

Comparing occlusal contact quality after aligner and fixed appliance treatment using computerized occlusal analysis during 6 months of retention

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Abstract

Objective

Less than ideal contacts have been reported following aligner therapy, which is believed will resolve with settling, despite settling improving occlusal balance has not been scientifically confirmed. The aim of this study was to compare the outcome quality of occlusal contacts in patients treated with fixed appliances or clear aligners.

Methods

39 orthodontic patients (14 treated with aligners; 25 with fixed appliances) were evaluated with a digital occlusal analysis system (T-scan10™), assessing Maximum Intercuspation contact simultaneity, symmetry, and relative force distribution. The Occlusion Time, the Right/Left force percentage (%R/L), the Anterior/Posterior contact ratio (RAP), and the anteroposterior Center of Force (COF) locations were recorded at treatment completion, and 3 and 6 months after.

Results

No significant differences in measured occlusal contact quality parameter were found between groups at treatment completion or follow-up (OT, %R, RAP nor COF position). The COF moved posteriorly and remained stable after 3 months, near to the first molar, but was located more anterior in females ($p= 0.01$). 10 patients finished treatment with marked asymmetry, ($\%R/L > 50\pm 10\%$), especially in the fixed appliance group (9/25 = 36%) versus the aligner group (1/14 = 7%). 1/3 of all patients (both groups combined) after 6 months retention had %R/L imbalances $> 50\pm 10\%$.

Conclusions

Occlusal contacts were comparable at completion of treatment with aligners or brackets and after 3-6 months of retention. Contacts increased in the posterior region with time, but settling did not improve marked asymmetry in all patients.

Background

Obtaining a stable and functional occlusion is a main responsibility of the orthodontist. Occlusal aims for closure intercusped contacts include achieving simultaneous, evenly distributed contacts, that are stronger posteriorly and very light anteriorly (1). Respecting these objectives has been suggested as a key factor to ensure long-term stability of the orthodontic result (2, 3). In addition, many authors have reported that occlusal disharmonies could be correlated with potential problems such as temporomandibular disorders (4), periodontal disease (5), cervical abfraction or less efficient mastication (6, 7), though these relations remain controversial.

Whether fixed bracket therapy or aligner therapy obtains better occlusal contact outcomes remains a modern-day and unanswered orthodontic question. In 2019, a systematic review comparing the results obtained with aligner therapy or conventional fixed appliances, concluded that aligners were less effective in producing adequate occlusal contacts (8), when evaluated on plaster casts with the Objective Grading System (9). Fortunately, it is expected that the quality of contacts would improve during the retention period (10), as teeth once freed from the orthodontic appliances would have a natural tendency to come into contact through the physiologic eruption process (settling). However, little scientific evidence supports that settling results in ideal occlusal contact force and timing relationships. Independent studies (11–13) reported that occlusal balance did not always result following orthodontic treatment, when evaluated using a digital occlusal analysis technology. Furthermore, the type of retention, consisting of classic Hawley type appliances, bonded lingual retainers or Essix-type with occlusal coverage could influence the occlusal settling quality or duration (14–16).

The primary objective of this study was to determine whether a difference in contact distribution (surface, intensity and symmetry) could be observed in patients that were treated with fixed appliances compared with those treated with aligners, at appliance removal. The secondary objective was to follow these two groups during retention, after three and six months, to describe the quality and timing of settling.

To objectively measure and determine occlusal contact quality in the fixed appliance or aligner groups, the T-Scan 10 Novus System was chosen (Tekscan Inc. S. Boston, MA, USA). The T-scan 10 is an innovative technology, that records in real-time the contact force distribution as it changes functionally from 1st contact through until complete Maximum Intercuspation (MIP). This method has been proven precise and reproducible (17), while eliminating the clinician subjectivity of occlusal paper mark interpretation (18–22) or shim stock removal “feel”. The T-Scan overrides the limitations of waxes and silicone impressions techniques that are static, as it accurately quantifies many differing relative occlusal contact force parameters and contact timing sequence durations for clinical occlusal diagnosis and treatment, that can be statistically analyzed (23).

Methods

Participants

All included patients had completed non-extraction, non-surgical, comprehensive orthodontic therapy into an ideal class I occlusion at either a university orthodontic clinic, or at a senior orthodontist's practice. The study population included 39 patients total, comprised of 25 patients (mean age 18.7 ± 5.2 ; 6 females, 19 males) that received self-ligating fixed appliance therapy (Speed™ brackets, Canada or Empower™ brackets, American Ortho, USA), while 14 patients (mean age 20.6 ± 7.3 ; 10 females, 4 males) received clear aligner therapy (Invisalign™, Align Technology, San Jose, CA, USA).

