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Occlusal Examination of Printed Orthodontic Retainers - Clinical Trial with T-Scan Novus

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Abstract

Background: Digital technologies are very useful in dentistry. It can be found in every of its brands.

Materials and Methods: Twenty-one patients in the retention phase after orthodontic treatment were studied. The gender distribution was almost even- 10 boys (47.6%) and 11 girls (52.4%). Patients were aged 15 to 35 years, with a mean age of 19.71 (± 6.27), of which 76.2% were under 18. At the start of orthodontic treatment, 14 patients were with Angle Class I and 7 with Angle Class II. 14 (66.7%) were treated without extractions, 7 (33.3%) with extractions. An intra orals can was performed using Trio's color (3 Shape, 2014). The digital models are used to create the retainer using 3 shape design software-splint studio. T-Scan Novus was used to check occlusion. Descriptive statistical methods were used to assess the demographic and clinical characteristics of the study group. Counts and percent ages were used for the categorical variables. The study aims to establish the occlusal force distribution by quadrants during the placement of orthodontic retainers printed from a biocompatible material.

Result: The dentition was divided into four zones- two frontal and two distal the mean forces were: Right distal 37.14%, right frontal 11.4%, left frontal 11.46% and left distal 39.99%. A statistically significant difference was found between the frontal and distal regions, but not between the left and right halves.

Conclusion: The uniform balanced contacts obtained in a digital design are uniform in distribution but not in force. The distal sections are significantly more loaded than the frontal sections at uniform design contact.

Keywords: Digital occlusion; Digital design; Retainer; 3 Shape; T-Scan Novus; Orthodontics

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Introduction

Digitalization in dentistry cannot be stopped. There is no dental field without some digital approach. The initial step is receiving a digital model [1]. 3D scanning technologies are used to convert a physical model into a digital 3D Computer-Aided Design (CAD) file. 3D scanning has various benefits in dentistry-rapid production with customized design, comfort for the patient, time and cost efficiency, effective planning for the procedure and simplified procedure, view dental anatomy from different angles, and increased success rate of treatment [2].

There is consensus about the need for retention after orthodontic treatment. The orthodontic retention phase is one of the most important phases in orthodontic treatment. Maintaining tooth alignment after orthodontic treatment has always been an important goal for orthodontists. Without retention, the treatment would be useless as a relapse occurs in almost all cases with variable amount [3]. There are two main types of retainers-fixed and removable. Long-term studies show positive results with fixed retention. A removable retainer should also be given to the patient to retain those teeth not included in the fixed retention and as a backup retainer in case of failure of the fixed retainer [4]. Removable retainers can be conventional vacuum-formed, and 3D printed. In a comparative study, including linear translational measurements in the field of canines, first and second premolars and first molars, the new method for fabricating a 3D printed retainer is more accurate and reliable than the vacuum formed retainer [5]. The presence of impacted teeth requires surgical treatment to reveal these "hidden" teeth. This often requires extending the period of orthodontic treatment and the retention phase [6,7]. Arnautska presents a protocol for primary prevention of potential maxillary canine impaction in the late mixed dentition [8,9].

Similar application is the creation of sports mouth guards with complete digital workflow. Authors notice improving the occlusal design and material, greatly simplifying the manufacturing process and saving medical resources [10]. Although inaccuracies have been reported due to software safeguards. The design as initial information requires the choice of material that has certain features, such as minimum thickness. This thickness is set automatically, and this could change the design, which is especially evident on occlusal surfaces [11,12].

Another similar apparatus is aligners. Thermoformed aligners demonstrating weaker compression strength and more extensive irreversible deformation are because of the fact that these are thermoplastic-based materials. In comparison, a high yielding, higher load resisting, and lower deforming clear dental aligners obtained from 3D printing could provide a superior alternative solution. 3D printed and cured clear biocompatible dental aligners have superior geometric accuracy, load resistance, yielding, stiffness, and lower deformation. Curing condition scan be further engineered to design customized strength clear dental aligners for suitability of patients based on the variable biting forces, which could further assist in reducing manufacturing costs [13].

