ORTHODONTIC TREATMENT- INDUCED CHANGES IN OCCLUSAL CONTACT IN SUBJECTS WITH CLASS I AND CLASS II MALOCCLUSIONS

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Abstract

Orthodontic Treatment Induced changes in Occlusal Contact in Subjects with Class I and Class II Malocclusions

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Introduction: The purpose of this study was to determine differences in occlusal contact area amongst Class I and Class II malocclusions and to compare how orthodontic treatment modifies the occlusal contact areas. The influence of age, gender, initial type of malocclusion, final occlusal classification and type of treatment (extraction vs. non-extraction) was evaluated. **Methods:** This retrospective study included consecutively treated patients from the Graduate Orthodontic Clinic of the University of Washington, who started treatment between January 2017 and June 2019, and were de-bonded by January 29th of 2021. Intraoral scans were obtained pretreatment and immediately after completing orthodontic treatment. A 3D metrology software (GOM) was used to evaluate occlusal contact areas and interocclusal distances in the 0.25 to -1.25 mm range. Heat maps of the surface area were created, and the areas were recorded for the total surface area of the dental arch as well as for the anterior and posterior segments. The differences in occlusal contacts and interocclusal spaces as a function of malocclusion type, age, gender and extractions were analyzed. Additionally, occlusal contacts were compared to pre- and post-treatment PAR scores. **Results:** 96 patients were included in this study. Areas of tight, near and approximating contacts reduced significantly in response to orthodontic treatment, while areas of open and no contact increased. Age and gender did not have an effect in the overall change of occlusal contacts. There were pretreatment and pre-post treatment differences between subjects with Class I and Class II malocclusions. Subjects who received extractions of maxillary premolars have the least amount of posttreatment tight+ near + approximating contacts. **Conclusion:** After Orthodontic treatment, occlusal contact areas tend to decrease. Several factors influence the amount of contact area decrease and the posttreatment amount of occlusal contacts.

TABLE OF CONTENTS

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1. INTRODUCTION:

Since 1949, when Yurkstas first demonstrated the relationship between masticatory performance and occlusal contact area, many other studies have investigated this association (Yurkstas and Manly, 1949; Yurkstas, 1965). In 1993, Wilding observed that occlusal contact areas in an individual are good predictors for chewing efficiency (Wilding, 1993). Owens et al. found that subjects with greater areas of occlusal contact and near contact were more successful at breaking down food than those with reduced occlusal contact area (Owens et al., 2002). A later study found that increased functional occlusal area is related to a greater chewing efficiency for foods of all consistencies (Laird et al., 2015). When Lepley et al. investigated the influence of occlusion, chewing cycle kinematics and maximum bite force on masticatory performance they found that the area of occlusal contact was the most important determinant of masticatory performance (Lepley et al., 2011).

Subjects with a malocclusion have decreased masticatory efficiency and significantly smaller occlusal contact areas when compared to those with normal occlusions (English et al., 2002). When considering anteroposterior malocclusions, individuals with Class III malocclusion had the lowest masticatory performance and reported the greatest masticatory difficulty, followed by Class II and Class I malocclusions respectively (English et al., 2002). Toro and collaborators found that children and adolescents with Class I malocclusions showed decreased masticatory performance when compared to adequate Class I occlusions (Toro et al., 2005). However, in a study conducted by Bourdiol et al. studying the association between dentofacial deformity and masticatory deficiency, only subjects with severe malocclusion demonstrated hindered mastication, whereas subjects with moderate malocclusion were able to increase their number of chewing cycles to compensate for their impaired occlusion (Bourdiol et al., 2016). Yet, in this study, they concluded that the compromised mastication related to severe malocclusion was due to a significantly reduced functional occlusal area. Wilding also found that subjects with reduced occlusal area compensate for their malocclusion by chewing for a longer period before swallowing, however they found that this is not enough to completely compensate

for their decreased efficiency (Wilding, 1993). With regards to vertical malocclusions or the overbite, subjects with anterior open bite present fewer occlusal contacts and significantly decreased masticatory performance when compared to patients with deep bite (Abrahamsson et al., 2014).

Although numerous studies have demonstrated that malocclusion is associated with a reduced functional occlusal area and an altered masticatory efficiency, few studies have investigated the effect of orthodontic treatment on occlusal contact areas in diverse malocclusion groups. One of the first studies that sought to determine this effect compared two groups that were orthodontically treated to two control groups and found that orthodontic treatment may lead to a permanent reduction in occlusal contacts, which may not recover even after a prolonged period of occlusal settling (Sullivan et al., 1991). Although this study matched control and experimental patients for age and sex, no mention of the control groups' type of occlusion was included. Furthermore, this study compared the occlusal contacts of experimental and control groups and did not compare the pretreatment and post-treatment occlusal contacts of the groups that received orthodontic treatment. A more recent study performed by Yoon et al. on female patients under the age of forty, investigated the relationship between occlusal contact area and occlusal force with non-extraction, two premolar extraction and four premolar extraction orthodontic treatment. They found that the immediate post-treatment area of occlusal contacts is reduced by approximately half of the pretreatment value, however, the non-extraction and the two maxillary premolar extraction groups recovered within two years of occlusal settling, whereas the four premolar extraction group did not fully regain the occlusal contact area (Yoon et al., 2017). In contrast, Choi et al., analyzed the occlusal contacts of patients who underwent non-extraction and four premolar extraction orthodontic treatment and found that premolar extraction did not reduce the functional occlusal contacts (Choi et al., 2010). Another study reported that patients who commenced and finished treatment with Class I molar relations and underwent 4 premolar extractions had significantly greater contact areas than patients who began and finished orthodontic treatment with Class II molar relations and only received extractions of the maxillary first premolars (Lee et al., 2014).

The technique of registration of occlusal contact used in earlier studies, such as that employed by Yurkstas, consisted in obtaining inter-occlusal registrations by requesting patients to bite down on a wax wafer and later recording the perforations produced by the contacts by holding the resulting wafer to the light (Yurkstas and Manly, 1949, Wilding, 1993, Fulks et al., 2017). Abrahamsson et al. recorded occlusal contacts by means of registering the markings left on teeth by a thin, folded plastic foil (Abrahamsson et al., 2015). Later studies recorded areas of contact and near contact through use of silicone-based registrations in maximum intercuspation that were then scanned and analyzed on computer software (Owens et al., 2002, Bourdiol et al., 2017). Yoon employed pressure sensitive films and requested participants to bite on the film with maximum force for 5 seconds (Yoon et al., 2017). Since masticatory efficiency is heavily related to the number of occlusal contacts, it is crucial to evaluate these by the most reliable method available.

Intraoral digital scanners have become widely used in orthodontic practices. These scanners have been demonstrated to improve both patient comfort and practice efficiency when compared to more traditional forms of impressions such as alginate and PVS, while still maintaining impression accuracy (Ender et al, 2011). Intraoral digital scanners are Class I medical devices and have three main components: a handheld camera wand that collects the scan data, a computer monitor to view the scan and enter prescriptions, and a wireless mobile workstation. To gather data points, the handheld camera emits a white light which projects onto the surface that is being scanned and is then reflected onto a sensor within the wand, creating hundreds of measurements and reconstructing a 3D image of the object. The iTero scanner, fabricated by Cadent, possesses a sensor that is placed at the confocal imaging plane of the object and is capable of filtering out reflected light that is out of focus, thus increasing the scan's accuracy (Kravitz et al., 2014). To analyze specific details on the intraoral scans, software such as GOM Inspect, a free software for 3D inspection and mesh processing, can be used. The analysis of occlusal contact by this type of software has been proven to be significantly more accurate than analyzing contacts based on the traditional physical interocclusal records (Solaberrieta et al., 2015).

In order to objectively compare orthodontic treatment results and quantify the improvement achieved from treatment, standardized measures or indexes have been developed (Cook, et al 2005). These indexes compare the pretreatment and posttreatment records to determine the quality of the result obtained through Orthodontic treatment and the degree of improvement of the malocclusion. The Peer Assessment Rating (PAR) Index is a widely used, valid and reliable method to objectively evaluate the orthodontic treatment outcome. This assessment analyzes both the pretreatment and posttreatment models using the same criteria to evaluate both time points. The score that results from the pretreatment analysis indicates the deviation of the particular case from ideal alignment and the severity of the malocclusion. The assessment is then repeated on the post treatment casts. The difference between the pretreatment and posttreatment scores demonstrate the improvement accomplished through orthodontic treatment. The closer the score is to zero the more ideal the occlusion, while a greater score is consistent with a more severe malocclusion. (Richmond et al. 1992). Studies have shown that a reduction of 65% of the PAR score is considered a great improvement in overall alignment and occlusion (DeGuzman et al. 1995). A study conducted by Holman and collaborators found that both extraction and non-extraction orthodontic treatments can obtain similar improvements in in the PAR index. However, they found that subjects that had treatment with extractions had a greater initial PAR score mostly due to higher scores in anterior segment crowding and overjet (Holman et al. 1998) Few studies have analyzed the association between PAR scores and occlusal contacts.

2. MATERIALS AND METHODS

2.1 Study Design

This retrospective study compared the changes in occlusal contacts using 3D images of patients at T1 (pretreatment scan) and T2 (immediately after debonding; posttreatment scan). Institutional Review Board (IRB) approval was obtained from the University Human Subjects Divisions before starting data collection on June 4th, 2019.

2.2 Participants, Eligibility criteria and Data collection

A list of all patients who started treatment at the Orthodontic Clinic of the University of Washington between January 2017 and June 2019 was obtained. Inclusion criteria were having received comprehensive orthodontic treatment, presence of good quality initial and final iTero scans with erupted permanent dentition of first molar to first molar in both arches and having finished orthodontic treatment by January 29th 2021. Exclusion criteria were Class III or subdivision malocclusions, impacted permanent teeth, retained primary teeth, use of Orthognathic surgery, presence of dental prosthodontic treatment during T1 and T2, treatment with clear aligners and unfinished or prematurely discontinued treatments due to reasons such as missed appointment or poor compliance. Data related to patient demographics (age and gender), and extractions for orthodontic treatment was collected from the patient's digital records. Data regarding initial type of antero-posterior malocclusion and overbite were collected from the participant's digital scans. The Angle Classification of Malocclusion was assessed from the patient scans. To be considered Class I the mesiobuccal cusp of the maxillary first molar occluded in the mesiobuccal groove of the mandibular first molar. To classify as a Class II Angle occlusion the subject presented with at least and End-on Class II molar relationship. Overbite was also assessed on the intraoral scans, where normal overbite included edge to edge occlusion up to 3 mm of vertical overlap between maxillary central incisors and the mandibular central incisors. Open bite represented no contact between the maxillary and mandibular central incisors and a deep bite was any overlap greater than 3 mm of the mandibular central incisors by the maxillary central incisors. The initial and final PAR scores were obtained from the Clinic's archives.

2.3 Methods

2.3.1 Intraoral Scans

Each patient underwent an intra-oral scan with the same generation of iTero (Align Technology, Inc. San José, CA) digital scanner at the University of Washington Orthodontic clinic at two time points (T1- pretreatment scan, T2- posttreatment scan on the day of debond). All patients were scanned in supine position and were asked to bite in their most comfortable position or Maximum Intercuspation. The intraoral scans were then exported

from www.mycadent.com as a single open shell STL file with the maxilla and mandible oriented in occlusion. These files were then imported into the GOM Inspect Software for their analysis (GOM Precise Industrial 3D Metrology, Braunschweig, Germany).

2.3.2 Measurements on the Scan

The STL of the mandibular teeth was imported into the GOM Inspect software as a "mesh" element, while the STL of the upper teeth was added as a "CAD body". The upper model was then selected and inverted. Following this, the lower model was selected, and the occlusal table was outlined. At this point it was possible to perform a CAD comparison and a surface comparison on the Actual, setting the minimum distance detected between the upper and lower models at 0.25 mm, while the greatest distance was set at -1.25 mm. 0.25mm was the lowest collision value detected in this study, in physical models this would be equivalent to a distance of 0 mm, however, in articulating 3D digital models, "the computer cannot stop the images from moving through each other once the models have made contact" (Xia, et al. 2010). However, since two digital models should not be able to penetrate each other, these collisions represent the relationship between the upper and lower model where in conventional models, there is virtually no space between the opposing teeth represented in collision (Xia, et al. 2010). The greatest distance that was analyzed between the models for this study was of -1.25 mm which would reflect 1.25 mm of space between opposing antagonist teeth. Once the upper and lower limits were set, the display was then changed from a heat map to a tolerance legend, where each range could be inputted and the resulting area from each range was displayed in a statistic table, the data for all the ranges were added to an Excel spreadsheet (Microsoft Excel, Microsoft Office 365, Redmond,

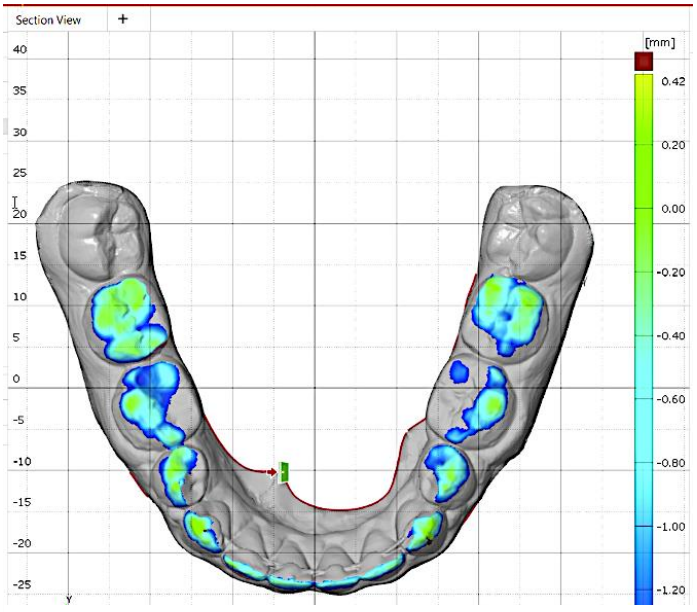


Figure 1: *example of an iTero scan with GOM Inspect heat map*

Washington). The ranges evaluated were areas of "tight contact" (0.25 to 0 mm), areas of "near contact" (<0 to -0.25 mm), areas of "approximating contact" (-0.26 to -0.5 mm) and areas of "open contact" (-0.51 to -1.00) and "no contact" (<-1.0 to -1.25 mm). The occlusal tables were divided into anterior (canine to canine) and posterior (premolars to molars, bilaterally) segments. The *Total Surface Area within Range* and five subcategories were measured for each segment. A heat map was created for each time point: T1 (pretreatment) and T2 (post-treatment). If, in the T1 scan, the second mandibular molars were not fully erupted they were not included in the occlusal selection of the T1 or the final T2 heatmap for that subject. Please refer to Figure 18 in Appendix for further illustration of these ranges.

