	1.000	-23.4669	12.7617
		Class III	-0.67900	6.29071	1.000	-18.1412	16.7832
	Class II	Normal	9.62917	6.61628	0.920	-8.7367	27.9951
		Class I	5.35261	6.52564	1.000	-12.7617	23.4669
		Class III	4.67361	7.15450	1.000	-15.1863	24.5335
	Class III	Normal	4.95556	6.38468	1.000	-12.7675	22.6786
		Class I	0.67900	6.29071	1.000	-16.7832	18.1412
		Class II	-4.67361	7.15450	1.000	-24.5335	15.1863

malocclusion, then class I malocclusion, and the lowest discrepancy was found in the normal occlusion; (24.7292 ± 12.46588, 20.0556 ± 17.50490, 19.3766 ± 14.97600, and 15.1000 ± 13.59180) respectively (Table 3). The results showed that there was no statistically significant difference between the mean values of occlusion force between the selected teeth (16, 26, 36, and 46) within groups. There was no statistically significant difference within groups as determined by one-way ANOVA in regards of right and left side (p = 0.238), similarly, to the NET discrepancy there was "no" statistically significant difference between groups (p = 0.544) (Table 3).

Multiple comparisons show which groups differed from each other. In Table 4 the results showed that there are no significant differences between the groups as whole. The Tukey post-hoc test was used for conducting post-hoc tests on a one-way ANOVA. A Tukey post-hoc test showed that there were no significant differences between the groups as whole as the p-value ranged from 0.375 to 1.000.

The crosstabulation table showed that seven (25.9%) of the participants had discrepancy compared to five (35.3%) without discrepancy, with normal occlusion. While eight (29.6%) participants had a discrepancy compared to six (35.3%) in class I malocclusion. Moreover, seven (25.9%) participants vs one (5.9%) participant in class II malocclusion had discrepancy in occlusion force. In class III malocclusion, five (18.5%) had a discrepancy compared to four (23.5%) without discrepancy. In total, 27 participants had a discrepancy compared to 16 participants without discrepancy (Table 5) (Figure 5).

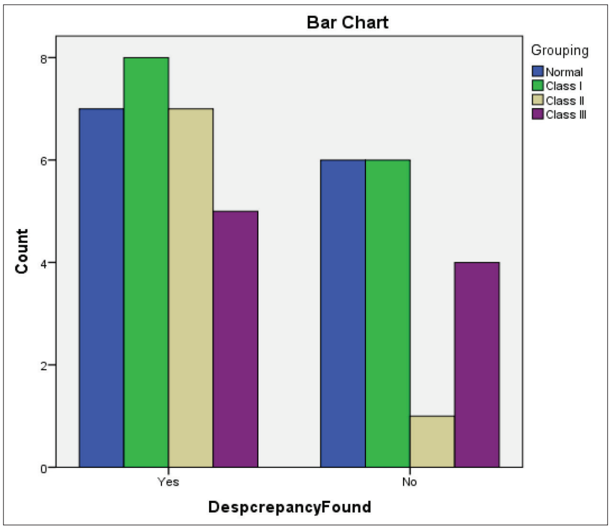

Figure 5. Discrepancies of occlusion force of all situations as outcome of χ^2

Table 5. Grouping cross-tabulation

Parameters		Grouping				Significance
		Normal	Class I	Class II	Class III	
Discrepancy found	Yes	7 (53.8%)	8 (57.1%)	7 (87.5%)	5 (55.6%)	p = 0.416
	No	5 (46.2%)	6 (42.9%)	1 (12.5%)	4 (44.4%)	
Total		12 (100%)	14 (100%)	8 (100%)	9 (100%)	

DISCUSSION

An important part of dental assessment in orthodontics, prosthetics, implantology, and other branches of dentistry is information about occlusal contacts. Over the years this information was obtained in many ways of which the most used occlusal analyzer for determining contact points between the maxillary and mandibular arch was articulating paper. Chowdhary and Sonnahalli [1]. stated that this manner of intermaxillary contact assessment resulted as less accurate, since the only information are the dots and shapes that cannot be quantified. Nevertheless, the novel generation of intraoral digital occlusal contact identifier T-Scan III Novus (Tekscan Inc.) is the most reliable system for dental contact assessment. This system provides 2D and 3D visualization of dental contacts and measures the force between the teeth. In this study statistical analysis was done with information obtained with T-Scan III Novus (Tekscan Inc.) and measurement of occlusal force.