The final step of 3D printing is support's removing. It can be done in two ways: 1. Soluble support material: This method uses an automated support-removal process in which the material is removed in a tank *via* an agitated water based detergent solution. 2. Break Away support material: This is a manual removal process in which you twist, break, and scrape support material from the part by the help of a needle pliers [14]. Removing the support pillars *via* manual is a time-consuming process. At present, the 3D printing process can be automated, but it still relies on manual to remove the support pillars, which adds a lot of labor costs to the 3D printing technique. Moreover, after removing the support column, the roughness of the surface increases, the step of polishing is inevitable [15].

In order to carry out absolutely digital protocol, the following devices are necessary: An intraoral scanner, a T-Scan system, and some specific dental software. By means of a virtual procedure, the T-Scan system detects the occlusal contacts, and the occlusal surfaces are obtained using an intraoral scanner. Once the alignment between the 3-Dimensional occlusal surface and the T-Scan registration is carried out, the resulting contacts are projected onto the patient's occlusal surfaces; in this way, occlusal forces are obtained overtime. The results obtained with this procedure demonstrate the feasibility of integrating different tools and software and the full integration of this procedure into a dental digital work flow [16].

The evolution of the T-Scan from 1st to 8th generation (1847-2015) has revolutionized the concept of occlusal analysis. The 8th version of the system released in 2012 was purposefully designed to minimize the T-Scan 3 user interface complexity. T-Scan 8 has reversed desktop graphics for simpler data display with less software, toolbar buttons and icons. The patient is asked to bite on ultra-thin sensor. The occlusal contact is transferred to the computer and presented in a dynamic movie format. It thereafter allows for full color 3- or 2-dimensional graphics. It depicts the percentage of force per tooth. The analytic software displays such as Centre of Force (COF) and COF trajectory provides an in depth understanding of the overall balance of occlusion [17]. The most modern version of the T-Scan system released in 2018 is T-Scan 10 that improved on T-Scan 8's original software version. T-Scan 10 contains many new software features which enhanced the clinician's ability to analyze occlusal function, including an overloaded implant warning tool, a force eraser that removes sensor artifact when the sensor folds between and around overlapping anterior teeth, and the Digital Impression Overlay which is where T-Scan data can be overlayed onto a STL digital arch scan [18]. Important desktop changes maintained from T-Scan 8 include the enlarged Force *vs.* Time Graph for easier visualization of all the color-coded force and timing lines, and a rotating 3-Dimensional force view window that improves the visualization of the moving individual force columns observed during movie playback. The rotating 3-D force view allows the clinician to orient the window in any view that during playback, to best eliminates the overlap of the rising and falling force columns. With T-Scan 10, the main desktop tool bar displays additional icons that activate important new software features that were recently added into the newest version of the program. Doctors can import and export patient data, generate reports, attach notes and photos, and create MP4 files of the scan, while also being able to import intraoral digitally-impressed .STL files of a patient's arch, which can then be overlaid with T-Scan force data. These robust features give clinicians the ability to efficiently diagnose and treat patients occlusally, using objective and comprehensive force and timing data [19].

According to Halperin, The patient's perception of occlusal thickness ranges from 12.5 μm to 100 μm. The thickness of an occlusal registration strip should be below the patient's perception. The foils should be less than 21 μm thick and should posses' plastic deformation to be suitable for occlusal analysis [20]. The thickness of T-Scan sensor is 60 μm because consists of an X-Y coordinate system with 1,500 sensitive receptor points made of conductive ink, and is subject to elastic deformation [21]. According to Yamamura, exists certain non-sensible areas caused by its constructional feature. The most sensible area can be measured from 0.1 Kg to 2.1 Kg, and therefore, this device is more suitable for recording within lower loadings. Although the system has a certain disadvantage of reproducibility, this contributes to attain diagnosis and treatment of occlusal contacts for a quantitative evaluation [22]. The T-Scan always recorded fewer occlusal contacts than were actually present [23]. The 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 and at the second molars in a dentition of 28 teeth [24].