Subjects were excluded if they presented with occlusal coverage retainers, tooth agenesis (excluding 3rd molars) microdontia (unless related to 3rd molars), severe periodontal disease or had had large restorations installed during the time of data (Figure 1).

Data Collection

Patients were assessed at three points in time: on the day of treatment completion (T0), at 3 months' post treatment (T3), and at 6 months' post treatment (T6), by the same examiner (CB) for consistent data acquisition. Each assessment follow-up visit included: a T-Scan 10 digital occlusal analysis recording into MIP, patient self-report of their retainer compliance and self-assessment of occlusal comfort using a visual analog scale (VAS) ranging from 0 – 10 (0 = very uncomfortable; 10 = maximum comfort). The examiner confirmed that each patient had not undergone dental restorative or occlusal adjustment treatments since the previous visit.

Digital Occlusal Analysis

The digital occlusal analysis employed the T-Scan 10 system, that records occlusal data with a 100μ thin, flexible horseshoe-shaped Mylar sensor (Novus HD sensor, Tekscan, Inc. S. Boston, MA, USA), that contains 1370 active pressure sensing cells, known as sensels, arranged in a compact grid, shaped as a dental arch. The Mylar coating encases sophisticated printed electronic components, allowing the HD sensor to withstand occlusal stresses from between occluding teeth, and repeatedly record 256 relative occlusal force levels and occlusal contact timing sequences. This system has been validated by several laboratory and clinical studies from 2006 to 2020 (11, 17, 23–25), and has shown consistency to report relative occlusal force mapping and timing data, without sustaining significant sensor damage breakdown from intercusating teeth.

Prior to recording actual study data, the sensitivity of the sensor was adapted the patient's muscular strength to avoid oversaturating the sensor. Also, patients were given recording instructions and performed practice registrations that familiarized them with the Multi-bite recording procedure. Then, 3 consecutive self-intercusated closure-into-MIP registrations were recorded, without removing the sensor from the patient's mouth. Each patient then rested for one minute before replicating the procedure a second time, if needed. When several recordings were obtained during a single visit, the one presenting the most consistency between the three consecutive intercusations was used for analysis. Importantly, the same sensor was used during all 3 visits, unless the sensor demonstrated excessive wear.

An estimate of the occlusal contact surface area can be determined from the number of activated sensels on the sensor at maximum force intercusation (MIP, maximum loading of the sensor). The total surface of contacts, and the area ratio between anterior (canine to canine) to posterior (premolar to second molar) contact surfaces were extracted from the underlying ASCII data. The overall relative force distribution was assessed by the position of the Center of Force (COF) Icon (the force summation location that averages all occlusal contact forces, similar to a barycenter). The COF position was calculated using ASCII data, to give a numerical value of the anteroposterior position of occlusal forces at MIP (ranging from 0 to 1). A greater value signified a more posterior concentration of forces. The symmetry of contact distribution was expressed as the percentage of contacts on the Right side to the Left side (%R/L). Lastly, the time-simultaneity of the closure into MIP contacts was calculated by the Occlusion Time (26) measurement, which is the duration in milliseconds between first contact and the time MIP was reached. When the OT is prolonged (> 0.2 seconds), it indicates the presence of premature or prolonged closure occlusal contacts within the contact sequence (27).

Figure 2a illustrates the graphic way the 3 consecutive bites into the sensor show loading reproducibility (3 similar Force vs. Time curves illustrate repetitive loading across time; bottom pane), along with the 2 and 3-Dimensional histograms that detail contact force intensity per tooth; upper 2 ForceView windows). For visual comparison, an occlusal photograph of the same patient's occlusal contact markings were obtained with horseshoe-shaped occlusal paper (200μ Articulating Paper, Bausch, Nashua, USA) (Figure 2b).

Statistical Analysis

A two-sided two-sample t-test estimated that a sample size of 15 participants per group would provide a power of 80% to reject the null hypothesis that there were no significant between-group differences at an alpha level of 5%, assuming a difference in the anteroposterior position of COF = 5.5 ± 1.4 mm, based on a pilot study of COF absolute position.