Other authors emphasized the role of the first molars in balanced occlusion and Angle was the first who stated that the key of the occlusion were the first molars, that is why the first molar load distribution was of particular interest for this study [2–5]. First of all, the individual load of the first molars was assessed, tooth T26 in normal occlusion showed the highest values of load barring (B1 14.8, B2 14.0, B3 14.6). The T16 in the normal occlusion had similar but somewhat lower values of load barring (B1 12.06, B2 10.68, B3 14.13). Which indicates that the highest load was measured in region of upper first molars. In class I malocclusion tooth T26 was also barring the highest load (B1 12.523, B2 11.783, B3 10.090), but the differences between the measured teeth (T16, T26, T36, T46) were not as high, ranging from 9.4 to 12.523. This indicates similar load distribution in each one of the first molars. Class II malocclusion also showed the highest load on the tooth T26 – B1 11.6, B2 10, B3 9.7. While in class III malocclusion T26 and T36 had higher readings compared to the T16 and T46, which indicates higher load force in the first molar region on the left side of upper and lower dental arch (Table 1).

When the first molar occlusal units (16:46;26:36) were assessed the data showed that the lowest force was in class II malocclusion between teeth 16 and 46 (5.7444 ± 5.98567 and 3.0519 ± 4.18051) respectfully. Nevertheless, the highest force was noted in normal occlusion between teeth 16 and 46 (13.5917 ± 10.50322 and 14.4296 ± 5.79900) respectfully. In class I malocclusion the occlusion force between teeth 16 and 46 was slightly higher than between 26 and 36. In contrast, the occlusion force in class III malocclusion between teeth 26 and 36 was higher than between 16 and 46. In total the highest values were noted at normal occlusion (Table 2). This illustrates the load distribution through contact surfaces in different classes, the load is changing depending on number and size of contacts.

As Rubió-Ferrer et al. [3] stated slight lateral asymmetries in occlusal contact area and masticatory muscle force are relatively frequent, because maximum bite force and occlusal contact area are key to masticatory performance, mastication is more frequently dominant on one side which usually offers the most efficiency. This was also suggested in our study where one-way analysis of variance ANOVA was used to determine whether there are any differences in occlusion force mean values between groups, which showed that the highest occlusion load mean was noted at the right side in class III malocclusion, while on the left side the highest mean value was noted in class II. NET discrepancy showed that the highest mean value was in class II followed by class III than class I and normal occlusion (24.7292 ± 12.46588, 20.0556 ± 17.50490, 19.3766 ± 14.97600, and 15.1000 ± 13.59180) respectfully (Table 3). This data demonstrates that the normal occlusion with lowest NET discrepancy mean, showed the most balanced relationship between left and right side. Analysis of variance ANOVA showed that there were no statistical differences within groups between the mean values of occlusion force of the teeth 16, 26, 36, and 46. This illustrates that in every group there was similar load distribution in each one of the first molars as shown in Table 3.

The results of comparison of groups to establish how groups differed from each other showed that there were no statistically significant differences between groups as whole, which indicates that groups did not differ in a significant manner. Post-hoc Tukey test on one way ANOVA showed that there were no statistically significant differences between groups as whole since the p value ranged 0.375–1.000 (Table 4).

CONCLUSION

Normal occlusion was the most equilibrated, with the best load distribution, lowest discrepancy and highest force values, while in other classes there was a need for load equilibration and similar force distribution throughout dental arches to minimize discrepancy between left and right side of the jaws.

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Значај Т-скена у регистровању оклузалних параметара код ортодонтских пацијената

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САЖЕТАК

Увод/Циљ У ортодонцији је од великог значаја тачна евиденција о оклузалним аспектима: контактима, силама, оптерећењима, укупној сили оптерећења и билатералној расподели силе.

Циљ ове проспективне клиничке студије била је процена оклузалних параметара код различитих малоклузија и нормалне оклузије коришћењем *T-Scan III Novus*-а (Tekscan Inc., Бостон, МА, САД).

Методе Група од 43 пацијента подељена је у три типа малоклузије (класа I, II, III) и нормалну оклузију. Регистровано је скенирање више загрижаја коришћењем *T-Scan III Novus*-а (*Tekscan Inc*.). Подаци су анализирани софтвером *T-Scan v* 10. Анализирана је укупна сила на првим моларима и упоређен је просечни проценат силе. За билатералну расподелу оптерећења анализирали смо укупне силе у првом и четвртом наспрам другог и трећег квадранта, а за сваку малоклузију процењена је и упоређена просечна сила.

Резултати Оклузално оптерећење првих молара показало је да је зуб #26 поднео највеће оптерећење од свих првих молара у класама II, III и нормалној оклузији. У класи I малоклузије сви молари су имали сличне силе. Највећа средња сила оклузије на десној страни била је у класи III, а на левој страни у класи II. Највеће одступање било је у класи II, па у класи III и класи I, а најмање у нормалној оклузији.

Закључак Нормална оклузија је била најуравнотеженија, са најбољом расподелом оптерећења, најнижим одступањем и највећим вредностима силе, док је у другим класама постојала потреба за уравнотежењем оптерећења и сразмерном расподелом силе кроз зубне лукове како би се минимизирало неслагање између леве и десне стране вилица.

Кључне речи: Т-скен; малоклузија; оклузално оптерећење