The aim of the study is to establish the occlusal force distribution by quadrants during the placement of orthodontic retainers printed from biocompatible material.

Materials and Methods

The study sample included 21 patients (10 male and 11 females, mean age 19.71 ± 6.27 years) in the retention phase after orthodontic treatment. Patients were aged 15 to 35 years, mean age 19.71 (± 6.27), of which 76.2% were under 18. At the start of orthodontic treatment, 14 patients were with Angle Class I, and 7 with Angle Class II. Fourteen of them (66.7%) were treated without extractions, 7 (33.3%) with extractions. The exact distribution is shown in Table 1.

Orthodontic treatment of the presented patients had an average duration of 28.57 (± 4.61) months. The average age in the group of

Figure 1: Digital design of the retainer.

Figure 2: Retainer in the patient's mouth.

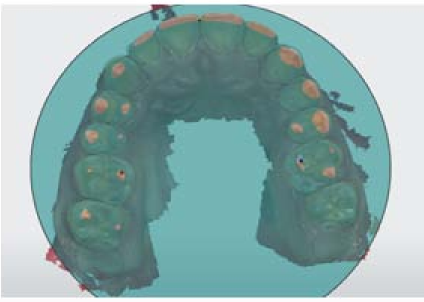

Figure 3: Occlusal plane (3Shape).

men is 17.80 (± 2.57), and in women- 21.45 (± 8.12). The average length of treatment for men was 29.4 (± 5.97) and for women 27.82 (± 3.02).

An intraoral scan was performed using Trio's color (3 Shape, 2014) -imaging of upper and lower jaw, right and left bite. The digital models were used to create the retainer using 3 Shape design software-splint studio, shown in Figure 1. The retainer was made using the 3D printing method. Biocompatible resin ortho clear (Nextdent) was used, demonstrated on Figure 2.

T-Scan Novus (Tekscan, 2018) was used to check occlusion. The pressure-sensitive sensor was positioned between the dental arches with a marker resting between the upper central incisors. The patient was placed in a sitting position, but with the head up right so that the sensor was positioned horizontally. The patient was asked to close to tight contact. Three consecutive measurements were taken- first a training trial for correct performance by the patient and two consecutive ones from which arithmetic averages were taken. For a more accurate comparison of the images between the two digital systems, the intraoral images from Trio's color scanner were previously imported into the T-Scan system. Licensed software version 10.0.40 (T-Scan 10) was used. A software function is the division of the dental arches into quadrants, where the percentage force distribution is automatically calculated. In the study, distribution of maximum intercuspation by quadrants is performed.

Descriptive statistical methods were used to assess the demographic and clinical characteristics of the study group. Counts and percentages were used for the categorical variables. The mean and standard deviation were calculated for the percentage of occlusal force in the four zones- two frontal and two distal, respectively right distal, right frontal, left frontal and left distal. Statistical analysis was performed with statistical software SPSS v23.

To visualize the results, a clinical case of a 21-year-old patient is used after orthodontic treatment of both dental arches, including positioning of impacted teeth and their subsequent leveling with a preadjusted edge wise bracket system.

Results

Digital design of the retainer was made by the help of digital software 3 Shape splint studio. The first step in making a retainer (modified splint) is to place an occlusal plane. It very visibly shows the good leveling of the incisal edges and the tops of the tubercles, Figure 3. The following parameters of the retainer were chosen-thickness 0.7 mm, laterotrusion 0 mm. The occlusal distance with the mandible may vary depending on the protrusion. In order not to change the occlusal relationships, the value of both values is no more than 1 mm (0.7 mm to 1.1 mm). In the case shown, they are 1 mm protrusion and 1.1 mm gap between the jaws, respectively. The software set these markers and changed the ratio between the two tooth arches, Figure 4.