Two methods of selecting the occlusal table of the mandibular model were tested for the pre and post-treatment scans of 10 patients. In Method 1, the occlusal table was selected by

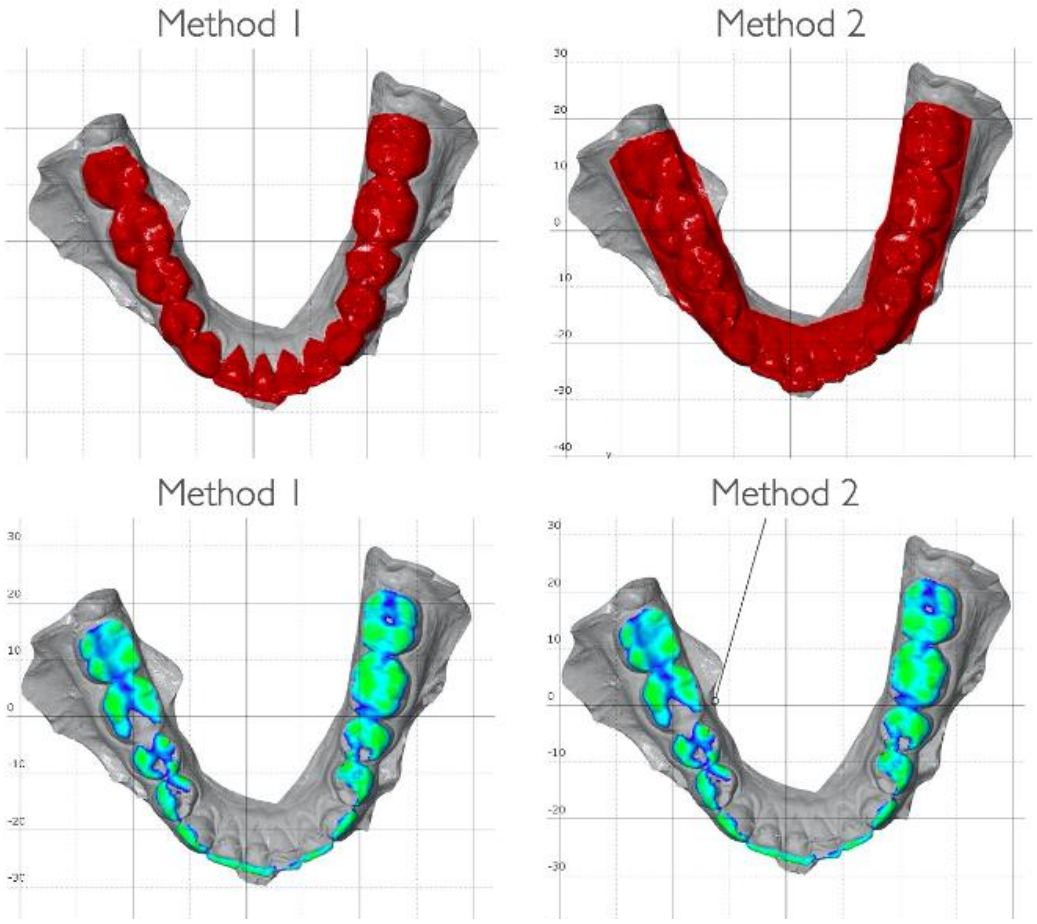


Figure 2 and 2A: *The upper figure shows the area selection with both Method 1 and Method 2 respectively. Figure 2A below it shows the resulting heat map from each method of selection.*

carefully outlining each tooth of the mandibular model, with care to not include any gingiva. In Method 2, the teeth were selected in more of a horseshoe outline, in which some gingiva was included, with care to never include the retromolar pads (Figures 2 and 2a). As Method 1 was much more time consuming than Method 2, these two were tested to ensure that Method 2 was a reliable method of selecting the occlusal table. Results from these two methods can be found in Table 1. Method 2 was used in this study to outline the occlusal table.

2.4 Verification of Measurement Error

Four months after initial measurements, 5 subjects were randomly selected and their T1 and T2 scans were remeasured by the investigator. The measurements obtained at the two sessions were compared to verify intra-examiner and measurement error.

3. Sample size

A sample size of 128 patients was determined to have power of 80% to demonstrate a change in contact area between pre- and post-treatment equal to 0.25 standard deviations and 99% power to demonstrate a change in contact area equal to 0.50 standard deviations based on two-sided paired t-test at a 0.05 significance level. Based on pilot data from 17 patients the change was expected to range from 0.26 standard deviations for open contact to 1.10 standard deviations for near contact or from a 2.1 to 7.5 point change in the contact percentage. The differences in the change in the contact area by various patient characteristics were expected to be smaller. Based on a two-sample t test at a 0.05 significance level, a sample size of 128 patients would have 80% power to demonstrate a difference of 0.5 standard deviations, corresponding to a 1.3 to 4.5% point difference in the average change in percent contact area between two patient groups of equal size. Due to a delay in patient care due to the COVID pandemic, only 96 patients were available for the study. With a sample size of 96 patients, power is 80% to demonstrate a change of 0.29 standard deviations between pre- and post-treatment, and a difference of 0.58 standard deviations between two patient groups of equal size.

4. Data analysis

For each type of contact the mean and standard deviation were used to summarize the amount and percentage of the total contact at pre-treatment, post-treatment and the change between pre- and post-treatment. In addition, a 95% confidence interval for the average change was computed. To test for change between pre- and post-treatment, multivariate analysis of variance (MANOVA) was used first to test for any change among the 5 contact types and then paired t-tests were used to test for change for each contact type. To account for the multiple testing (5 tests) the paired t-test p-values were adjusted using the Bonferroni method to maintain a 0.05 significance level. Summaries and comparisons were done for the total contact area and for the anterior and posterior contact.

The amount and percentage of contact were compared by various patient characteristics; sex (female or male), age (11-18 or 19-25 years old), Angle malocclusion (Class I or Class II), overbite (normal, deep bite or open bite) and use of extraction (none, extraction of 4 premolars or extraction of maxillary premolars only). For each patient characteristic, the amount and percent of contact was summarized for pre-treatment, post-treatment and the change between pre- and post-treatment using the mean, standard deviation and 95% confidence interval. In addition, paired t-tests were used to test for change between pre- and post-treatment, and the paired t-test p-values were adjusted using the Bonferroni method to maintain a 0.05 significance level. MANOVA was used test for any difference in contact at pre-treatment and post-treatment, and in the change in contact between pre- and post-treatment for each patient characteristic. Separate two sample t-tests for binary characteristics (sex, age, and malocclusion) and one-way analysis of variance (ANOVA) for three-category characteristics (vertical malocclusion and extraction) were used to test for difference in the contact change for each contact type. The two-sample t test and ANOVA p-values were adjusted using the Bonferroni method to maintain a 0.05 significance level. All analyses were done using R statistical software.

3. RESULTS

3.1 Sample Population Characteristics

A total of 117 patients qualified for this study, and their initial scans were analyzed. 21 patients who had initially been included in the study were eliminated since they had not completed treatment by January 29th of 2021 due to increase in treatment time secondary to COVID19 clinic closures. A total of 96 patients were included in this study. See Figure 3 for a flowchart of the patient selection during the study.

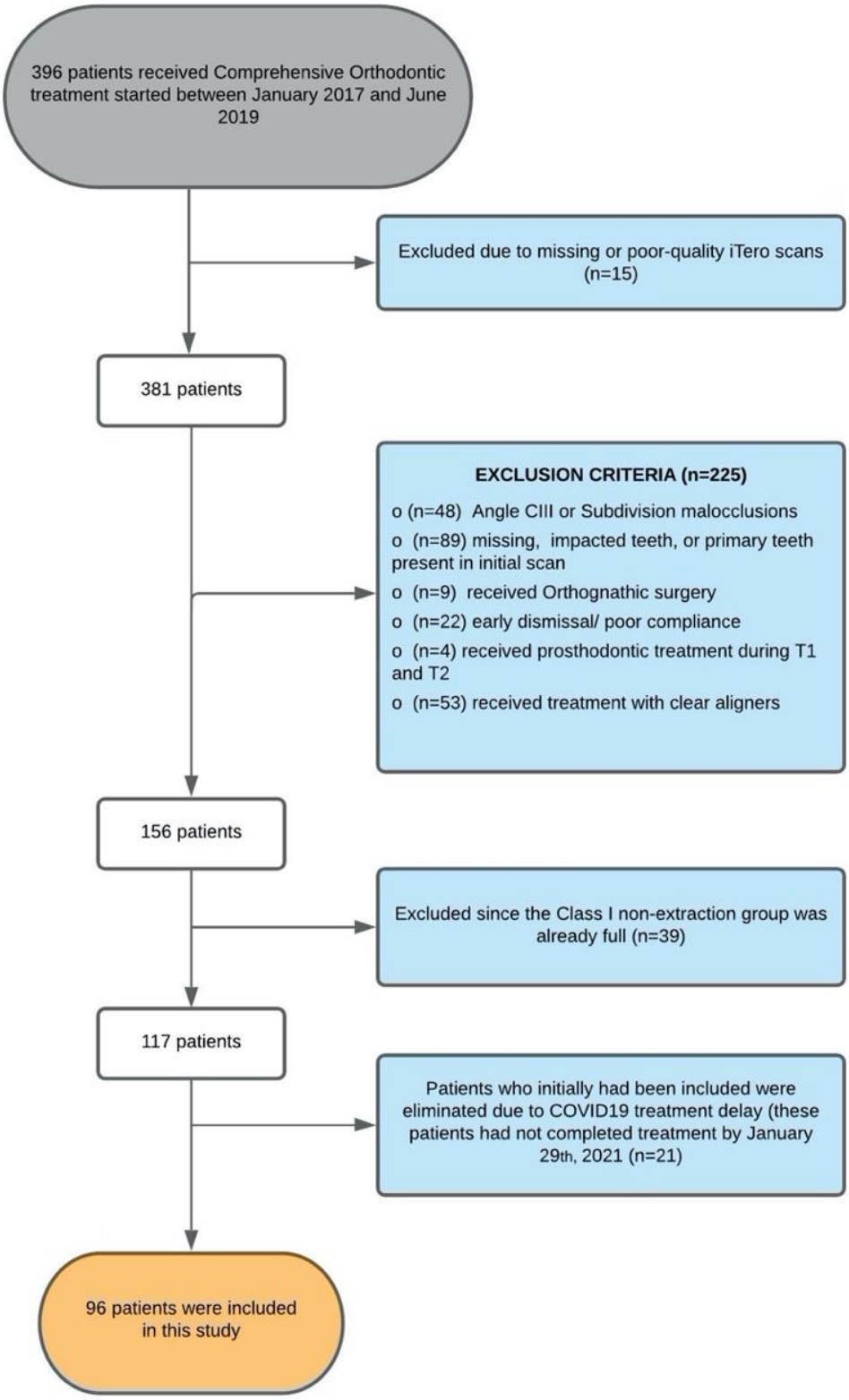


***Figure 3**: Participants´ Flowchart*

3.1.1 Patient Demographics

Table 1 shows the patient's demographic data, initial Angle classification of malocclusion, initial overbite and presence of extractions as part of orthodontic treatment. 52.1% of the patients were female, while 47.9% were male. The majority of the patients (70.8%) were young adolescents between ages of 11-14, followed by adolescents in the 15-18 year-old group (19.8%), with the smallest group being comprised of adults between ages of 19-25 (9.4%).

Table 1: *Demographics and patient characteristics*

		N	%
Gender			
	Female	50	52.1
	Male	46	47.9
Age			
	Adolescents age 11-14	68	70.8
	Adolescents age 15-18	19	19.8
	Adults age 19-25	9	9.4
Angle Classification			
	Class I malocclusion	58	60.4
	Class II malocclusion	38	39.6
Initial overbite			
	Normal (1-3 mm)	43	44.8
	Deep bite (>3 mm)	39	40.6
	Open bite (<0 mm)	14	14.6
Extractions			
	Extraction of 4 premolars	27	28.1
	Extraction of maxillary premolars	13	13.5
	Non-Extraction	56	58.3

3.1.2 Patient Demographics of 21 eliminated patients

Table 2 shows the patient's demographic data, initial classification of Angle malocclusion, initial overbite and use of extractions for orthodontic treatment of the 21 patients that did not complete treatment by January 29th 2021, due to clinical delay secondary to COVID19 Clinic closures. Note a significantly large percentage of patients that underwent extraction

of 4 premolars (47.6%) as well as a greater percentage of patients with Angle Class II malocclusions (61.9% or 13 patients).

Table 2: *Demographics and patient characteristics of 21 patients who did not complete treatment in time to be included.*

		N	%
Gender			
	Female	12	57.1
	Male	9	42.8
Age			
	Adolescents age 11-14	14	66.6
	Adolescents age 15-18	4	19
	Adults age 19-25	3	14.2
Angle Classification			
	Class I malocclusion	8	38
	Class II malocclusion	13	61.9
Initial overbite			
	Normal (1-3 mm)	13	61.9
	Deep bite (>3 mm)	6	28.5
	Open bite (<0 mm)	2	9.5
Extractions			
	Extraction of 4 premolars	10	47.6
	Extraction of maxillary premolars	3	14.28
	Non-Extraction	8	38.1

3.2 Comparison of Method 1 and Method 2

To compare the two methods of area selection (Method 1 and Method 2) 10 subjects were randomly selected and measured using both methods at pre- and post-treatment. The mean and standard deviation (SD) were computed for each method for each contact type, the mean difference and 95% confidence interval (CI) for the mean difference, and intraclass correlation coefficient (ICC) and 95% CI for the ICC. Results can be found in Table 3.