Statistical analyses were carried out using IBM-SPSS Statistics for Windows (Version 28, IBM, USA). All results were presented as mean \pm standard deviation for continuous variables, as percentages (%) for nominal variables, with all values tested for normal distribution using the Shapiro-Wilk test. For descriptive statistics, both parametric and non-parametric tests (ANOVA-type statistic for repeated measures; Mann-Whitney U tests; Chi-square) were used, including mixed models for repeated measures. The null hypothesis was rejected at $p < 0.05$.

Results

Thirty-nine subjects were enrolled in the study (25 in the fixed therapy group and 14 in the aligner group), and 8 subjects were excluded during the course of the project (4 in each group), because of a change in the retention protocol or a missed visit (Figure 1).

There were no significant differences between the fixed or aligner treated groups for age, Angle's classification, asymmetry nor facial type (Table 1) except more girls being in the aligner group ($p = 0.007$). The retention protocol was similar in both groups, without any difference in the total number of bonded lingual wires ($p=1$ Fisher's exact test) but subjects having received aligner therapy had significantly more bonded lingual retainers in the upper arch (10/12 subjects in the aligner group vs. 7/15 in the fixed appliance group; $p = 0.10$ Fisher's exact test). Self-reported compliance with Hawley retainer was not different between groups ($p = 0.83$ Fisher's exact test).

Table 1
Baseline sample description of fixed appliance and aligner groups. * $p < 0.01$

	Fixed appliances (n=25) Mean \pm SD	Aligners (n=14) Mean \pm SD	P value
Age when entering the study (y)	18.7\pm 5.2	20.6\pm 7.3	0.41
Female patients (%)	24	71.4	0.007*
Angle's classification before treatment (%)	84	85.7	1
Class I	12	14.3	
Class II	4	0	
Class III			
Presence of asymmetry pre-treatment (%)	12	14.3	1
Facial type (%)	0	0	0.445
Brachyfacial	72	85.7	
Mesofacial	28	14.3	
Dolichofacial			

At treatment completion, the total surface of occlusal contacts and the number of teeth out of contact were not significantly different between the aligner and the fixed orthodontics groups (Table 2). Qualitatively, the type of teeth out of occlusion did not differ between groups, and mostly involved central or lateral incisors (incisors involved in 5/12 in aligner group, n=9/15 in fixed appliance group). The relative proportion of anterior to posterior contact areas (RAP), the anteroposterior position of the COF and %R (estimating symmetry) were not significantly different in either group.

Table 2
Occlusal Parameters between groups at treatment completion and during retention. Mann-Whitney independent sample U tests were applied bilaterally

	T0			T3			T6		
	Fixed Appliances (n=25)	Aligners (n=14)	p	Fixed Appliances (n=24)	Aligners (n=12)	p	Fixed Appliances (n=22)	Aligners (n=9)	p
Total contact area (n. of pixels)	129.00±40.17	126.93±41.47	0.740	129.25±44.88	110.92±38.91	0.199	129.91±44.53	110.22±30.58	0.356
Number of teeth out of occlusion	0.92±1.19	1.29±1.14	0.276	1.13±1.51	1.83±1.64	0.156	1.00± 1.23	1.67± 1.5	0.236
Ratio of AP contacts (surface areas)	0.25±0.09	0.28±0.11	0.426	0.22±0.07	0.23±0.11	0.949	0.22±0.08	0.21±0.66	0.256
AP position of COF (pressure)	0.53±0.09	0.51±0.09	0.640	0.55±0.09	0.53±0.09	0.708	0.55±0.11	0.55±0.06	0.350
Contacts on the Right side (%R)	50.29±9.11	49.07±6.11	0.693	47.95±9.49	45.10±6.75	0.445	51.58±10.55	46.56±11.18	0.236
Occlusion Time (seconds)	0.14±0.58	0.17±0.62	0.411	0.14±0.52	0.15±0.13	0.933	0.14±0.58	0.14±0.57	0.985
Patient's comfort	8.04±0.93	8.15±1.40	0.627	9.27±1.08	8.61±1.66	0.271	9.43±0.87	9.58±0.67	0.754

Although the %R/L per group were not significantly different, neither treatment resulted in ideal occlusal balance. In natural occlusions, ideal %R/L balance measured with the T-scan has been described to be = 50±2% (28–30). Taking a wider normal range = 50±5%, only some patients reached this equilibrium at treatment completion: 3/25(12%) for the fixed appliance group and 7/14 (50%) for the aligner group (Figure 3a). Right/Left 50±5% balance improved at T3 for both groups (11/24, 45.8% for fixed appliance group vs 8/13, 61.5% for aligners in Figure 3b), and worsened at T6 follow-up, with only 5/22 (22.7%) in the fixed appliance group, and only 4/9 in the aligner group (44.4%) demonstrating %R/L symmetry (Figure 3c). Figure 4 displays the individual %R/L measurements per group.

