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Impact of orthognathic surgery on occlusal contacts and bite force distribution in patients with skeletal Class III malocclusion by T-Scan™

Утицај ортогнатске хирургије на оклузалне контакте и дистрибуцију силе загрижаја код пацијената са III скелетном класом применом Т-скен система

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SUMMARY

Introduction/Objective Primary aim of malocclusion treatment is to achieve optimal occlusion. The purpose of this pilot prospective clinical study was to investigate digital occlusal features pre and post orthognathic surgery among individuals with skeletal Class III malocclusion.

Methods Nine patients confirmed to have skeletal Class III malocclusion participated in this study, including four females and five males. Single bite scan was performed seven days before and 6–8 weeks after surgery using T-Scan Novus (Tekscan Inc., Norwood, MA, USA). Occlusal time, total average occlusal force of upper and lower arch and projection of center of force (COF) were assessed and compared before and after surgery.

Results Compared to the pre-surgical period; occlusal time was significantly reduced ($p = 0.011$). While the total force in the anterior segment increased ($p = 0.008$), a decrease was noted in the posterior segment ($p = 0.008$). The COF demonstrated a markedly improved position in the post-surgical period, indicating a more stable occlusion ($p = 0.026$).

Conclusion In subjects with skeletal Class III malocclusion, surgical treatment significantly improves occlusal quality, including occlusion and disclusion times, the distribution of total force in the antero-posterior direction, and the COFs, compared to the pre-surgical condition.

Keywords: T-Scan; skeletal Class III; orthognathic surgery; digital occlusal analyzer

САЖЕТАК

Увод/Циљ Примарни циљ лечења малоклузије је постизање оптималне оклузије. Сврха ове проспективне клиничке пилот студије била је да се процене дигитални оклузални параметри пре и после ортогнатске хирургије код пацијената са III скелетном класом.

Методе Студија је обухватила девет пацијената, четири особе женског и пет мушког пола, код којих је дијагностикована малоклузија III скелетне класе. Скенирање једног загрижаја извршено је седам дана пре и 6–8 недеља након хирургије, користећи Т-скен Новус (*Tekscan Inc.*, Норвуд, МА, САД). Време оклузије, укупна просечна оклузална сила горњег и доњег зубног лука и пројекција центра силе (*COF*) су процењени и упоређени пре и после операције.

Резултати У поређењу са преоперативним периодом, време оклузије било је значајно смањено ($p = 0{,}011$). Док је укупна сила у предњем сегменту порасла ($p = 0{,}008$), у задњем сегменту је забележено њено смањење ($p = 0{,}008$). *COF* показао је значајно бољу позицију у постоперативном периоду, што указује на стабилнију оклузију ($p = 0{,}026$).

Закључак Код пацијената са III скелетном класом, хируршка терапија значајно побољшава квалитет оклузије укључујући време оклузије и дисклузије, расподелу укупне силе у антеро-постериорном правцу, као и *COF*, у поређењу са преоперативним стањем.

Кључне речи: Т-скен; III скелетна класа; ортогнатска хирургија; дигитални оклузални анализатор

INTRODUCTION

The primary aim of malocclusion treatment is to achieve optimal occlusion, regardless of the presence of skeletal discrepancies. The development of dental occlusion is under the influence of functional and genetic factors, while in certain cases, malocclusion arises due to adaptations of masticatory muscles and temporomandibular joint during dental arch formation. [1]. Premature occlusal contacts on teeth can induce dental stress, which in turn may contribute to pathological alterations in the supporting periodontal structures, temporomandibular joint complex, and the masticatory musculature [2]. Orthodontic therapy corrects malocclusion through precise alignment of the dentition and the establishment of an optimal interarch relationship, thereby achieving normal occlusion as characterized by the criteria of Ricketts, Roth, Andrews, and Angle [1, 3]. Orthognathic surgery is indicated in cases involving skeletal deformities. The primary goal of orthodontic treatment is to achieve optimal oral health by establishing proper aesthetics, function, and stability. A stable centric occlusion and maximal intercuspation serve as key indicators of a well-established and functional occlusion [1]. Following post-surgical orthodontic treatment and orthognathic surgery in patients with discrepancies in skeletal structure, it is crucial to establish reliable occlusal contacts that promote a balanced and uniform transmission of masticatory forces throughout the mandible [4, 5].