Two steps follow- choosing the insert direction and delineating the boundaries of the future retainer, before choosing the occlusal surface. In the case of a retention apparatus, contact with the antagonists is preferred. The retainer should be worn for 16 h a day, which if it does not maintain contact, the growth of the opposite teeth is possible. The software created a color map of the tight contacts that the structure would have. The densest contacts with an added negative value are marked in red, Figure 5. It is also possible to just outline the areas of these contacts, Figure 6. The thin design of the retainer was noted by the software (there is an option for minimal thickness 0.5 mm) and the system warned of the possibility of perforation, despite the entered distance of 1.1 mm. These are the places opposite the sharp tubercles, in Figure 5, 6 these areas are colored dark red. Due to our previous experience; we preferred the function "accept" not "correct" [25].

The finished frame work was placed on the upper dentition and a digital measurement of the occlusion was taken using T-Scan Novus.

Figure 4: Bite configuration (3Shape).

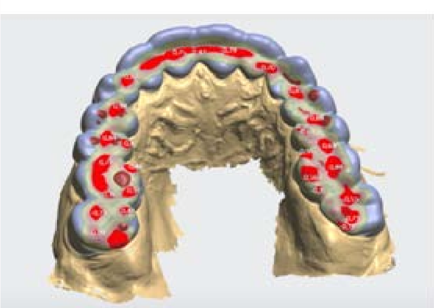

Figure 5: Color map of occlusal contacts (3Shape).

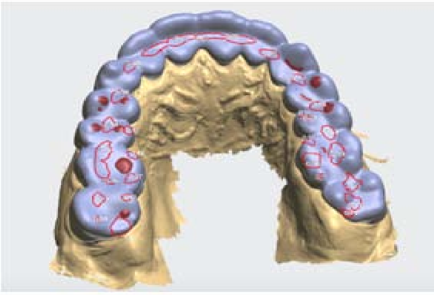

Figure 6: Occlusal zones and thin design areas (3Shape).

Table 1: Demographic and Clinical characteristics of the patients included in the study.

Demographic and Clinical characteristics	Subjects N=21
Age (years)	19.71 ± 6.27*
Gender	
Male	10 (47.6%)
Female	11 (52.4%)
Angel Class	
Class I	14 (66.7%)
Class II	7 (33.3%)
Surgical treatment	
Extraction	7 (33.3%)
Non-extraction	14 (66.7%)

The T-Scan system also generates a color map that is based on the pressure on the sensor, taking into account the force of contacts. The different color markings are based on strength-strong contacts are in violet and red, going through yellow, green, with weak contacts in blue. Pre-importing the intraoral images allows the software to place the contacts in their correct locations on the tooth surfaces (Figure 7).

During the statistical processing of the data, a significant preponderance of the strength of the contacts in the distal area was found. The distribution of contacts by area is uniform, but they differ in strength. To report the results, the dentition is conditionally divided into 4 zones- two frontal and two distal, respectively right distal, right frontal, left frontal and left distal. A statistically significant difference was found between the frontal and distal regions, but not between the left and right halves. The overall distribution of contact force by zone is shown in Table 2.

The gender distribution of contact force by zone is demonstrated in Table 3. A comparison was made between frontal and distal zones.

Table 2: The percentage force distribution in the frontal and distal zones of the study group.

	Mean ± SD (%)	Minimum (%)	Maximum (%)
Right distal zone	37.1 ± 2,1	33.8	40.4
Right frontal zone	11.4 ± 1.9	6.8	14.6
Left frontal zone	11.5 ± 1.6	8.2	14.35
Left distal zone	40.0 ± 2.9	35.4	45.4

The following conclusions can be drawn from the obtained results:

- The projected absolute uniformity of the contacts is with different strength, proven by the T-Scan system
- The strong contacts demonstrated by T-Scan Novus are located in the same places as in the digital design (left and right molars)
- The weaker contacts registered by the T-Scan Novus also occupy their designed places by the digital software
- The frontal contacts from the digital design are registered as weak or missing by the T-Scan system.