Importantly, 10 patients finished treatment with marked asymmetry (%R/L >50±10%), especially in the fixed appliance group with 9/25 (36%), showing side force differences (5 right dominant, 4 left dominant), versus only 1/14 (7%) in the aligner group (left dominant). This imbalance did not resolve with 6 months of settling in 7/22 (31.8%) patients in the fixed appliance group (5 right dominant; 2 left dominant), and for 3/9 patients in the aligner group (33.3%) (2 left dominant; 1 right dominant). At T3 (36.3%), 8/22 fixed appliance patients maintained marked asymmetry (5 right dominant; 2 left dominant), while 2/12 (16.7%) aligner patients also were asymmetric (2 left dominant).

The Occlusion Time (an estimate of contact simultaneity) appeared slightly increased in the aligner group at treatment completion (0.17±0.62 vs 0.14±0.58), without reaching statistical significance. Occlusal comfort was similar in both groups at treatment completion: the Median score = 8 for both groups (range 6-10 for fixed appliance group; 5-10 for aligners). During the first 6 months of settling, there was a net increase with regards to patients' comfort level, with a Median of 10 (p < 0.0001), with both treatment modalities (range 7-10 for fixed appliance; 8-10 for aligners). Comfort scores could not be correlated to any occlusal feature (OT, %R/L, RAP, COF) nor associated with sex, age or pretreatment malocclusion type.

The COF moved posteriorly in both groups from T0 to T6, in parallel with a decreased ratio of anterior to posterior surface area, while the %R/L and OT remained statistically unchanged. Figure 5 shows the anteroposterior position of the COF, which moved posteriorly during the first three months of retention (p = 0.003), after which it did not vary significantly regardless of treatment modality (p = 1.000). A statistically significant difference was observed in the anteroposterior position of COF between sexes, being more anterior in females at all times (p < 0.002) (Figure 6).

Examples of Tscan-records can be seen in Figures 7 and 8, illustrating contrasting treatment outcomes: a balanced outcome vs. and an asymmetrical outcome with the COF anteriorly positioned.

Discussion

Despite published reports suggest that non-ideal contacts result following orthodontic treatments with aligners compared to fixed appliances, the results of this study found no difference in occlusal parameter quality between patients treated with aligners or fixed orthodontic appliances, with respect to contact surface area, overall force distribution and symmetry of contacts in MIP. Settling quality indicators, such as patient comfort and Occlusion Time (simultaneity), were also not statistically different between the two groups, suggesting that both therapies obtained similar closure contact occlusal outcomes.

It was a common finding at the end of treatment to see light contacts in the incisor area, and frequently, a lack of contacts on the lateral incisors, both of which should not be considered problematic. In a mutually protective occlusion, it has been advocated that the contacts should be stronger posteriorly, with molars anatomically shaped to sustain larger proportions of the total occlusal load, with light contact existing on the incisors in MIP.

The antero-posterior position of the COF six months after completion of orthodontic treatment stabilized in both groups in an identical position (0.55 ± 0.11 vs 0.55 ± 0.06), which corresponds with a position located qualitatively at the level of the mesial of the first molar, which has been shown to be its ideal position in patients with normal occlusions (27). The COF moved posteriorly in both groups from T0 to T3 ($p=0.003$), after which time, no statistically significant difference was noted. This suggests that most of the settling occurred within the first three months' post-treatment, which corresponds with conclusions drawn in earlier studies (31). Interestingly, a statistically significant difference was observed in the anteroposterior position of COF between sexes, with it being positioned more anteriorly in female patients at all times.

A scientific basis for using the COF (equivalent to a barycenter of occlusal force) as an indicator of functional occlusal balance has been described by different research teams using different methods, that obtained similar overall results. In the early 1980's, two studies determined the physiologic equilibrium point of the mandible, using electronic means (32, 33); when Class I patients clenched their teeth in centric relation with an applied force of 24 pounds the equilibrium point was estimated to lie within the mesial third of the mandibular 1st molar, while being close to the mid-sagittal plane. Using the Dental Prescale System™, another group determined that the Center of Force was not influenced by ethnicity, gender or age in a non-orthodontic sample (26).