Occlusal relations may be evaluated through a range of occlusion analysis instruments, with articulating paper serving as the primary method for precisely identifying contact points between the upper and lower dental arches. However, while the articulating paper effectively records contact points, it cannot accurately assess the force applied at these points or quantify the strength of the occlusal loads generated [4, 5]. The T-Scan™ (Tekscan Inc., Norwood, MA, USA) computerized occlusal analysis system provides real-time occlusal contact force distribution and monitors dynamic changes from the initial tooth contact to the maximum intercuspal position during occlusion. This allows dental specialists to assess the location, force, and timing of occlusal contact using an ultrathin sensor foil, measuring around 0.1 mm (100 μm) in thickness. The center of force (COF) trajectory and the force-time graph are presented in two- and three-dimensional (2D, 3D) graphs. Digital data from the T-Scan™ (Tekscan Inc.) system allow accurate, focused modifications to achieve optimal occlusal balance. The dentition can also be divided into anterior (A) and posterior (P) regions, creating four analytical study units. There is also a possibility to upload stereolithography files from intraoral scans (Figures 1 and 2) [6, 7].

The aim of this pilot prospective clinical study was to assess changes in occlusal timing, total average occlusal force of the upper and lower arches, and the projection of COF in patients with skeletal Class III malocclusion, pre- and post-orthognathic surgery.

METHODS

This prospective clinical pilot study was performed at School of Dental Medicine, University of Belgrade, Serbia. The clinical study involved nine consecutive participants treated at our clinic, all of whom fulfilled the predefined inclusion criteria. The sample included four females and five males, confirmed to have skeletal Class III malocclusion who were treated with fixed orthodontic appliances, 0.018-inch slot, Roth prescription, with second molars included in both maxilla and mandible as preparation for orthognathic surgery. All patients underwent bimaxillary surgery. All participants provided written informed consent.

Digital occlusal parameters were recorded seven days before surgery and 6–8 weeks after (at the first orthodontic appointment) orthognathic surgery.

Inclusion criteria: Skeletal class III malocclusion (ANB<1°, Wits<0mm, patient may present discrepancies in either the vertical or transverse dimension); Orthognathic surgical treatment. Age 19-35 years.

Exclusion criteria: Systemic diseases; TMJ disorders; Bruxism; Cleft lip and/or palate; Craniofacial syndromes.

Three variables were assessed:

1. Occlusal time changes (time taken to go from initial contact to maximum intercuspation).

2. Total average occlusal force of the upper and lower arch withstanding at maximum intercuspation position.

3. Projection of COF before and after surgery illustrating the balance of occlusion.

Patients were seated in dentist's chair with a right angle (90°) between their upper and lower body. Data were recorded using the T-Scan™ (Tekscan Inc.) system. Prior to recording, the upper central incisor dimensions and tooth distributions were inserted into the T-Scan dental chart to personalize the graphical dental arches for more accurate occlusal arch mapping during measurements. Sensor calibration was performed to adjust its sensitivity level to the occlusal forces of each individual. Occlusal data were acquired using the T-Scan™ (Tekscan Inc.) system by recording contact points with a sensor foil. Data were carried out through a module known as the 'handpiece', which was connected to a computer running processing software for visualizing the observed parameters (Figure 2 and 3).

Graphical interface is supported by the T-Scan software v 10 (Tekscan Inc.) [8, 9]. The sensor of the T-Scan™ system was placed in the mouth of the subject in the upright position, with its position guide located between the central incisors. Recording began by activating button on the handlebar. As parallel as possible to the occlusal plane, the sensor's handle was positioned. Each participant was instructed to occlude once onto the sensor foil applying maximal bite pressure for 1–2 seconds. Defined as the interval from first contact to maximum intercuspation, occlusal time was determined using the time tables provided by T-Scan software (version 10.0, Tekscan Inc.). A value of ≤ 0.2 seconds was regarded as ideal for occlusion time, and ≤0.4 seconds for disclusion time [10,11, 12].