Table 3: *Comparison of Method 1 and Method 2 for area selection, Pre-treatment total contact measurements.*

	Method 1	Method 2	Method 1 – Method 2	
Measure	Mean (SD)	Mean (SD)	Difference (95% CI)	ICC (95% CI)
Total	576.7 (117)	579 (118.5)	-2.26 (-4.3, -0.22)	1 (1, 1)

Tight %	3.7 (2.2)	3.7 (2.1)	0.04 (-0.02, 0.1)	1 (1, 1)
Near %	15.7 (5.5)	15.6 (5.5)	0.09 (0, 0.18)	1 (1, 1)
Approx. %	17.3 (1.3)	17.3 (1.2)	0.05 (-0.11, 0.2)	1 (1, 1)
Open %	35.6 (3.4)	35.7 (3.4)	-0.11 (-0.2, -0.02)	1 (1, 1)
No %	27.6 (5)	27.7 (4.9)	-0.07 (-0.3, 0.16)	1 (1, 1)
Tight	22.8 (14.5)	22.7 (14.4)	0.09 (-0.15, 0.32)	1 (1, 1)
Near	93.6 (46.4)	93.6 (46.4)	-0.04 (-0.11, 0.03)	1 (1, 1)
Approx.	99.3 (24.6)	99.6 (24.6)	-0.36 (-0.99, 0.27)	1 (1, 1)
Open	200.2 (35.5)	202.1 (36.3)	-1.93 (-3.34, -0.51)	1 (1, 1)
No	152.2 (16)	153.7 (16.9)	-1.49 (-3.82, 0.85)	1 (1, 1)

The was a statistically significant difference in Using Method 1 and Method 2 between areas of Total, Near and Open contact, however the difference was small relative to the variability between subjects, as indicated by the ICC of 1 (i.e. excellent agreement).

3.3 Intra-examiner reliability of contact measurements

A comparison of the first and second measurements of contact area, including the pre – post-treatment change in contact area, pre-treatment contact area and post-treatment contact area was conducted.

To compare the two measurements the mean and standard deviation (SD) was computed for each set of measurements for each contact type, the mean difference and 95% confidence interval (CI) for the mean difference, and intraclass correlation coefficient (ICC) and 95% CI for the ICC. The Dahlberg error was also computed.

A 95% CI for the mean difference that does not include the value of zero indicates a statistically significant difference. The ICC is a relative measure of agreement, measuring how much of the variation in contact is due to differences between subjects and differences between the two measurements. An ICC > 0.75 generally indicates excellent agreement.

Comparisons were done for the total contact, anterior contact and posterior contact.

The summaries are based on 5 subjects whose initial and final scans were measured twice. Refer to Table 4 for a full summary.

Table 4: *Post- pre-treatment change in total contact measures. Note that the repeated measures were exactly the same during the first and second measurements for the Tight contact range, therefore it was not possible to calculate a 95% CI.*

	First measurement	Second measurement	$1^{st} - 2^{nd}$ measurement		
Measure	Mean (SD)	Mean (SD)	Difference (95% CI)	ICC (95% CI)	Dahlberg's error
Total	-22.8 (103.1)	-21.9 (103.3)	-0.93 (-1.83, -0.02)	1 (1, 1)	1.47
PERCENTAGE					
Tight (%)	-1.3 (0.9)	-1.3 (0.9)	0 (-0.01, 0.01)	1 (1, 1)	0.00
Near (%)	-7.6 (3.7)	-7.6 (3.7)	0.01 (-0.01, 0.04)	1 (1, 1)	0.02
Approx. (%)	-5.2 (2.5)	-5.3 (2.5)	0.03 (-0.01, 0.07)	1 (1, 1)	0.05
Open (%)	6.5 (3.4)	6.5 (3.3)	-0.02 (-0.08, 0.05)	1 (1, 1)	0.03
No (%)	7.7 (4.0)	7.7 (4.0)	-0.03 (-0.13, 0.08)	1 (1, 1)	0.04
AMOUNT					
Tight	-6.7 (4.8)	-6.7 (4.8)	0 (NaN, NaN)	1 (1, 1)	0.00
Near	-36.9 (29.1)	-36.8 (29.1)	-0.03 (-0.11, 0.05)	1 (1, 1)	0.05
Approx.	-27.1 (22.6)	-27.1 (22.6)	-0.05 (-0.13, 0.03)	1 (1, 1)	0.08
Open	19.9 (62.5)	20.4 (62.4)	-0.48 (-0.98, 0.01)	1 (1, 1)	0.77
No	28 (23.1)	28.4 (23.5)	-0.37 (-1.00, 0.27)	1 (1, 1)	0.58

The reliability of the change was excellent (ICC ≥0.99) for all measurements. These tests were also performed on the pretreatment and posttreatment contact measures separately and also demonstrated excellent intra-examiner reliability.

3.4 Pretreatment differences in Occlusal contact between the groups

3.41. T1 Differences in overall, anterior and posterior occlusal contact due to gender

There were no pretreatment differences in the overall contact (anterior + posterior segments) for any contact range due to gender (p=0.4771). However, there was a significant difference of the approximating contacts in the anterior segments between females and males, with males having an initial mean of 16.6 units of approximating contacts, while

females had a mean of 11.4 (p=0.045). There was no difference in T1 posterior contact for any of the contact ranges due to gender (p=>0.8). Refer to Table 20 in Appendix

3.4.2 T1 Differences in overall, anterior and posterior occlusal contact due to age

While it appears that adolescent patients had a smaller number of tight and near contacts than adult patients, this difference was not significant (p= 0.81, p=0.31 respectively). There was no significant difference between pretreatment anterior or posterior contacts due to age. Refer to table 21 in Appendix.

3.4.3 T1 Differences in overall, anterior and posterior occlusal contact due to initial Angle classification of malocclusion

There was a statistically significant difference in Approximating and Open contacts between subjects with Class I and Class II malocclusions. Subjects with Class I malocclusions had a mean pretreatment amount of approximating contact of 98.3, while the mean of subjects with Class II malocclusions was 81.7 (p=0.007). With regards to Open contacts, subjects with Class I malocclusion had a mean amount of 206.1, while subjects with Class II malocclusion had a mean of 172.3 pretreatment (p=0.0006). There was no statistically significant difference in initial anterior contact due to Angle classification of malocclusion (p=1). However, there was a significant difference in posterior approximating and open contacts due to initial differences in Angle classification of malocclusion. Patients with Class I malocclusions had an initial mean amount of 83.8 units of approximating contacts, while patients with Class II malocclusions had a mean of 68.9 (p=0.0047). With regards to open contacts, subjects with Class I malocclusions also had a greater mean amount of open contact than subjects with Class II malocclusion (mean of 172.0 and 144.2, respectively, p=0.0012).

3.4.4 T1 Differences in overall, anterior and posterior occlusal contact due to initial overbite

There was no statistically significant difference in overall (anterior +posterior) contacts due to overbite at T1 for any of the contact ranges. However, there was a significant difference between the amounts of all of the contact ranges in the anterior segment of patients with a

T1 open, deep or normal overbite. There was also a statistically significant difference in the initial percentages for all contact ranges except open contacts, for these different groups. See Table 22 and 23 in Appendix for full summaries. Patients with an initial deep bite had the greatest amount of tight, near and approximating contacts, while patients with an anterior open bite had the least amounts of anterior contacts (p=<.0001). There were no statistically significant differences in initial posterior contacts in subjects with normal anterior overbite, deep bite or open bite (p=1).

3.4.5 T1 Differences in initial overall, anterior and posterior occlusal contact in patients who later underwent different extraction patterns

There was a statistically significant difference in overall contacts between the non-extraction, 4 premolar and U4 premolar extraction groups in the tight contact range. Patients who would later receive non extraction treatment had a mean of 11.4 units of tight contact, patients who had extraction of 4 premolars had a mean of 13.7 and patients who had extractions of maxillary premolars only (U4s) had an initial mean amount of 6.2 units of tight contacts (p=0.0032). There were no statistically significant differences in anterior contact between these groups (p=>0.1). However, there was a significant difference of initial posterior contacts in the tight range for subjects who would later receive non extraction, 4 premolar extraction or maxillary premolar (U4s) extraction orthodontic treatment. Subjects who would later receive extractions of U4s had the least amounts of approximating contacts with a mean of 5.0, which was statistically different than subjects who received non extraction or 4 premolar extractions treatment (means of 9.1 and 12.6 respectively, p=0.017)

3.5 Changes in Occlusal contact secondary to Orthodontic treatment

3.5.1 Changes in Occlusal contact of the overall occlusal area secondary to orthodontic treatment

Table 5 and Figure 4 demonstrate the statistically significant changes in all five categories of occlusal contact from T1 to T2 of the total occlusal area. Areas of tight contact pretreatment consisted in a mean of 2.4% of the total occlusal contact area within range, whereas the

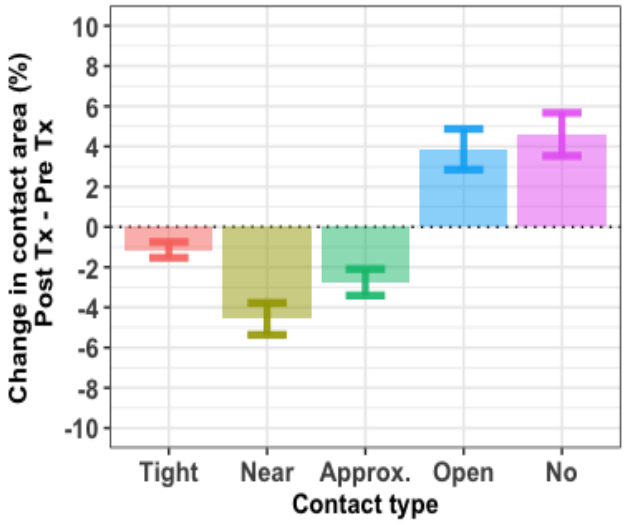
posttreatment mean reduced to 1.2% (this is equivalent to a 45.8% reduction from their pretreatment value). The areas of near contact at T1 had a mean of 14.2% and had reduced to 9.7% by T2 (decreased by 32.39%). Areas of approximating contact pretreatment were on average 19.8%, and post-treatment were 17.1% (decrease of 13.6%). Conversely areas of open contact increased between T1 and T2, with a T1 mean of 42.4% of the total contacts, and a T2 mean of 46.3% (increase of 9%). Areas of no contact pretreatment consisted, on average, of 21.1% and by treatment completion, they had increased to 25.7% (increased by 21.8%).

Table 5:*Summary of Pre and Post treatment and Post-Pretreatment change (%) . Test for any post-pretreatment change (MANOVA), p-value < .0001*

		Pre-Tx	Post-Tx	Post-Pre Tx Change		
Contact (%)	N	Mean (SD)	Mean (SD)	Mean (SD)	95% CI	Adj. P-value
Tight	96	2.4 (1.9)	1.2 (0.9)	-1.1 (1.9)	(-1.5, -0.8)	<.0001
Near	96	14.2 (4.0)	9.7 (2.8)	-4.6 (3.9)	(-5.4, -3.8)	<.0001
Approx.	96	19.8 (2.6)	17.1 (3.2)	-2.7 (3.3)	(-3.4, -2.1)	<.0001
Open	96	42.4 (4.9)	46.3 (4.2)	3.9 (5.0)	(2.8, 4.9)	<.0001
No	96	21.1 (4.8)	25.7 (5.4)	4.6 (5.3)	(3.5, 5.7)	<.0001

The multivariate analysis of variance (MANOVA) indicates there was a significant change in the contact areas between pre- and post-treatment (p-value < .0001). A decrease for tight, near and approximate contact and an increase for open and no contact (Bonferroni, p-value < .0001).

Figure 4: *pre- post-treatment change in total contact area (%)*



3.5.2 Changes in area of contact of the anterior and posterior segments

3.5.2.1 Changes in <u>anterior</u> area of contact

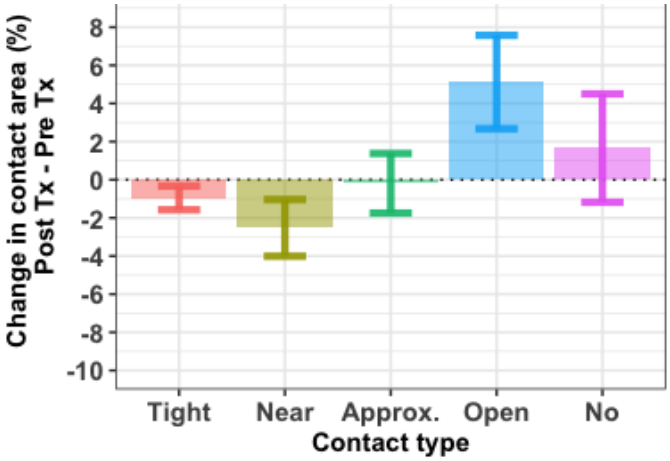
The anterior segment, from canine to canine, demonstrated statistically significant changes in the tight, near and open contacts. Areas of tight contact decreased from comprising 2.1% of the contacts to 1.1%. Areas of near contact decreased from 11.2% to 8.6%, while areas of open contact increased from 41.1% to 46.2% between T1 and T2. Areas of approximating and no contact had no significant (p=1.0) change between T1 and T2 in the anterior segment. Refer to Table 6 and Figure 5.