Another unexpected finding of this study, was that an asymmetrical force distribution between the left and right sides remained in 1/3 of the treated patients after 6 months of settling. Right/Left balance appeared worse in fixed appliance group immediately after treatment completion and improved at T3. After 6 months of retention, less than 50% of all patients ended up with ideal symmetrical loading of the sensor, in the %L/R 50 ± 5 range, and one third depicted a significant functional asymmetry. This study's occlusal force asymmetry findings coincide with those reported by Qadeer et. al, where significant occlusal force imbalances were observed in 2 separate post orthodontic T-Scan studies (12, 13). Although not related to occlusal comfort or the appearance of any symptoms, this observed asymmetry, of unknown etiology, illustrated post-orthodontic uneven contact force distribution. This asymmetry could reflect the patient's preference for chewing on a particular side, as a type of hemispheric laterality (34). One study showed significant and positive correlations existed between masticatory laterality, side differences in bite force, and side differences in occlusal contact area at MIP (35).

It is important to point out that the occlusal force asymmetry following the visual aligning of teeth to a predetermined ideal, appears to not translate into occlusal surface interactional force control. Although the teeth may fit together visually well, the visual ideal does not guarantee the functional interocclusal forces will be balanced, well-distributed, and of only low force intensity.

It is plausible that orthodontic appliances significantly interfere with the normal functioning of the masticatory muscles and that total neuromuscular recovery might vary between individuals. The reestablishment of normal function after orthodontic treatment was studied by Winocur et al. (36), who found that neuromuscular adaptability started immediately at bracket removal, with a maximal bite force increase of about 15%, followed by another 15.5% increase in the first 3 months, whereas only an additional 2% increase was noted after 6 months. Varga et al. using electromyography, reported weaker forces of mastication in females at the time of debonding, and their settling took longer than for male patients (31). The authors hypothesized that women, being cautious, avoided biting forcefully during their orthodontic treatment.

Study limitations

The findings of no difference in the quality of occlusal parameters in MIP after orthodontic treatment with aligners or conventional bonded brackets, still need to be interpreted with caution. These results may be specific to a university setting, where much care is conferred to obtaining ideal results, and may possibly not correspond to what can be seen following aligner therapy in a broader context. For the aligner group, on average, 3.9 modifications were made to each patient's Clincheck™ (the virtual treatment planning with simulated movements software) prior to

approval, 1.6 “refinements” were performed in the finishing stages, and the mean treatment time was 19.4 (± 7.98) months, longer compared to the 12-18 months’ average treatment time reported by Align Technology.

Reduced posterior contacts in the course of aligner treatment has been often described, linked to different potential factors: the relative intrusion of posterior teeth due to the interocclusal thickness of aligners, premature anterior contacts (often due to a lack of maxillary incisor torque or insufficient overjet), and difficulty extruding posterior teeth with aligners to level the Curve of Spee (Figure 9). Several strategies have been suggested to avoid creating a posterior open bite including exaggerating the overjet and the anterior torque on maxillary incisors in the simulation software, using adequate attachments, enamel reduction interproximally when needed to help level the lower arch, and using inter-arch vertical elastics in the premolar area. The results this study suggest that with careful planning and proper knowledge of the aligner system’s limitations and how to counter them, ideal static occlusal objectives can be achieved with aligners.

Case selection might also have played a role, as these cases did not involve extractions, and in this sample no dolichofacial case was represented.

Another possible limitation of this study was the choice to use maxillary bonded lingual retainers in a number of patients, that may have prevented the incisors from moving vertically into definitive occlusal contact. This would likely have affected the aligner group, as more maxillary bonded lingual retainers were employed with these patients.

Last, the current study focused on assessing static occlusion, therefore dynamic movements were not evaluated. Although an ideal static occlusion may lead to a balanced functional occlusion, Morton and Panchez demonstrated during the retention phase that settling, which improves static occlusion by increasing the amount of contacts, does not necessarily translate into better lateral and protrusive movements (37). This should be evaluated in another clinical study, with a larger sample of aligner cases.

A prospective design, with electromyographic measurements of the masticatory muscles before treatment, could establish the origin of the asymmetry of the measured forces, which could be present initially, or be caused by the treatment. The duration of follow-up could also be extended to 12 months or more.

Conclusions

When comparing fixed orthodontic treatment outcomes to aligner therapy outcomes in non-extraction and non-surgical patients finished in a Class I occlusal relationship, this study determined that:

There was no statistical difference in the quality of the occlusal contacts in MIP after appliance removal or aligner treatment, which did not change after 3-6 months of settling. Neither treatment obtained ideally balanced occlusal contact outcomes from tooth movement or settling.