The T-Scan™ (Tekscan Inc.) system calculates relative force percentages (%F) for each tooth based on the total occlusal force at a given moment. These values are presented alongside timing data in seconds and are visualized through the force outliers tab in the timing table [11]. In the maximum intercuspation position, occlusal time, COF position, and force distribution percentages in the right-left (RL) and antero-posterior (AP) areas were evaluated. Values of the three readings were assessed for each patient. Force distribution percentages in the RL and AP regions were calculated by splitting the dental arch into four sections: anterior right, anterior left, posterior right, and posterior left. Percentages of anterior force were obtained from the central incisors to the canines, including the lateral incisors [13].

In the 2D graph, the COF is depiced using red and white diamonds (Figure 4), illustrating the balance of occlusion. It is used to establish proper stability of occlusion [11]. The COF locations were classified into three patterns: ideal, where the COF appears as a white point within the center of the ellipse; good, when it is located within the silver area of the outside ellipse; if it falls outside both designated zones, it is classified as outside of area. To assess closure stability, the trajectory of COF from initial tooth contact to maximum intercuspation was classified into four separate patterns: First- trajectory was considered normal when it proceeded in a direct line from the front to the back of the arch, roughly following the midline. Second-when the trajectory localized within a defined region instead of following a straight-line course, it was considered a contact point. Third-slipping in left-right, described as the trajectory, was delineated horizontally across the midline. Fourth- slipping in right-left, described as the trajectory, was delineated horizontally relative to the midline [1] (Figure 5).

Using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, USA), the data were processed. To summarize the data, descriptive statistics was applied, including calculations of the mean, standard deviation, minimum, and maximum values for each variable. In order to assess the evidence of statistically significant differences between paired (related) variables, the Wilcoxon Signed Ranks Test was applied. Due to the non-normal distribution of the data, that test was chosen, as determined by preliminary assessments. The results were presented with corresponding p-values, statistical significance was regard at a p-value of less than 0.05. Statistical tests for all analyses were two-tailed.

Ethics: This study was performed at School of Dental Medicine, University of Belgrade, Belgrade, Serbia. Ethical approval was obtained from the institutional ethics committee (Approval No. 36/34), and was carried out in line with the ethical standards described in the Declaration of Helsinki for studies involving human subjects.

RESULTS

The results present the mean ($\overline{x}$), standard deviation (SD), median, and minimum–maximum values for occlusal time and total average occlusal force. These results showed that patients with skeletal Class III have a statistically significant improvement in occlusal time ($p=0.011$) following orthognathic surgery, whereas disclusion time increased (0.28 ± 0.41 seconds) compared to the pre-surgical condition (0.27 ± 0.27 seconds). (Table 1).

The results for total average occlusal force show that there was a statistically significant difference in force distribution in both the anterior and posterior segments of the dental arch. The anterior segment (A) shows an increase in total force after the surgical treatment, as seen in Table 1 (before 0.20 ± 0.11%, after 0.55 ± 0.18%), while the posterior segment (P) shows a decrease in total force compared to the pre-surgical condition (before 0.80 ± 0.11%, after 0.45 ± 0.18%).

In contrast to the anterior and posterior segments, the left (L) and right (R) sides of the dental arch didn't show statistically significant variation in force distribution in relation to the pre-surgical condition. However, it can be noted that the left side of the dental arch showed a decrease in total bite force after the intervention (before 0.55 ± 0.09%, after 0.48 ± 0.09%), while an increase in bite force was assessed on the right side (before 0.45 ± 0.09%, after 0.52 ± 0.10%).