Table 6: *Summary of Pre and Post treatment and Post-Pretreatment change (%) in the anterior segment. Test for any post-pretreatment change (MANOVA), p-value = 0.0002*

		Pre-Tx	Post-Tx	Post-Pre Tx-Change		
Contact (%)	N	Mean (SD)	Mean (SD)	Mean (SD)	95% CI	Adj. P-value
Tight	96	2.1 (2.7)	1.1 (1.4)	-1.0 (3.1)	(-1.6, -0.3)	0.0156
Near	96	11.2 (6.4)	8.6 (5.0)	-2.5 (7.3)	(-4.0, -1)	0.00552
Approx.	96	16.3 (6.5)	16.1 (6.0)	-0.2 (7.7)	(-1.7, 1.4)	1.0
Open	96	41.1 (10.8)	46.2 (6.0)	5.1 (12.1)	(2.7, 7.6)	<.0001
No	96	26.3 (12.8)	27.9 (10.1)	1.7 (14.0)	(-1.2, 4.5)	1.0

The MANOVA indicates there was a significant change in the contact areas between pre- and post-treatment (p-value < .0001). There was significant decrease for tight and near contact, and significant increase for open contact. Areas of approximating contact did not have a significant change due to orthodontic treatment.

Figure 5: *Error bar plot of Post-Pretreatment changes (%) of Anterior segment*



3.5.2.2 Changes in posterior area of contact

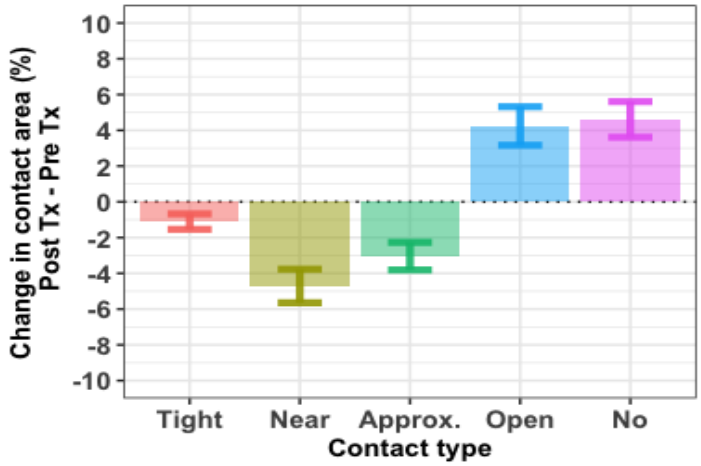
The posterior segment demonstrated statistically significant changes in all five contact ranges. Areas of tight contact at T1 consisted of a mean of 2.4% and decreased to 1.1% by T2. Areas of near contact decreased from 14.4% to 9.7% and areas of approximating contact decreased from 20.1% to 17.0% between T1 and T2. Area of open contact increased, with an initial mean of 42.2% to a final mean of 46.4%. Areas of no contact had a mean of 21.0% at T1 and increased to a mean of 25.6% by T2. Table 7 and Figure 6

Table 7: *Summary of Pre and Post treatment and Post-Pretreatment change (%) of Posterior segment. Test for any post-pretreatment change (MANOVA), p-value < 0.0001*

		Pre-Tx	Post-Tx	Post – Pre Tx Change		
Contact (%)	N	Mean (SD)	Mean (SD)	Mean (SD)	95% CI	Adj. P-value
Tight	96	2.4 (2.1)	1.3 (1.0)	-1.1 (2.1)	(-1.5, -0.7)	<.0001
Near	96	14.4 (4.7)	9.7 (3.3)	-4.7 (4.6)	(-5.6, -3.8)	<.0001
Approx.	96	20.1 (3.0)	17.0 (3.4)	-3.0 (3.8)	(-3.8, -2.3)	<.0001
Open	96	42.2 (5.0)	46.4 (4.7)	4.2 (5.3)	(3.2, 5.3)	<.0001
No	96	21.0 (5.2)	25.6 (5.7)	4.6 (4.9)	(3.6, 5.6)	<.0001

The MANOVA indicates there was a significant change in the contact areas between pre- and post-treatment (p-value < .0001). There was significant decrease for tight, near and approximate contact, and significant increase for open and no contact.

Figure 6: *Error bar plot of Post-Pretreatment changes (%) of Posterior segment of the 96 patients.*



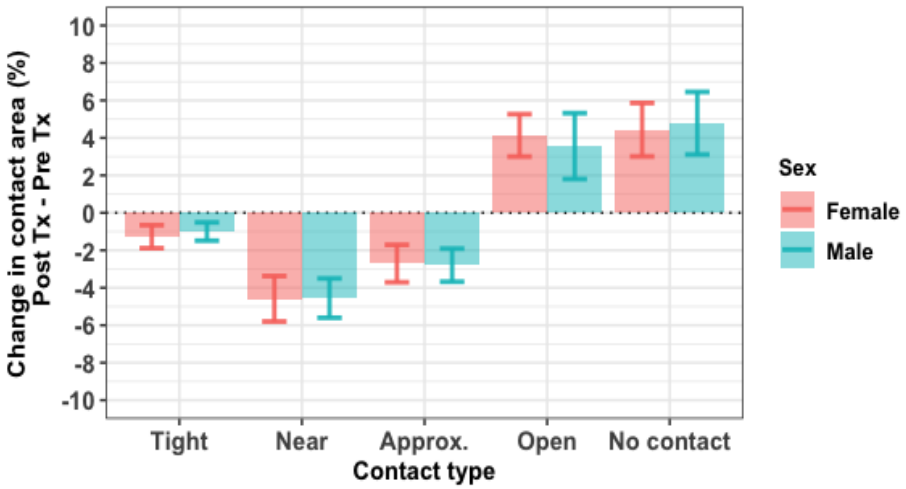
3.5.3 Influence of gender in changes in Occlusal contact from Orthodontic treatment

There were no significant differences between the T1 and T2 change in occlusal contacts between females and males (p=1.0). Refer to Table 8 and Figure 7.

Table 8*: Comparison of Post-Pre treatment change (%) between Females and Males. Any difference between by sex for post – pre tx change, MANOVA p-value = 0.9027*

	Female		Male		Female vs Male
Contact (%)	Mean (SD)	95% CI	Mean (SD)	95% CI	Adj. P-value
Tight	-1.3 (2.2)	(-1.9, -0.7)	-1.0 (1.6)	(-1.5, -0.5)	1.0
Near	-4.6 (4.3)	(-5.8, -3.4)	-4.6 (3.5)	(-5.6, -3.5)	1.0
Approx.	-2.7 (3.5)	(-3.7, -1.7)	-2.8 (3.0)	(-3.7, -1.9)	1.0
Open	4.1 (4.0)	(3.0, 5.3)	3.6 (5.9)	(1.8, 5.3)	1.0
No	4.4 (5.0)	(3.0, 5.9)	4.8 (5.6)	(3.1, 6.5)	1.0

Figure 7: *Error bar plot of Post-Pretreatment changes (%) due to gender (total = 96, female=50 participants, male=46 participants)*



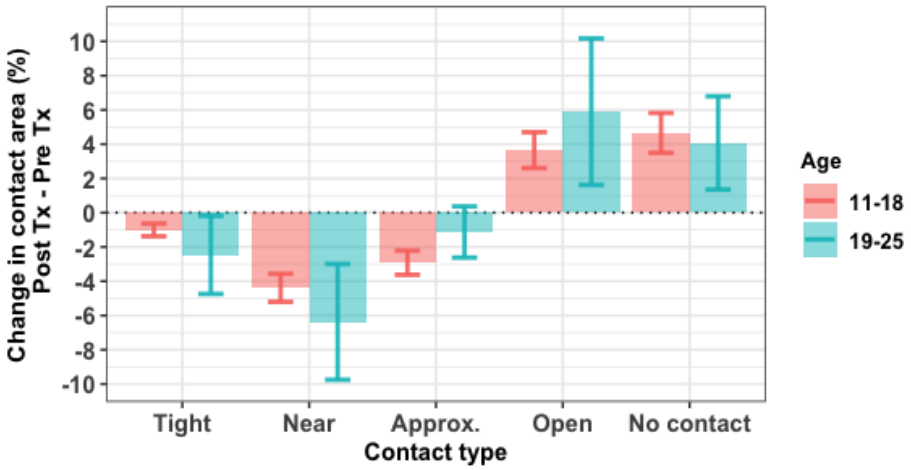
3.5.4 Influence of age in changes in Occlusal contact and interocclusal space from Orthodontic treatment

No significant difference in the change of occlusal contacts due to age, were found.

Table 9: *Summary of Post-Pretreatment change (%) of total contacts by age. MANOVA p-value = 0.0958*

	11-18 year-olds		19-25 year-olds		
Contact (%)	Mean (SD)	95% CI	Mean (SD)	95% CI	Adj. P-value
Tight	-1.0 (1.8)	(-1.4, -0.6)	-2.5 (3.0)	(-4.7, -0.2)	0.9093
Near	-4.4 (3.8)	(-5.2, -3.6)	-6.4 (4.4)	(-9.8, -3)	0.2227
Approx.	-2.9 (3.3)	(-3.6, -2.2)	-1.1 (1.9)	(-2.6, 0.4)	0.1518
Open	3.6 (4.9)	(2.6, 4.7)	5.9 (5.6)	(1.6, 10.2)	1.0
No	4.7 (5.5)	(3.5, 5.8)	4.1 (3.5)	(1.3, 6.8)	1.0

Figure 8: *Error bar plot of Post-Pretreatment changes (%) due to age. (11-18 age range=87 participants, 19-25 age range= 9 participants).*



3.5.5 Influence of initial malocclusion in changes in Occlusal contact and interocclusal space from Orthodontic treatment

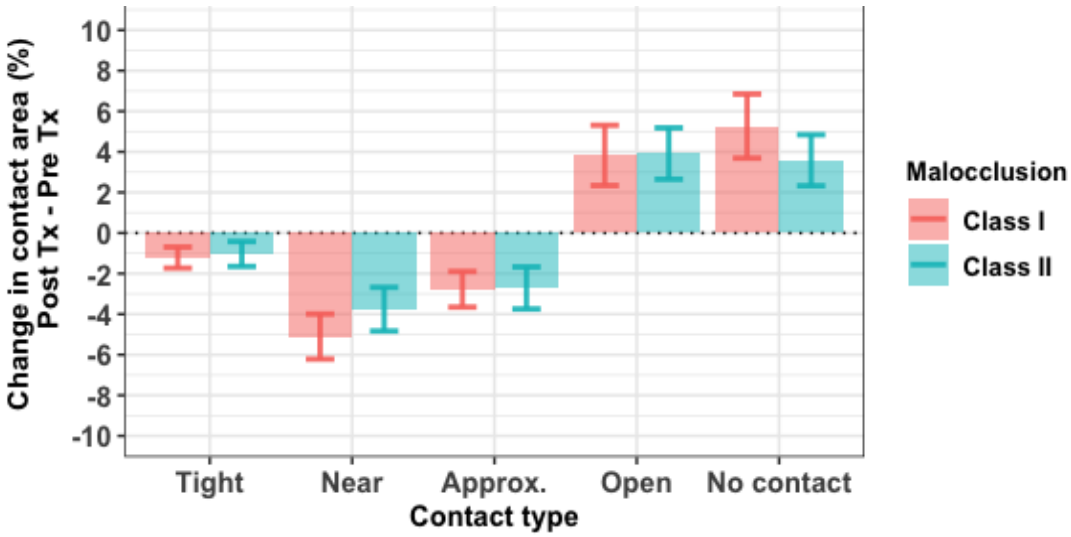
3.5.5.1 Influence of Initial Angle malocclusion classification in changes in Occlusal contact from Orthodontic treatment

There were no significant differences in the percent changes for any of the contact ranges between T1 and T2 due to Angle Malocclusion. Refer to Table 10 and Figure 9.

Table 10: *Summary of any difference for Post-Pretreatment change (%) of total contacts between Class I and Class II malocclusions, MANOVA p-value = 0.1657*

	Angle Class I		Angle Class II		
Contact (%)	Mean (SD)	95% CI	Mean (SD)	95% CI	Adj. P-value
Tight	-1.2 (2.0)	(-1.7, -0.7)	-1.0 (1.9)	(-1.7, -0.4)	1.0
Near	-5.1 (4.2)	(-6.2, -4)	-3.8 (3.3)	(-4.8, -2.7)	0.4132
Approx.	-2.8 (3.3)	(-3.7, -1.9)	-2.7 (3.2)	(-3.7, -1.7)	1.0
Open	3.8 (5.6)	(2.3, 5.3)	3.9 (3.8)	(2.6, 5.2)	1.0
No	5.3 (6.0)	(3.7, 6.8)	3.6 (3.8)	(2.3, 4.8)	0.4848

Figure 9: *Error bar plot of Post-Pretreatment changes (%) between Class I (n= 58) and Class II (n=38) malocclusions*

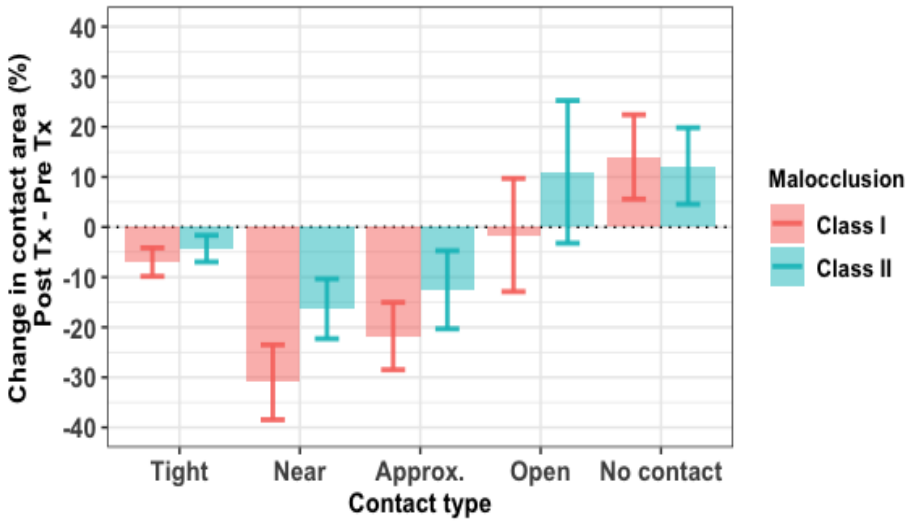


However, there was a significant difference in the post-pretreatment change in contact amount between Class I and Class II subjects. A significant difference in the decrease of Near Contacts between the Class I and Class II subjects was found (p=0.0135). Subjects with Class I malocclusions had a mean decrease of 31.0 of near contacts between T1 and T2, while subjects with a Class II malocclusion had a lesser decrease, with a mean of 16.3 units. View Table 11 and Figure 10.