Asymmetric left-to-right side occlusal force distribution resulted from tooth movement in 1/3 of patients, whether fixed or aligner treatment was employed. Most occlusal changes occurred within the first 3 months following active tooth movement, with more posterior contacts forces developing in both groups. Settling for 6 months did not resolve the force asymmetries in all patients.

Females maintained a relatively more anterior Center of Force (COF) at all assessment times during the 6 months of study observation.

Declarations

- Ethics approval and consent to participate

This prospective study was assessed and approved by the Ethical Comity of Clinical Research of the University de Montréal (18-060-CERES-D). A signed consent was obtained for each of the subjects included in the study.

- Consent for publication

All authors contributed to the manuscript and agreed on its publication.

- Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

- Competing interests

Dr JCL, Dr CB, PR and Dr AM declared no conflict of interest. Dr. RBK is a consultant to Tekscan, Inc, S. Boston, MA USA, but receives no monetary gain from sales of any Tekscan products.

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- Authors' contributions

Dr JCL, AM and RBK designed the study. Dr CB collected data and wrote the first version of the manuscript. PR performed statistical analysis, critically reviewed conclusions and several manuscripts. Dr JCL and RBK reviewed and modified data presentation, wrote the discussion and updated references. All authors read and approved the final manuscript.

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Figures

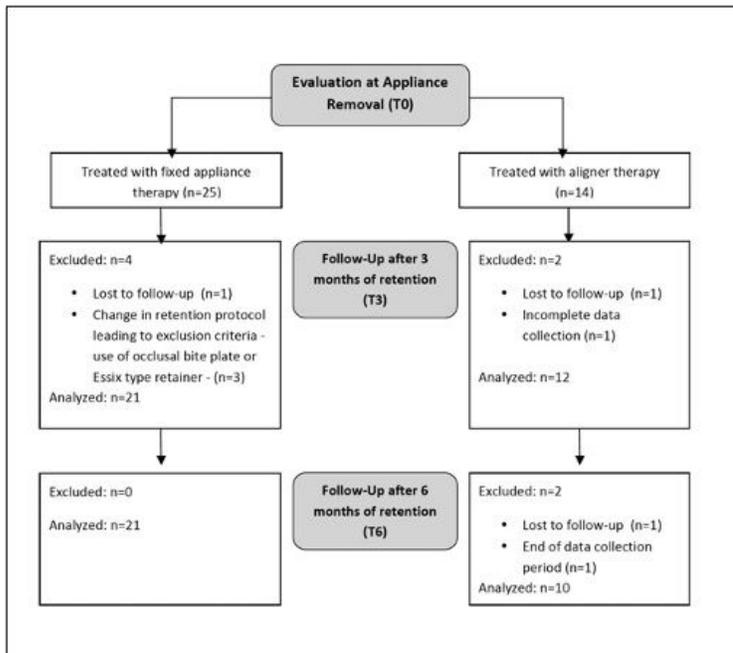


Figure 1
Patient's flowchart

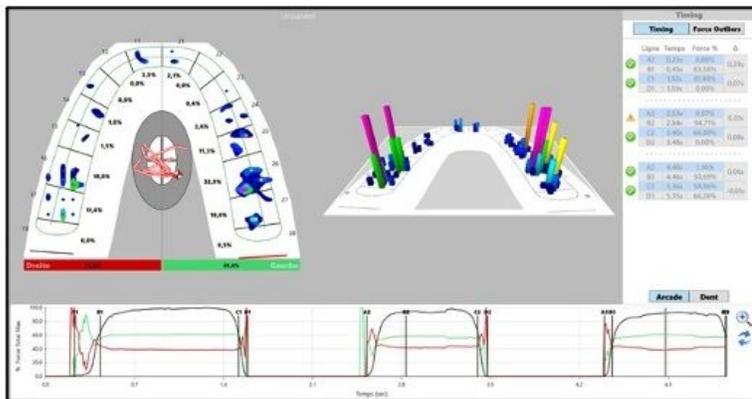
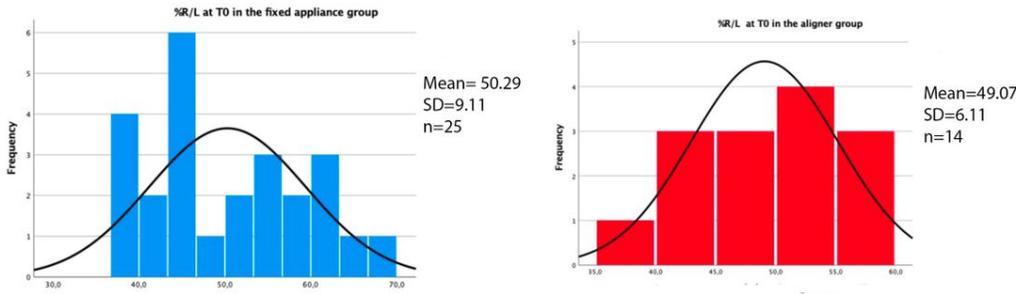
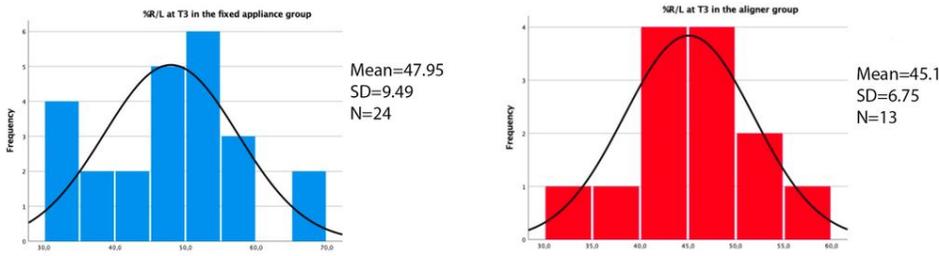