COF is explained as a diamond-shaped icon. During data recording before surgery, patients exhibited various positional variations of the diamond-shaped icon, as shown in Table 1. All four possible trajectories, previously explained and illustrated in Figure 5, were present. After surgery, the COF tended to be more centralized, and all examined patients indicated a statistically significant difference ($p = 0.026$) in the position of COF. Its post-surgical position was within normal limits (Table 2).

DISCUSSION

This pilot study examined occlusal factors in participants confirmed to have skeletal Class III malocclusion, seven days preoperatively and 6–8 weeks postoperatively. Previous studies have investigated occlusion in patients with various occlusal classes at two or three different time points [14, 15, 16]. Digital devices enable improved accuracy and enhanced precision in analyzing the timing and intensity of occlusal contacts, while the T-Scan™ (Tekscan Inc.) system enables accurate assessment of a patient's bite [2, 17]. This technology also captures objective occlusal patterns during jaw movement, which can be crucial for effective orthodontic treatment. Regular monitoring allows for early detection and correction of occlusal discrepancies and related musculoskeletal imbalances [18, 19, 20]. Consequently, assessing occlusion both pre- and post-surgery, as demonstrated in this study, proves to be highly beneficial for patient outcomes.

Occlusal time gradually decreased after surgery, approaching the ideal physiological range. These findings suggest that minimizing occlusal time is important for facilitating smooth mandibular closure into maximum intercuspation without premature contacts. In contrast, disclusion time was within the physiological normal range both prior to and following the surgical intervention, with our findings indicating only minimal variations that did not reach statistical significance. Previous studies have reported that ideal physiological occlusal times is less than 0.2 seconds, with some authors suggesting a typical range between 0.1 and 0.4 seconds [1, 13]. The results of our research are consistent with those reported by Tammataratarn et al. [1]. Evidence from multiple studies by Ellis et al. [21] reported that individuals scheduled for orthognathic surgery due to dentofacial deformities exhibited lower maximum bite force compared to healthy controls, emphasizing the clinical relevance of evaluating masticatory strength prior to surgical intervention. Similar findings are also reported by Iwase et al. [22], who showed that their patients had a decreased forces postoperatively, compared to presurgical bite force. Results for total average occlusal force showed a statistically significant improvement in force distribution in AP area. Specifically, there was a notable increase in force distribution in the A segment after surgery, while a decrease in total occlusal force is observed in the P segment. As a result of the surgical intervention, subjects with skeletal Class III malocclusion achieve proper incisal overjet, which allows the inclusion of a greater number of anterior teeth and a beneficial force distribution compared to the preoperative state [22].

In contrast to the AP segment, RL areas didn't show statistically significant variations in force distribution after surgical procedure. This outcome may depend on several factors, such as the surgeon's skill, tooth positioning, or potential postoperative relapse. Compared to our study, Tammataratarn et al. [1] did not find a statistically significant variation between the experimental and control groups in the AP and RL areas. However, they did observe a significant difference in bite force between the preoperative period and one month after surgery.

Postoperative assessments revealed improved force distribution and occlusal force transmission, this finding was consistent with the resulting trajectory course. The COF is a very important parameter that indicates the stability of a patient's occlusion [23, 24]. Analysis of the preoperative condition revealed a wide range of movement of the diamond shaped icon, indicating that most patients had highly unstable occlusion, with the exception of one patient who showed a consistent contact relationship (Table 2). Surgical intervention led to a significant improvement at the stability of occlusion in patients with skeletal Class III malocclusion, which can be attributed to the applied combined orthodontic-surgical treatment [21]. Other authors have also reported findings consistent with ours, emphasizing that their patients exhibited a more centric COF [1].

This study is limited by a modest sample size and a short-term follow-up, considering that these patients typically undergo two or three years of combined orthodontic-surgical treatment. Future research will focus on expanding the variables being observed, such as standard deviations of force on individual teeth, including and monitoring a larger number of these patients across different time points and various phases of therapy, which may provide insight into the improvement or deterioration of the evaluated parameters, and consequently, the enhancement or decline in occlusal stability.