Discussion

Due to their better mechanical strength qualities, 3D printed aligners and retainers are expected to replace the classic vacuum-formed ones [13]. 3D printed retainers are more accurate and reliable than the vacuum formed retainers [5]. Another advantage is the easy laboratory protocol, saving time and cost, as well as precise design [10].

The strength of distal contacts has been demonstrated in natural dentition [24]. With digitally designed constructions, evenly spaced contacts are expected. In cases of minimal inter occlusal distance, for examples with a retainer, areas of excessive proximity are observed, especially against sharp tubercles. Our previous experience shows that if this warning is followed and minimal thickness material is placed everywhere by software, preliminary contacts are obtained, which should be removed manually after testing in the patient's mouth. So, we took the warning but didn't he edit and left the retainer very thin in some areas [12,25].

The difference between design and reality can be found in the thickness of the sensor and its deformation when closed. According to Halperin, foils less than 21 µm thickness do not have plastic deformation and are suitable for occlusal analysis [20]. The thickness of T-Scan sensor is 60 µm and it can be deformed during the maximal intercuspation [21]. The T-Scan always recorded fewer occlusal contacts because the sensor has non-sensible zones [22,23].

Another possible error option is the position of the supports and their removal by a dental technician. Even the most thorough removal and polishing could alter the occlusal features [14,15].

Conclusion

The uniform balanced contacts that are obtained in a digital design are actually uniform in distribution but not in force. The distal sections are significantly more loaded than the frontal sections at uniform design contact. A statistically significant difference in strength was found between the distal sections in men but not in women. T-Scan system allows precise measurement of occlusion force.

Table 3: Force distribution by gender.

Zone	Male (N=10)		Female (N=11)	
	Mean ± SD	Std. Error Mean	Mean ± SD	Std. Error Mean
Right distal zone	36.74 ± 1.89	0.60	37.51 ± 2.28	0.69
Right frontal zone	11.32 ± 2.10	0.66	11.48 ± 1.80	0.54
Left frontal zone	11.57 ± 2.03	0.64	11.37 ± 1.21	0.37
Left distal zone	40.38 ± 2.92	0.92	39.64 ± 3.00	0.91

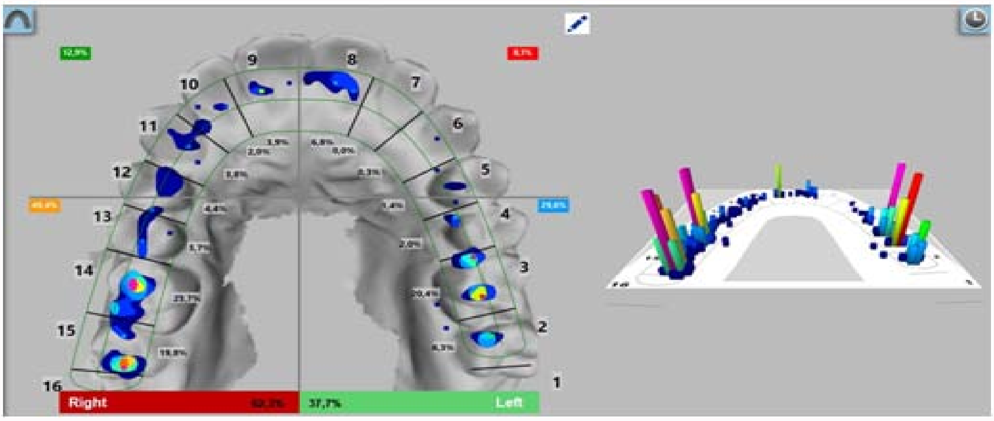

Figure 7: Digital analysis of occlusion with T-Scan Novus (Tekscan) - maximum intercuspation.

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