Figure 2
a - T-Scan recording showing 3 consecutive closures into MIP on the HD Novus sensor. The Force vs. Time graph (bottom pane) represents the 3 individual closures loading the recording sensor across time. The red/white diamond icon marks the Center of Force location (posterior left). Histograms in the 3D view and the pixel areas on the 2D occlusal view, represent contact force intensity and surface area respectively. b - An

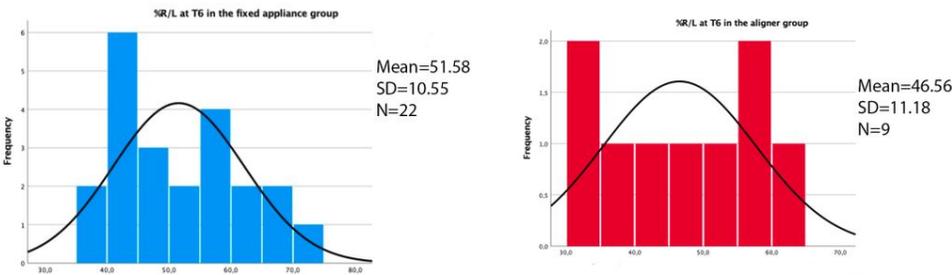
occlusal view photograph of the same patient in Figure 2a, of the maxillary MIP contacts marked with horseshoe articulating paper. Note the false positive contacts due to staining of the paper ink on the incisal borders of the lateral and central incisors.



A) Percentage of Force recorded on the right side in MIP at T0



B) Percentage of Force recorded on the right side in MIP at T3



C) Percentage of Force recorded on the right side in MIP at T6

Figure 3

Distribution of patients according to %R/L force in MIP, for fixed appliance groups (in blue) and aligners (in red). Figure 3a at T0, 3b at T3, Figure 3c at T6.

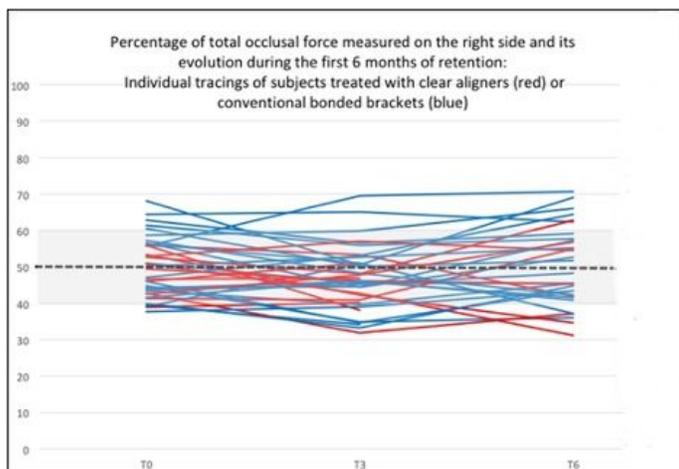


Figure 4

Estimation of occlusal contact symmetry and its evolution during the retention period between groups. Note the divergence of many of the colored lines away from the hyphenated midline (=50%) in both aligner and fixed treatment patients. This indicates that settling for 6 months did not improve patient occlusal balance