Table 11: *Summary of any difference for Post-Pretreatment change (amount) of total contacts between Class I and Class II malocclusions, MANOVA p-value = 0.0851*

	Class I		Class II		Class I vs Class II
Contact	Mean (SD)	95% CI	Mean (SD)	95% CI	Adj. P-value
Tight	-7.0 (10.8)	(-9.8, -4.2)	-4.3 (8.1)	(-7.0, -1.7)	0.8363
Near	-31.0 (28.4)	(-38.5, -23.5)	-16.3 (18.2)	(-22.3, -10.4)	0.0135
Approx.	-21.8 (25.6)	(-28.5, -15)	-12.5 (23.7)	(-20.3, -4.7)	0.3703
Open	-1.6 (43.0)	(-12.9, 9.7)	11.0 (43.3)	(-3.2, 25.3)	0.8285
No	14.0 (32.0)	(5.6, 22.4)	12.2 (23.2)	(4.6, 19.8)	1.0

Figure 10: *Error bar plot of Post-Pretreatment changes (amount) between Class I (n=58) and Class II (n=38) malocclusions*



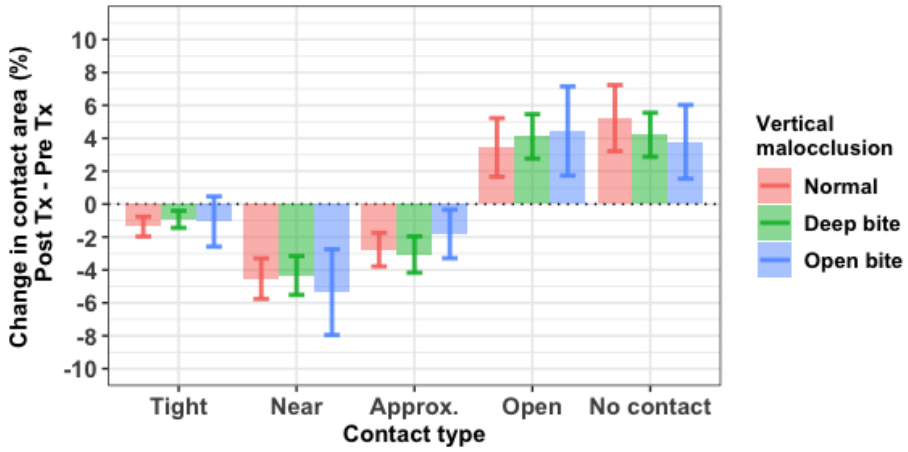
3.5.5.2 Influence of initial overbite in changes of occlusal contact from Orthodontic treatment

The presence of a normal overbite, deep bite or open bite at T1, had no effect on any difference for post-pretreatment change in percentage of the total contacts (p=1.0). Refer to table 12 and Figure 11.

Table 12: *Summary of any difference for Post-Pretreatment change (%) of total contacts between normal initial overbite, deep bite and open bite, MANVOA p-value = 0.5225*

	Normal overbite		Deep bite		Open bite		
Contact (%)	Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI	Adj. P-value
Tight	-1.4 (2.0)	(-2.0, -0.8)	-0.9 (1.6)	(-1.4, -0.4)	-1.1 (2.6)	(-2.6, 0.5)	1.0
Near	-4.5 (4.0)	(-5.8, -3.3)	-4.3 (3.7)	(-5.5, -3.2)	-5.3 (4.5)	(-8.0, -2.7)	1.0
Approx.	-2.8 (3.3)	(-3.8, -1.7)	-3.1 (3.4)	(-4.2, -2)	-1.8 (2.6)	(-3.3, -0.3)	1.0
Open	3.4 (5.8)	(1.7, 5.2)	4.1 (4.2)	(2.8, 5.5)	4.4 (4.7)	(1.7, 7.2)	1.0
No	5.2 (6.5)	(3.2, 7.2)	4.2 (4.1)	(2.9, 5.5)	3.8 (3.9)	(1.5, 6)	1.0

Figure 11: *Error bar plot of Post-Pretreatment changes (%) between normal initial overbite (n=43) , deep bite (n=39) and open bite (n=14) malocclusions*

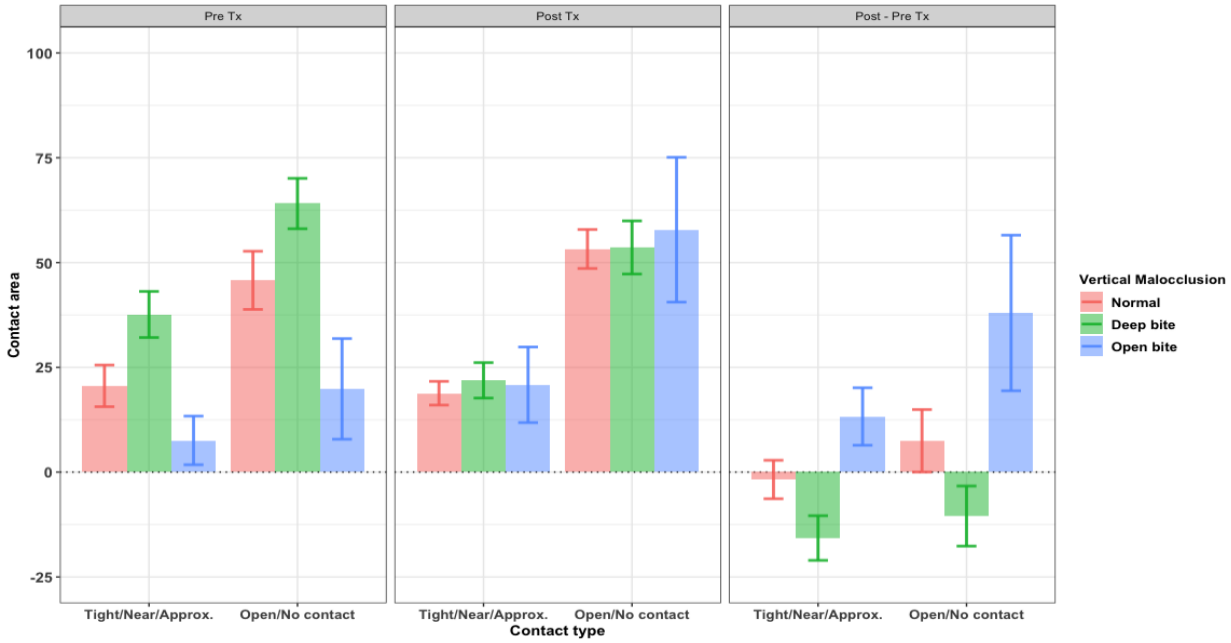


However, the sum of the anterior tight + near + approximating contacts pretreatment, posttreatment and the T1-T2 change for the different groups showed statistically significant differences. Subjects with an initial deep bite had the greatest amount of pretreatment anterior contact, followed by those with a normal overbite, while those with an anterior open bite had the least amount of anterior contact (p=<0.0001). Subjects with a deep bite lost the greatest amount of tight+ near+ approximating contact during treatment (-15.7) or all groups, followed by a small loss of 1.8 units from the normal overbite group, on the other hand, the open bite group gained 13.3 units of tight + near + approximating contact. The deep bite group also had a mean decrease in areas of open and no contact, while these increased in both the normal overbite and the open-bite groups. Refer to table 13 and Figure 12.

Table 13: *Summary of any difference for Pretreatment, Post-treatment, Post-Pre treatment change (amount) of anterior contacts between normal initial overbite, deep bite and open bite in the tight+ near+ approximating range and the open+ no contact range. MANOVA p-value= 0.5225*

	Pre-Tx				Post-Tx				Post-Pre Tx			
	Normal	Deep bite	Open bite		Normal	Deep bite	Open bite		Normal	Deep bite	Open bite	
Contact	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value
Tight/Near/Approx.	20.6 (16.1)	37.6 (17.0)	7.6 (10.1)	<.0001	18.8 (9.2)	21.9 (13.0)	20.8 (15.6)	0.9541	-1.8 (14.9)	-15.7 (16.4)	13.3 (11.9)	<.0001
Open/No contact	45.8 (22.6)	64.1 (18.6)	19.9 (20.8)	<.0001	53.2 (15.1)	53.6 (19.5)	57.8 (29.9)	1	7.5 (24.2)	-10.5 (22.1)	38.0 (32.1)	<.0001

Figure 12: *Error bar plot for Pretreatment, Post-treatment, Post-Pretreatment change (amount) of anterior contacts between normal initial overbite, deep bite and open bite in the tight+ near+ approximating range and the open+ no contact range*



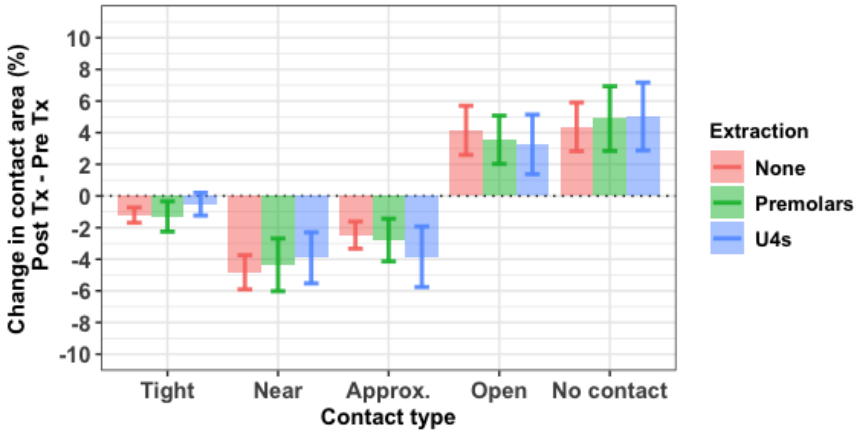
3.5.6 Influence of extractions in changes in Occlusal contact from Orthodontic treatment

The influence of extractions on percent changes of occlusal contact from orthodontic treatment, indicated no significant differences for any of the ranges between the non-extraction, 4 premolars and U4s groups (p=1). Refer to table 14 and Figure 13.

Table 14: *Summary of any difference for Post-Pretreatment change (%) of total contacts between extraction types (none, extraction of 4 premolars, extraction of maxillary premolars only), MANOVA p-value = 0.8038. (non-extraction=56 subjects, 4 premolars=27 subjects and maxillary premolars=13)*

	None		4 Premolars		U4s (2 maxillary premolars only)		
Contact (%)	Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI	Adj. P-value
Tight	-1.2 (1.8)	(-1.7, -0.7)	-1.3 (2.4)	(-2.3, -0.3)	-0.5 (1.2)	(-1.2, 0.2)	1.0
Near	-4.8 (4.0)	(-5.9, -3.7)	-4.4 (4.2)	(-6.0, -2.7)	-3.9 (2.7)	(-5.5, -2.3)	1.0
Approx.	-2.5 (3.2)	(-3.3, -1.6)	-2.8 (3.4)	(-4.1, -1.4)	-3.8 (3.2)	(-5.8, -1.9)	1.0
Open	4.1 (5.8)	(2.6, 5.7)	3.6 (3.9)	(2.0, 5.1)	3.3 (3.1)	(1.4, 5.1)	1.0
No	4.4 (5.7)	(2.8, 5.9)	4.9 (5.2)	(2.8, 6.9)	5.0 (3.6)	(2.9, 7.2)	1.0

***Figure 13**: Error bar plot of Post-Pretreatment changes (%) between extraction types (none, extraction of 4 premolars, extraction of maxillary premolars only) (non-extraction=56 subjects, 4 premolars=27 subjects and maxillary premolars=13)*



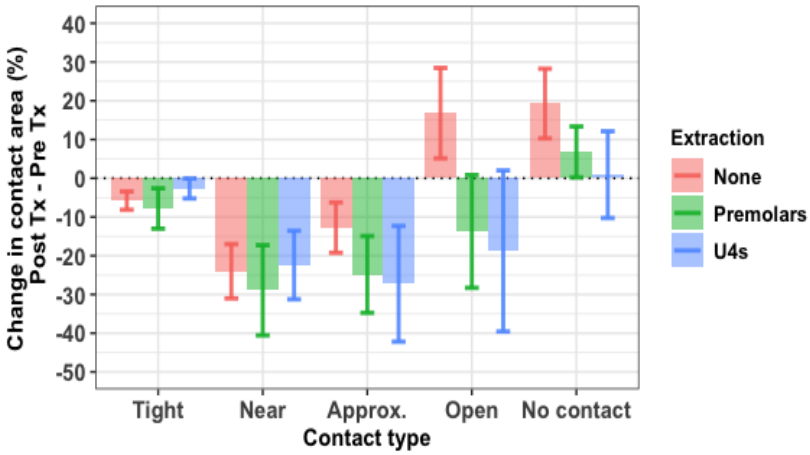
However, there was a significant difference in the amount of open contact between the T1 and T2 changes between the different extraction types. Subjects received non extraction orthodontic treatment had a mean increase of 16.8 units of open contacts, whereas subjects who had extractions of 4 bicuspids had a decrease of open contacts by 13.7 (p=0.0045). There was also a significant difference between subjects with non- extraction treatment and patients who had maxillary bicuspids extracted, where subjects from the U4s group had a mean decrease of 18.8 of the open contacts. Refer to table 15 and Figure 14.