CONCLUSION

Surgical therapy significantly improves occlusal quality among individuals with skeletal Class III malocclusion. It has been proven that it leads to improvements in occlusion time, the distribution of total force in AP direction, projection of COF, compared to the pre-surgical condition. The results have shown that further investigation is needed into distribution of force on the right and left regions, expanding the variables being observed, such as standard deviations of force on individual teeth in order to enhance the occlusal stability in these patients.

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Conflict of interest: None declared.

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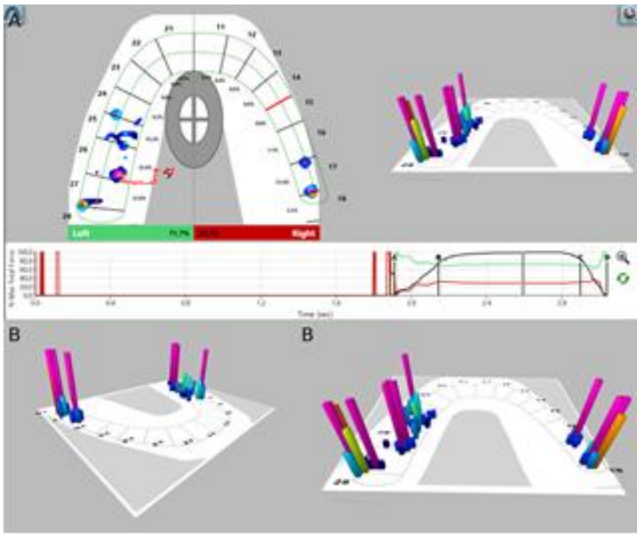

Figure 1. A – 2D occlusal load interpretation; B – 3D occlusal load interpretation

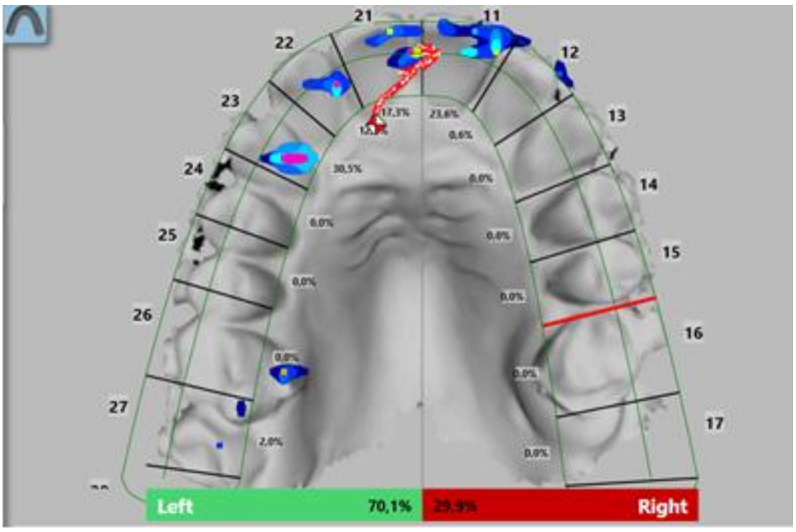

Figure 2. 3D occlusal load interpretation with imported stereolithography file

Figure 3. T-Scan Novus (Tekscan Inc., Norwood, MA, USA) handpiece with sensor film

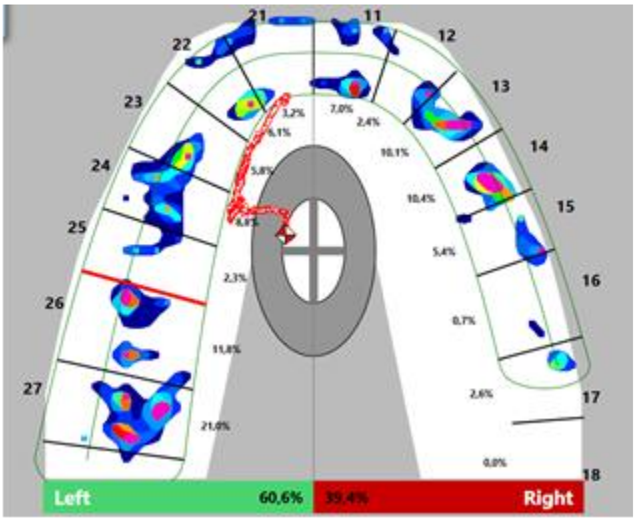

Figure 4. Presentation of center of force by the red and white diamonds in the 2D graph