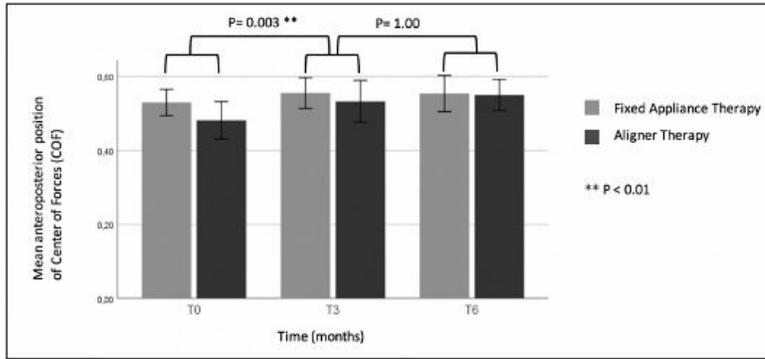


Figure 5

Variation in time of the anteroposterior position of COF (relative force value) for fixed appliance and aligner groups

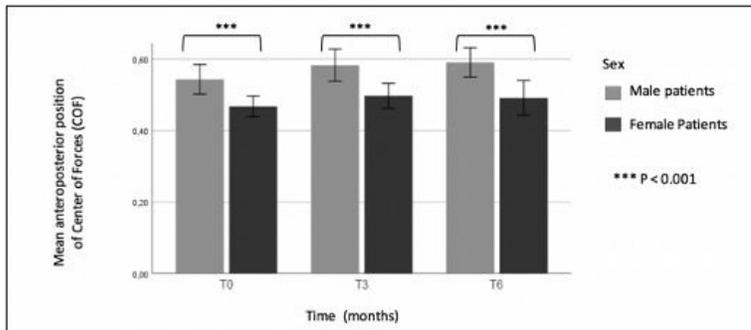


Figure 6

Variation in time of anteroposterior position of COF (relative force summation) for male and female patients

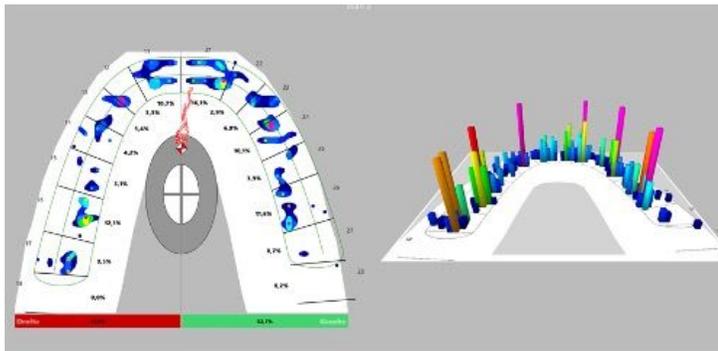


Figure 7

A balanced symmetric outcome after tooth movement with the COF centered and the right to left force imbalance = 47.3% right -52.3% left. Despite the overall balance, multiple differing individual contact force levels resulted from treatment, stronger in the anterior teeth. COF is anterior, posterior contacts are located in the palatal cusps of molars, and 27 has very little contact.

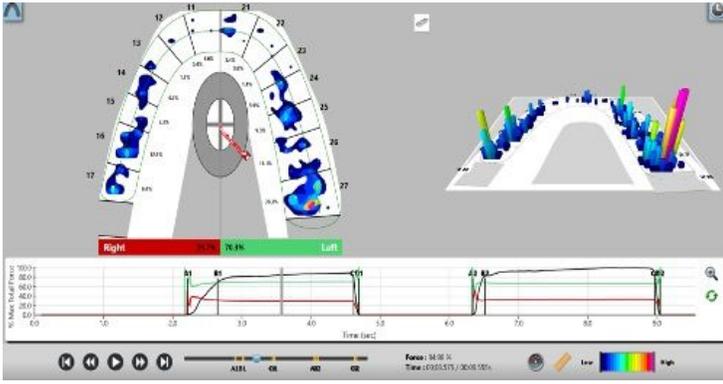


Figure 8

An imbalanced and highly asymmetric aligner outcome with the COF located in the posterior left. The large occlusal force imbalance (29.7% right -70.3% left) did not change with settling.



Figure 9

The development of a "posterior open bite" in the course of aligner treatment has been linked to the intrusion of posterior teeth due to the interocclusal thickness of aligners, premature anterior contacts (upright maxillary incisors in this case) and the difficulty of extruding posterior teeth with aligners.