***Table 15:** Summary of any difference for Post-Pre treatment change (amount) of total contacts between extraction types (none, extraction of 4 premolars, extraction of maxillary premolars only), MANOVA p-value = 0.0211*

	None		4 Premolars		U4s		
Contact	Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI	Adj. P-value
Tight	-5.8 (8.8)	(-8.2, -3.4)	-7.8 (13.1)	(-13.0, -2.6)	-2.6 (4.3)	(-5.2, -0.1)	0.4163
Near	-24.0 (26.1)	(-31.0, -17)	-28.9 (29.4)	(-40.6, -17.3)	-22.4 (14.6)	(-31.3, -13.6)	1.0
Approx.	-12.7 (24.3)	(-19.2, -6.2)	-24.8 (25.0)	(-34.7, -14.9)	-27.3 (24.7)	(-42.2, -12.3)	0.2817
Open	16.8 (43.6)	(5.1, 28.5)	-13.7 (36.8)	(-28.3, 0.8)	-18.8 (34.4)	(-39.6, 2)	0.0079*
No	19.3 (33.6)	(10.3, 28.3)	6.8 (16.6)	(0.2, 13.4)	0.9 (18.5)	(-10.3, 12.1)	0.1293

*The change for no extraction was significantly different for no extraction as compared to 4 premolars and U4s (adjusted p-value < 0.05; None vs 4 Premolars, p-value = 0.0045; None vs U4s, p-value = 0.0086; 4 Premolars vs U4s, p-value = 0.648)

Figure 14: *Error bar plot of Post-Pretreatment changes (amount) between extraction types (none, extraction of 4 premolars, extraction of maxillary premolars only) (non-extraction=56 subjects, 4 premolars=27 subjects and maxillary premolars=13)*



When looking at the sum of the overall tight + near + approximating contacts and the sum of the open+ no contacts for the post-pretreatment change there were also some statistically significant differences. Subjects who received extractions of maxillary premolars only had a mean decrease in contact amount of 52.3, those who underwent extractions of four premolars had a decrease of 61.6 and those who received non extraction treatment had a decrease of 42.5 units. The differences in amount decrease between these groups were non-significant. When looking at the pre-post treatment change of open + no contacts, subjects who received non extraction treatment had a mean increase in open + no contacts of 36.1, which had a statistically significant difference from patients who had 4 premolars or U4s extracted only, as these subjects actually had a mean decrease in open and no contacts (-7.0 and -17.9 respectively, p=0.003). Refer to Table 24 in Appendix

3.5.9 Influence of extractions and Angle Malocclusion in changes in Occlusal contact from Orthodontic treatment

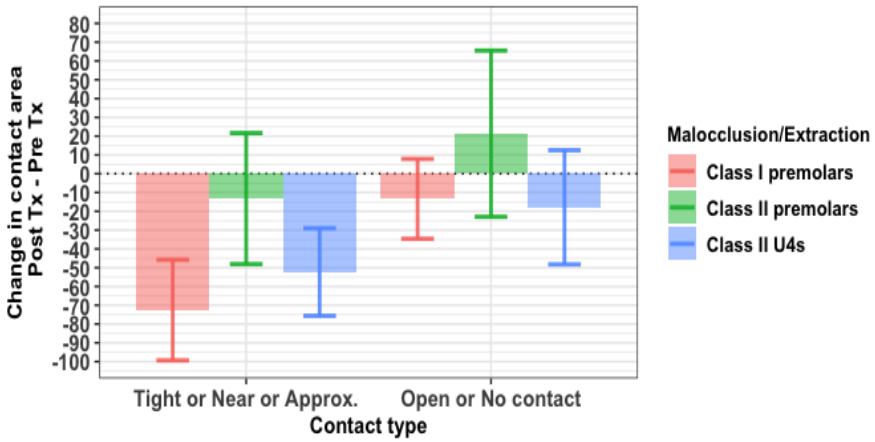
When analyzing areas of tight, near and approximating contacts together, patients who started with a Class I malocclusion and underwent extractions of 4 premolars had a mean decrease of 72.6 units of the sum of these ranges. Patients with an initial Class II malocclusion who also underwent extractions of 4 premolars only had a decrease of 13.2 of the sum of the tight, near and approximating contacts. Patients with a Class II malocclusion that underwent

extractions of maxillary premolars only, had a decrease of 52.3 of the sum of the above mentioned contact ranges. Refer to table 16 and Figure 15.

Table 16: *Summary of any difference for Post-Pretreatment change (amount) of total contacts between extraction types (none, extraction of 4 premolars, extraction of maxillary premolars only), MANOVA p-value = 0.1609*

	Class I, Extraction of 4 Premolars		Class II, Extraction of 4 Premolars		Class II, Extraction of maxillary premolars only (U4s)		
Contact	Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI	Adj. P-value
Tight, Near or Approx.	-72.6 (60.4)	(-99.4, -45.8)	-13.2 (28.1)	(-48.1, 21.7)	-52.3 (38.6)	(-75.6, -29)	0.0326
Open or No	-13.4 (48.0)	(-34.6, 7.9)	21.3 (35.6)	(-22.9, 65.6)	-17.9 (50.3)	(-48.3, 12.5)	0.3588

Figure 15: *Error bar plot of Post-Pretreatment changes (amount) of total contacts between extraction types (none, extraction of 4 premolars, extraction of maxillary premolars only)*



3.6 Post-treatment differences in Occlusal contact between the groups

3.6.1 T2 Differences in overall, anterior and posterior occlusal contact due to gender

There were no significant differences in the post-treatment overall contacts due to gender (p=>0.15). However, there was a statistically significant difference in anterior contacts in the ranges of near and approximating contacts due to gender. Males had a greater mean amount of near and approximating contacts at T2 (8.5 and 14.7, respectively) than females (5.3 and 10.6) (p=0.0049 for near contacts and p=0.013 for approximating contacts). There was a statistically significant difference in the percentage of anterior contact for the near and approximating contact in the anterior segment between females and males. For the near

contact area, this comprised 6.8% of the anterior contacts for females, while it corresponded a greater amount of 10.6% for males (p=0.0005). For areas of approximating contacts, males also had a greater percentage of contact in this range with 18.1%, compared to 14.2% for females (p=0.0054), There were no statistically significant differences in the posterior contact amount due to gender (p=>0.4). There were no statistically significant differences in posterior contact percentage due to gender (p=1).

3.6.2 T2 Differences in overall, anterior and posterior occlusal contact due to age

No significant differences in overall, anterior or posterior contacts due to age, were found (p=>0.8). There were no statistically significant differences in contact percentage for overall, anterior or posterior contacts due to age (p=1)

3.6.3 T2 Differences in overall, anterior and posterior occlusal contact due to initial Angle classification of malocclusion

There was a significant difference in T2 overall contacts in the open contact range due to initial Angle classification of malocclusion, with patients with Class I malocclusion finishing with a mean of 204.5 units of contact, while patients with Class II malocclusions had a mean of 183.3 (p=0.0425). There was no statistically significant difference of anterior contacts due to Angle malocclusion (p=>0.3). There was a no statically significant difference in posterior contacts between subjects with Class I and Class II occlusions. There were no statistically significant differences in overall, anterior or posterior T2 contact percentage due to Angle classification (p=>0.3). When looking at the sum of the areas of tight, near and approximating contact it is clear that patient with a Class I malocclusion had a greater amount of T1 contacts than patients with a Class II malocclusion (p=0.0044). Patients with a Class I malocclusion had a greater decrease in tight near and approximating contacts than their Class II counterparts (-54.0 units for Class I and -28.3 units for Class II, p=0.01). Therefore, it is unsurprising that there was no statistically significant difference in the T2 amount of tight + near + approximating contact for the Class I and Class II subjects. There were no statistically significant differences in the T1, T2, or T2-T1 change in percentage. Refer to Table 17 and 18 for a full summary.

Table 17: *Pre-treatment, post-treatment and post-pretreatment differences in amount of occlusal contacts between the Class I and Class II subjects in the tight +near+ approximating range and the open+ no contact range.*

	Pre-Tx			Post-Tx			Post-Pre Tx		
	Class I	Class II		Class I	Class II		Class I	Class II	
Contact	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Adj. P-value
Tight/Near/Approx.	156.2 (54.6)	125.9 (39.7)	0.0044	102.2 (37.0)	97.6 (39.0)	1	-54.0 (50.6)	-28.3 (37.4)	0.0106
Open/No contact	255.5 (47.9)	217.5 (50.9)	0.0009	264.4 (61.4)	236.5 (47.6)	0.0285	8.8 (58.7)	18.9 (54.7)	0.7831

Table 18: *Pre-treatment, post-treatment and post-pretreatment differences in percent of occlusal contacts between the Class I and Class II subjects in the tight +near+ approximating range and the open+ no contact range.*

	Pre-Tx			Post-Tx			Post-Pre Tx		
	Class I	Class II		Class I	Class II		Class I	Class II	
Contact	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Adj. P-value
Tight/Near/Approx.	30.2 (12.3)	28.5 (14.1)	1	25.6 (10.8)	26.3 (11.2)	1	-4.6 (14.8)	-2.2 (15.3)	0.8786
Open/No contact	69.8 (12.3)	71.5 (14.1)	1	74.4 (10.8)	73.7 (11.2)	1	4.6 (14.8)	2.2 (15.3)	0.8786

3.6.4 T2 Differences in overall, anterior and posterior occlusal contact due to initial overbite

There were no significant differences in overall contacts due to initial overbite (p=1). There were no statistically significant differences in T2 anterior or posterior contact due to initial overbite (p=1). There were no statistically significant differences in overall, anterior or posterior T2 contact percentage due to initial overbite (p=>0.27).

3.6.5 T2 Differences in initial overall, anterior and posterior occlusal contact in patients with different extraction patterns

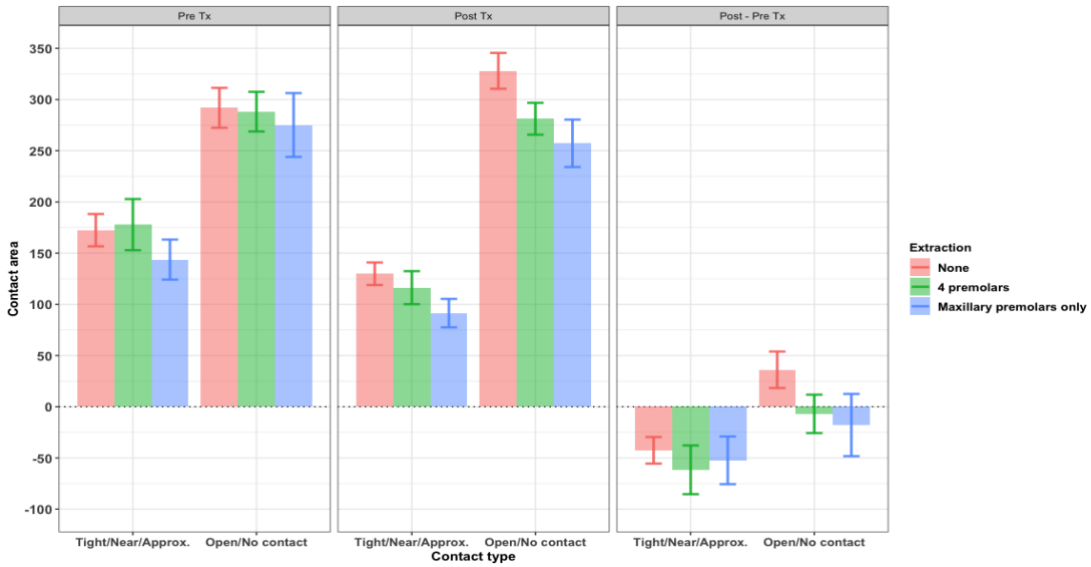
There was a significant difference in T2 *overall* contacts in the near, approximating, open and no contact ranges due to different extraction patterns. In the area of near contact, subject who underwent extraction of Maxillary premolars only (U4s) had a mean posttreatment amount of 31.6 units, which was significantly less than patients who underwent extractions of 4 premolars or had non-extraction treatments (41.8 and 44.1, respectively, p=0.0057).