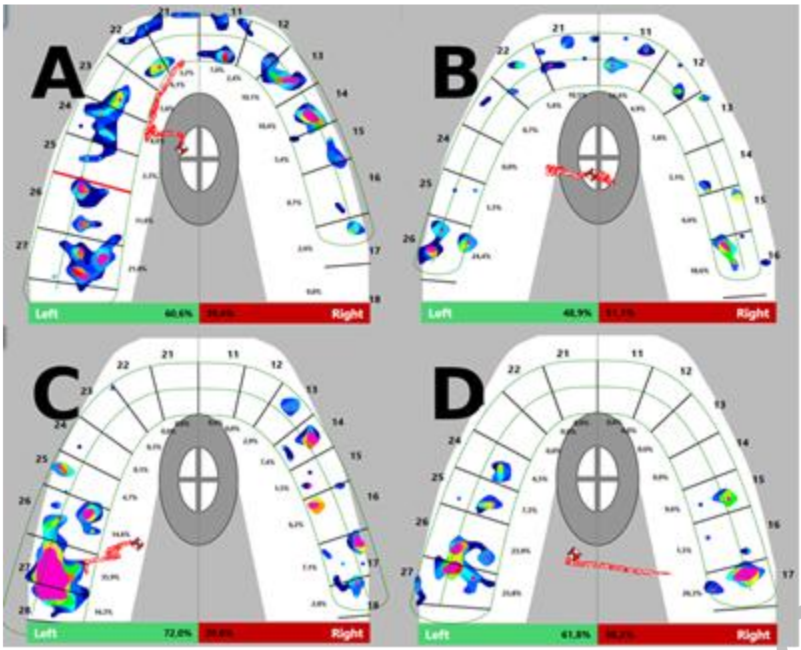

Figure 5. Four types of trajectories of the closing path: A – normal: the trajectory was straight-down in shape; B – contact point: the trajectory was clustered into a specific area; C – sliding in left-right, defined as the trajectory, was outlined horizontally across the midline; D – sliding in right-left: the trajectory was outlined horizontally, across the midline

Table 1. Descriptive statistics for occlusal time (seconds) and total average occlusal force (%)

Observed parameters	Before surgery $\overline{x}$ ±SD Med; min–max	After surgery $\overline{x}$ ±SD Med; min–max	Significance
Occlusion time	2.11 ± 0.76 1.7; 1.48–3.66	0.96 ± 0.64 0.75; 0.50–2.21	p = 0.011*
Disclusion time	0.27 ± 0.27 0.21; 0.00–0.96	0.28 ± 0.41 0.17; 0.05–1.37	p = 0.593
Total anterior occlusal force	0.20 ± 0.11 0.15; 0.06–0.35	0.55 ± 0.18 0.53; 0.37–0.93	p = 0.008*
Total posterior occlusal force	0.80 ± 0.11 0.85; 0.65–0.93	0.45 ± 0.18 0.47; 0.07–0.63	p = 0.008*
Total left occlusal force	0.55 ± 0.09 0.56; 0.36–0.64	0.48 ± 0.09 0.48; 0.37–0.71	p = 0.173
Total right occlusal force	0.45 ± 0.09 0.43; 0.36–0.63	0.52 ± 0.10 0.52; 0.28–0.63	p = 0.138

Table 2. Descriptive statistics of location of the center of force before and after surgery

Center of force	Before surgery	After surgery	Significance
normal	3 (33.3%)	9 (100%)	p = 0.026*
L→R	3 (33.3%)	/	
R→L	2 (22.2%)	/	
contact	1 (1.1%)	/	

* – statistical significance; L – left; R – right; contact – trajectory localized in defined region