There was a statistically significant difference in approximating contacts between patients who underwent extractions of U4s and those that received non-extraction treatment, where U4s extraction subjects had a mean amount of 56.2, while non-extraction had a T2 mean amount of 80.1 (p=0.0011). With regards to open contact, there was a statistically significant difference between patients who had non extraction, 4 premolar extraction and U4 extraction (p=0.0001). There was a statistically significant difference in T2 areas of no contact between subject that had non-extraction treatment (mean of 117.6 units) , and those that had 4 premolar and U4 premolar extractions (98.5 and 94.6 respectively, p=0.0343). When looking at the sum of areas of tight + near+ approximating contacts, there was also a significant difference in post treatment occlusal contacts between these groups. Subjects who underwent extractions of maxillary premolars only had the smallest amount of posttreatment tight+ near+ approximating contacts (91.4) and this amount was significantly different than that of subjects who had non extraction (129.9) or 4 premolar extraction (116.3) treatment (p=0.0005). Subjects who had non-extraction treatment also had a statistically significant greater amount of T2 open + no contact than those who had 4 premolars or upper premolars extracted. Refer to table 19 and Figure 16

Table 19: *Summary of any difference between, pretreatment, posttreatment and Post-Pre treatment change (amount) of tight+ near +approximating contacts and open+ no contacts between extraction types (none, extraction of 4 premolars, extraction of maxillary premolars only)*

	Pre-Tx				Post-Tx				Post-Pre Tx			
	None	Premolars	U4s		None	Premolars	U4s		None	Premolars	U4s	
Contact	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value
Tight/Near/Approx.	172.4 (58.9)	177.9 (63.1)	143.7 (32.4)	0.0662	129.9 (41.1)	116.3 (40.8)	91.4 (23.0)	0.0005	-42.5 (48.4)	-61.6 (60.2)	-52.3 (38.6)	0.689
Open/No contact	291.9 (72.8)	288.2 (48.9)	275.1 (51.6)	1	328.0 (65.3)	281.2 (39.3)	257.3 (38.3)	<0.0001	36.1 (66.5)	-7.0 (47.3)	-17.9 (50.3)	0.003

Figure 16: *Error bar plot of Post-Pretreatment changes (amount) between extraction types (none, extraction of 4 premolars, extraction of maxillary premolars only) (non-extraction=56 subjects, 4 premolars=27 subjects and maxillary premolars=13)*

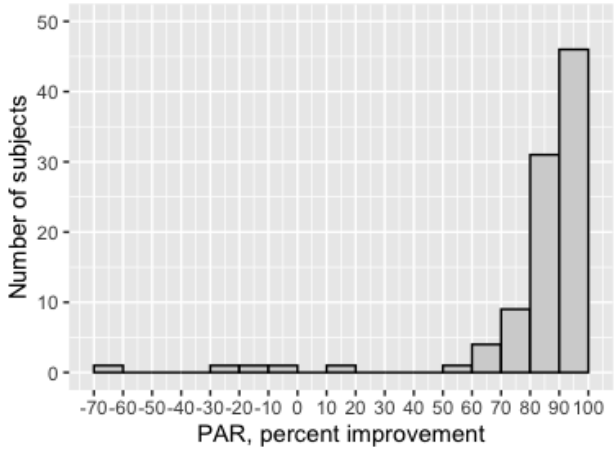


When looking at the role of extractions in differences in contacts in the anterior segment, a statically significant difference existed in T2 anterior contacts between the U4s extraction group, the 4 premolars and the non-extraction group for approximating and open contacts. Subject who underwent U4s extraction had a T2 mean amount of 7.4 units of approximating contact while those with extractions of 4 premolars and no extractions had a T2 mean of 12.3 and 13.9, respectively (p=0.0119). However, subjects who had extractions of U4s also had a smaller amount of open contact with a T2 mean of 24.6, compared to a mean of 35.9 from the 4 premolar extraction group and the non-extraction group (p=0.028). The extraction pattern also had a statically significant impact in amount of posterior contact for the approximating, open and no-contact ranges. Where subjects who had extractions of U4s had a smaller mean amount of T2 approximating contacts than those who had non extraction treatments (48.8 and 66.2, respectively, p=0.027). Yet, those who had non extraction treatment also had a greater amount of open and no contacts than those who underwent extractions of 4 premolars and U4s (p=0.0002 for open contacts and p=0.0127 for no contact range). There were no statistically significant differences in T2 contact percentage in the overall, anterior or posterior segments for any of the ranges due to extraction pattern (p=>0.18). Refer to table 25-27 in the appendix for full summaries.

3.7 Correlation between change in the occlusal contacts and PAR scores

The vast majority (94%) of the subjects in this study had a 60% or greater improvement in their PAR score. With 47 subjects having an improvement between 90-100%. There was 1 subject who had no change in PAR score and 3 subjects worsened following treatment. Refer to Figure 15.

Figure 17: *subjects from study and their respective PAR percent improvement*



A greater improvement in PAR score was correlated to a greater decrease in the percentage of Near contacts for the overall occlusal area (p=0.0277) and a greater improvement in the PAR score was also correlated to a greater increase in areas of Open contact (p=0.021). In the anterior segment, a greater improvement in the PAR score was correlated to an increase in areas of open and no contact (p=0.018 and p=0.02, respectively). In the posterior segment there were statistically significant correlations between the percentage of PAR score improvement and the decrease in near contacts and increase in open contacts (p=0.054 and p=0.0516, respectively). Refer to tables 29-31 in the appendix for full summaries.

4. DISCUSSION

4.1 Were there pretreatment differences between the groups?

Previous studies have reported that occlusal contact area is greater in male patients than in female patients (Yoon et al., 2010). In this study we found that there were no statistically significant differences in the contact ranges in the overall or posterior segments due to gender. However, we did find that males had a greater amount of pretreatment anterior approximating contacts than females. While previous research (Toro et al., 2005) found a relationship between greater age with an increased number of occlusal contacts, this study found no pretreatment differences in contact amount or percentage due to age. However, as the adult group included only 9 patients, it is possible that the adult group was too underpowered to detect a difference. With regards to initial differences due to Angle classification of malocclusion, subjects with Class I malocclusion had a greater amount of approximating and open contacts than subjects with Class II malocclusion. When looking at the sum of the tight, near and approximating contacts and the open and no contacts, the Class I subjects had a greater amount of contact in these ranges than the Class II subjects. This is in agreement with previous studies, as in 2002 Owens et al. found that subjects with Class I malocclusions had greater areas of contact and near contact than subjects with Class II malocclusions.

This study also analyzed pretreatment differences in overall, anterior and posterior contacts due to initial overbite. To the best of our knowledge no other studies have examined the effect of overbite on change in occlusal contacts through orthodontic treatment. We found that subjects with a deep bite at T1 had the greatest amount of anterior tight, near and approximating contacts while patients with an anterior open bite had the least amount. With

regards to the T1 occlusal contacts amongst patients who would receive different extraction treatments, in this study subjects who would later receive extractions of maxillary first premolars had the least amounts of tight contacts in the overall and posterior segments when compared to those who received non-extraction and 4 premolar extraction treatments. This is in contrast to the study conducted by Yoon et al in 2017, where they found no pretreatment differences amongst subjects who would later receive non-extraction, 4 premolar extraction or maxillary premolar extraction only. This difference may be attributed to differences in the methods of detecting areas of contact. In the study conducted by Yoon and collaborators a Dental Prescale system was used, which is stated to have a thickness of 97 micrometers and can prevent the recording of areas of actual contact (<50 micrometers) and near contact (50-350 micrometers).

4.2 Does orthodontic treatment change the occlusal contacts?

This study found that areas of tight contact reduced by approximately half of their pretreatment value, areas of near contact decreased by about a third of their pretreatment value and areas of approximating contact decreased, on average, 14% from their T1 value. This is consistent with previous studies who found that after orthodontic treatment, areas of occlusal contact reduce by approximately half of their pretreatment values (Yoon et al., 2017) (Lee et al.,2015). This study also examined changes in the interocclusal space and found that areas of open contact increase by 9% and areas of no contact increased by 20%. In the anterior segment, areas of tight contact also reduced by about half of their pretreatment value, areas of near contact reduced by about a quarter and areas of approximating contact reduced by only about 1%. Areas of approximating contact in the anterior region were, on average, the least reduced by orthodontic treatment, a possible

explanation for the little reduction in the areas of approximating contact is that in achieving acceptable overbite and overjet through orthodontic treatment, a distance of less than or equal to half a millimeter between the maxillary and mandibular anterior teeth must be maintained. With regards to changes in interocclusal space in the anterior segment, Areas of open contact increased by 12.4% of their pretreatment value, while areas of no contact had a small increase of 6.46%. In the posterior segment, areas of tight contact reduced by 45.8% of their pretreatment values, areas of near contact reduced by 32.6% and areas of approximating contact reduced by 14.9%. Areas of open contact increased by 9.95% while areas of no contact increased by 21.9%.

4.3 **What is the effect of gender in changes in occlusal contact through orthodontic treatment?**

While previous studies have reported that occlusal contact area is greater in male patients than in female patients (Yoon et al., 2010), Toro et al. found no differences in occlusal contacts or occlusal function due to gender (Toro et al., 2005). This study only found pretreatment differences in the anterior approximating contact due to gender, where males had a greater T1 amount of contact in this category than females. There was no difference in the percent or amount change of occlusal contacts for any of the ranges in the overall, anterior or posterior segments due to gender. This agrees with the study by Toro and collaborators. However, although there were no differences in the amount or percent change from T1 to T2, this study did find differences in the post-treatment amount and percentage of approximating and near contacts between males and females. Males had a greater amount of anterior approximating and near contact than females.

4.4 What is the effect of age in changes of areas of occlusal contact through orthodontic treatment?

Toro et al. found that age and the associated increase in body size was related to increased masticatory efficiency and greater occlusal contacts in children and adolescents (Toro et al., 2005). In this study, while there may have been a difference due to age with adult patient having a greater reduction in the amount of near and approximating contact, this group was underpowered and thus there was no statistically significant difference between the two age groups.

4.5 What is the effect of initial Angle malocclusion in changes of occlusal contact through orthodontic treatment?

In 2002, Owens et al. found that subjects with Class I malocclusions had greater areas of contact and near contact than subjects with Class II malocclusions. This study confirms those findings, as Subjects with a Class I malocclusion had a greater amount of tight + near + approximating contacts and open + no contacts than Class II subjects. This study also found that subjects with a Class I malocclusion lose a greater amount of tight+ near+ approximating contacts than subjects with a Class II malocclusion. Therefore, there was no significant difference between the posttreatment tight + near +approximating contacts amounts between subjects who had a T1 Class I or Class II malocclusion. It is important to keep this amount difference in mind, since when looking at the percentage differences amongst the Class I and Class II malocclusion groups there appears to be no differences. As for both the Class I and Class II groups, the sum of the tight, near and approximating contacts comprise roughly 30% of the total contacts (Class I=30.2%, Class II=28.5%, p=1), yet the Class I subjects had a greater amount of total contact than the Class II subjects.

4.6 What is the effect of the initial overbite in changes of occlusal contact through orthodontic treatment?

While there were no overall or posterior T1, T2 or T1-T2 differences due to initial overbite, there was a significant difference in the change of anterior contact between subjects with T1 normal overbite, deep bite or anterior openbite. Subjects with a deepbite had an overall loss of anterior contacts, subjects with a normal overbite had a small decrease in areas of tight + near + approximating contact and an increase in open+ no contact. Subjects with an initial open bite actually gained a greater amount of tight + near + approximating contact and open + no contact. Karkastos et al. found that anterior contacts increased from 40-70% in subjects with an anterior open bite through orthodontic treatment (Karkastos et al., 1993). It is interesting to note that there were no statistically significant differences between the T2 anterior contacts of the different groups despite having started with a normal overbite, deep bite or an open bite (p=>0.9).

4.7 What are the effects of extractions in changes of occlusal contact through orthodontic treatment?

While there was no difference in the percent change between subjects who received non-extraction, 4 premolar extraction or maxillary premolar extraction only, there were differences for the changes of amount. Subjects who had non extraction treatment had an increase in the areas of open+ no contact, while subjects who had extractions of 4 premolars and maxillary premolars actually had a decrease in these contacts. It was very interesting to find that subjects who had a Class I malocclusion and underwent extractions of 4 premolars had the greatest amount decrease (-72.6) in tight +near+ approximating contacts, followed by subjects with a Class II malocclusion who had extractions of maxillary premolars (-52.3) while subjects with Class II malocclusions who underwent extractions of 4 premolars had

the least amount of decrease (-13.2) of these contacts. This finding is in contrast to those reported by Yoon et al, who found that patients treated with four premolar extractions will experience the greatest reduction of occlusal contact area, followed by those treated with extractions of two premolars (Yoon et al., 2017). On the other hand, Lee et al found that patients who commenced and finished treatment with Class I molar relations and underwent 4 premolar extractions had significantly greater contact areas than patients who began and finished orthodontic treatment with Class II molar relations and only received extractions of the maxillary first premolars (Lee et al., 2014). This study supports the findings of Lee at al. as we found that subjects that had extractions of maxillary premolars only had the smallest amount of post treatment tight+ near+ approximating contact which was significantly less than that of subjects who had non-extraction or 4 premolars extraction treatment. This study also found that subjects in the U4s extraction group had the least amount of T2 approximating contacts of the three groups.

4.8 What is the relation between PAR improvement and changes in occlusal contact?

This study found a negative correlation between percent of PAR improvement and decrease in areas of near contact. While there was a positive correlation between the percentage of PAR improvement and the increase of open contacts. This has led the author to believe that while correlations exist between contact change and change of PAR score, the PAR improvement may not be the best tool at predicting change in the occlusal contacts.

5. LIMITATIONS AND STRENGTHS

Post treatment increase in occlusal contact area due to settling was not be taken into account. Furthermore, as this was a retrospective study, there was no means to detect technical error of bite registrations. As PAR scores were collected from the clinic's archives and were done by the residents who treated each patient, there is no data regarding reliability for these scores. Furthermore, as orthodontic treatment was performed by Graduate Orthodontic residents the results may not be as satisfactory as those of more experienced practitioners. Although patients with TMJ disorder often display hindered occlusal function and a reduction of functional occlusal contact areas may exist, these patients were not identified or excluded from the present study. Another limitation of this study is that the GOM inspect software uses a mathematical model and an arbitrary unit to measure total surface area in amount, therefore its correlation to a clinical measurement is presently unknown. However, this software allowed us to analyze changes in percentage of different ranges and allowed us to compare changes in amount between different groups. Future studies could explore how the area obtained by GOM software compares to actual clinical measurements. Future studies exploring the use of clear aligners and their effect on occlusal contacts would also be of value.

A strength of this study is that it included a large sample size of consecutively treated patients. This study also explores the effect of extractions on different classifications of Angle malocclusions, which has not been explored in earlier studies. This study also analyzes initial and final 3D scans of teeth taken from an iTero scanner, which is a widely used method of obtaining orthodontic records.

6. CONCLUSIONS

- There were no pretreatment differences in overall or posterior occlusal contact due to gender. However, males have greater pretreatment contact amount in some ranges of the anterior segment. This study could not demonstrate a difference in overall, anterior or posterior contacts due to age.

- Subjects with Class II malocclusion had a smaller pretreatment amount of tight+ near+ approximating contact as well as of open + no contact than those with Class I malocclusion.
- Subjects with an initial deep bite have the greatest amount of anterior contact while those with an anterior open bite have the least.
- Subjects who would later have extractions of upper first bicuspids had the least amount of pretreatment tight contact.
- Males had a greater amount of posttreatment approximating and near contact in the anterior segment than females.
- No statistically significant posttreatment differences in occlusal contact due to age could be found.
- There is no significant difference in the amount of posttreatment tight + near + approximating contact between subjects who had initial Class I and Class II malocclusions.
- There were no significant posttreatment differences in anterior contact between those who initially had a normal overbite, a deep bite or an anterior open bite.
- Subjects who underwent extractions of Maxillary first premolars had the least amount of posttreatment near and approximating contact and the least amount of tight + near + approximating contact. Subjects who had non-extraction treatment had a greater amount of post treatment open + no contact than those who underwent extractions.
- Subjects who undergo extractions of maxillary 4 premolars only have the least amount of posttreatment overall and posterior contacts, when compared to those who undergo non extraction treatment and extractions of 4 premolars. Subjects who have a Class II malocclusion and undergo extraction of 4 premolars have the least amount of decrease in the tight + near + approximating contact range.
- Orthodontic treatment causes a mean decrease in areas of tight, near and approximating contact while it increases areas of open and no contact.
- Age and gender do not influence changes in pre to posttreatment occlusal contact from orthodontic treatment.
- Subjects with an initial Class I malocclusion have a greater decrease in near contacts than Class II subjects through orthodontic treatment. Subjects with an initial Class I

malocclusion also have a greater decrease of the tight + near + approximating contact than subjects with an initial Class II malocclusion.

- Subjects with a deep bite had the greatest amount of contact loss of the tight + near + approximating contacts, subjects with an open bite gained contact.
- There was no significant difference between the amount of decrease of occlusal contacts in the non-extraction, U4 extraction or 4 premolar extraction groups.

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8. APPENDIX

Figure 18: These two figures demonstrate how areas of tighter contact appear in the green spectrum, while areas of open and no contact or greater interocclusal space appear in dark blue.

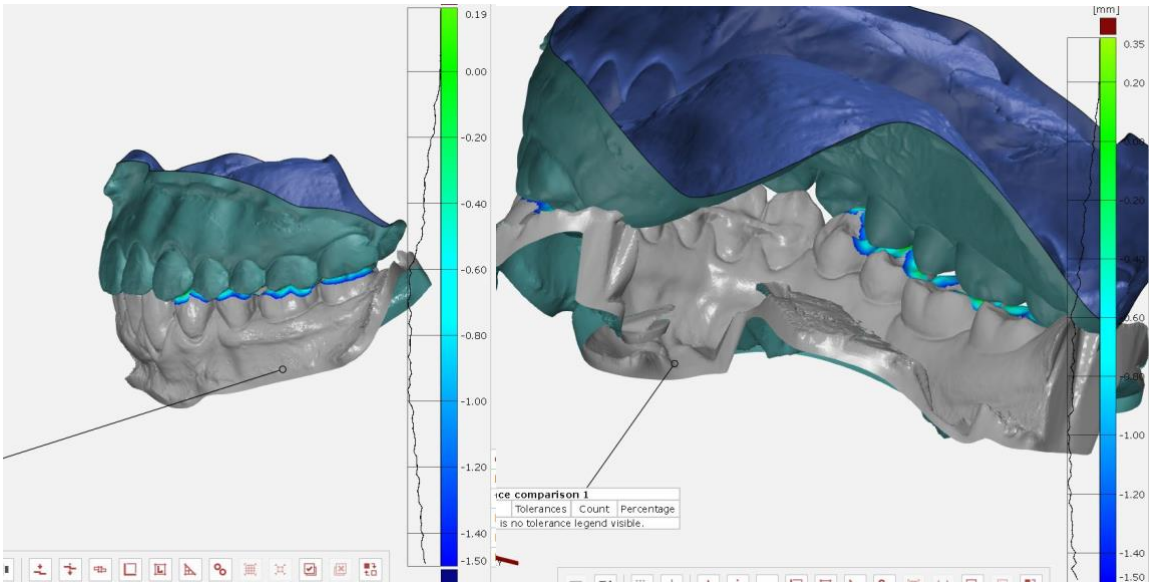


Table 20: pretreatment differences in occlusal contact due to gender

	Pre-Tx			Post-Tx			Post-Pre Tx		
	Female	Male		Female	Male		Female	Male	
Contact	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Adj. P-value
Tight	12.3 (12.1)	10.4 (7.8)	1	5.3 (4.8)	5.6 (4.3)	1	-7.0 (11.4)	-4.8 (7.8)	1
Near	67.4 (29.7)	66.4 (26.9)	1	41.3 (17.9)	42.2 (15.2)	1	-26.1 (27.8)	-24.2 (23.6)	1
Aprox.	90.6 (26.6)	93.0 (26.5)	1	71.5 (25.0)	75.9 (22.3)	1	-19.1 (26.5)	-17.0 (23.8)	1
Open	187.3 (40.0)	198.7 (46.3)	1	187.7 (33.5)	205.3 (44.2)	0.1588	0.4 (42.0)	6.6 (45.0)	1
No contact	95.1 (23.8)	96.6 (33.6)	1	106.0 (28.8)	112.5 (38.0)	1	10.9 (22.8)	15.9 (34.1)	1

Table 21: pretreatment differences in anterior contact due to Age.

	Pre-Tx			Post-Tx			Post-Pre Tx		
	11-18	19-25		11-18	19-25		11-18	19-25	
Contact	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Adj. P-value
Tight	10.6 (9.2)	19.0 (16.3)	0.8169	5.5 (4.7)	5.1 (3.0)	1	-5.1 (8.9)	-14.0 (14.7)	0.5541
Near	64.6 (26.8)	89.2 (33.7)	0.313	40.9 (16.0)	50.2 (20.5)	1	-23.7 (25.4)	-39.0 (27.1)	0.6872
Aprox.	90.6 (26.2)	103.1 (27.1)	1	72.1 (22.0)	88.0 (34.8)	1	-18.4 (25.7)	-15.1 (20.0)	1

Open	192.0 (43.6)	199.9 (41.3)	1	195.3 (40.4)	204.2 (33.7)	1	3.3 (43.3)	4.3 (45.7)	1
No contact	94.4 (28.4)	110.2 (30.4)	0.8299	108.2 (33.3)	118.1 (36.6)	1	13.8 (29.0)	7.9 (26.9)	1

Table 22: Pre-treatment, post-treatment and post-pretreatment differences in amount anterior contact in patients with initial differences in anterior Vertical malocclusion

	Pre-Tx				Post-Tx				Post-Pre Tx			
	Normal	Deep bite	Open bite		Normal	Deep bite	Open bite		Normal	Deep bite	Open bite	
Contact	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value
Tight	1.0 (1.4)	3.2 (3.3)	0.4 (1.0)	3e-04	0.6 (0.7)	1.2 (1.7)	1.2 (1.6)	0.3999	-0.4 (1.5)	-2.0 (3.8)	0.8 (1.5)	0.0054
Near	7.7 (6.9)	15.0 (8.0)	2.7 (3.8)	<.0001	5.9 (3.2)	7.7 (5.4)	7.4 (6.8)	0.912	-1.8 (6.4)	-7.3 (8.2)	4.7 (5.1)	<.0001
Aprox.	11.9 (9.2)	19.4 (7.9)	4.5 (6.0)	<.0001	12.3 (6.0)	13.0 (7.1)	12.2 (7.8)	1	0.5 (8.8)	-6.4 (7.6)	7.7 (6.7)	<.0001
Open	30.0 (17.9)	40.9 (12.4)	11.6 (13.9)	<.0001	34.4 (11.3)	34.2 (12.5)	34.8 (16.7)	1	4.5 (19.5)	-6.7 (13.8)	23.2 (18.0)	<.0001
No contact	15.8 (6.0)	23.2 (8.1)	8.3 (7.7)	<.0001	18.8 (6.0)	19.4 (9.9)	23.0 (15.0)	1	3.0 (7.8)	-3.8 (9.7)	14.7 (14.9)	7e-04

Table 23:Pre-treatment, post-treatment and post-pretreatment differences in percentage of anterior contact in patients with initial differences in anterior Vertical malocclusion

	Pre-Tx				Post-Tx				Post-Pre Tx			
	Normal	Depp bite	Open bite		Normal	Depp bite	Open bite		Normal	Depp bite	Open bite	
Contact	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value
Tight	1.6 (2.4)	3.1 (3.0)	1.0 (1.8)	0.0465	0.8 (0.9)	1.4 (1.8)	1.3 (1.6)	0.5333	-0.8 (2.5)	-1.6 (3.8)	0.3 (2.0)	0.3444
Near	10.0 (6.1)	14.2 (5.0)	6.5 (7.3)	0.0025	7.9 (3.3)	9.6 (5.9)	8.3 (6.2)	1	-2.1 (6.4)	-4.5 (7.1)	1.8 (9.0)	0.2747
Aprox.	16.1 (6.7)	18.6 (3.6)	10.3 (8.6)	0.0098	16.5 (4.7)	16.3 (6.7)	14.2 (7.3)	1	0.4 (7.5)	-2.4 (6.5)	4.0 (9.8)	0.2453
Open	44.7 (7.6)	40.7 (5.5)	31.1 (20.7)	0.0447	47.7 (5.0)	45.2 (6.8)	44.3 (5.2)	0.2753	3.0 (9.3)	4.5 (9.2)	13.2 (21.4)	1
No contact	27.7 (10.6)	23.4 (5.7)	29.7 (26.3)	0.3691	27.1 (7.5)	27.4 (11.7)	31.9 (12.3)	1	-0.6 (11.1)	4.0 (9.7)	2.2 (27.0)	0.7743

Table 24: Pre-treatment, post-treatment and post-pretreatment differences in amount of overall contact in patients who underwent different extraction patterns (none, 4 premolars, maxillary premolars(U4s)) in Tight+ Near + Approximating and Open+No contact

	Pre-Tx				Post-Tx				Post-Pre Tx			

	None	4 Premolars	U4s		None	4 Premolars	U4s		None	4 Premolars	U4s	
Contact	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value
Tight/Near/Approx.	172.4 (58.9)	177.9 (63.1)	143.7 (32.4)	0.0662	129.9 (41.1)	116.3 (40.8)	91.4 (23.0)	0.0005	-42.5 (48.4)	-61.6 (60.2)	-52.3 (38.6)	0.689
Open/No contact	291.9 (72.8)	288.2 (48.9)	275.1 (51.6)	1	328.0 (65.3)	281.2 (39.3)	257.3 (38.3)	<0.0001	36.1 (66.5)	-7.0 (47.3)	-17.9 (50.3)	0.003

Table 25: Pre-treatment, post-treatment and post-pretreatment differences in amount of overall contact in patients who underwent different extraction patterns (none, 4 premolars, maxillary premolars(U4s))

	Pre-Tx				Post-Tx				Post-Pre Tx			
	None	Premolars	U4s		None	Premolars	U4s		None	Premolars	U4s	
Contact	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value
Tight	11.5 (9.8)	13.7 (12.6)	6.2 (3.0)	0.0032	5.7 (4.8)	5.9 (4.7)	3.5 (2.3)	0.1877	-5.8 (8.8)	-7.8 (13.1)	-2.6 (4.3)	0.4163
Near	68.1 (28.6)	70.7 (31.4)	54.0 (14.3)	0.107	44.1 (16.5)	41.8 (18.4)	31.6 (8.3)	0.0057	-24.0 (26.1)	-28.9 (29.4)	-22.4 (14.6)	1
Aprox.	92.8 (27.7)	93.5 (26.4)	83.5 (20.2)	1	80.1 (24.3)	68.6 (21.1)	56.2 (14.5)	0.0011	-12.7 (24.3)	-24.8 (25.0)	-27.3 (24.7)	0.2817
Open	193.6 (48.1)	196.5 (37.5)	181.3 (31.7)	1	210.4 (40.3)	182.7 (29.3)	162.5 (25.0)	0.0001	16.8 (43.6)	-13.7 (36.8)	-18.8 (34.4)	0.0079
No contact	98.3 (33.6)	91.7 (16.5)	93.9 (26.9)	1	117.6 (38.6)	98.5 (19.8)	94.8 (20.3)	0.0343	19.3 (33.6)	6.8 (16.6)	0.9 (18.5)	0.1293

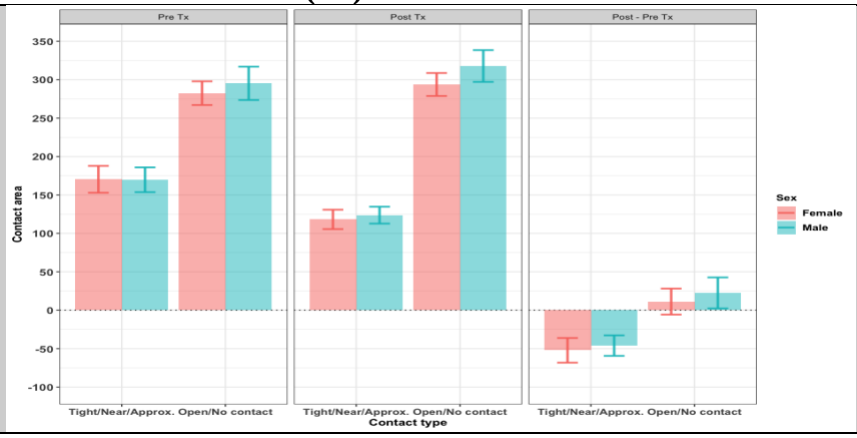
Table 26: Pre-treatment, post-treatment and post-pretreatment differences in amount of anterior contact in patients who underwent different extraction patterns (none, 4 premolars, maxillary premolars(U4s))

	Pre-Tx				Post-Tx				Post-Pre Tx			
	None	Premolars	U4s		None	Premolars	U4s		None	Premolars	U4s	
Contact	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value
Tight	2.4 (3.1)	1.0 (1.3)	1.1 (1.5)	0.1275	1.0 (1.5)	1.0 (1.2)	0.7 (1.1)	1	-1.4 (3.3)	0.0 (1.8)	-0.4 (2.1)	0.2839
Near	11.6 (8.9)	7.9 (7.0)	6.7 (6.1)	0.2066	7.5 (4.8)	6.6 (4.9)	4.4 (4.5)	0.4791	-4.1 (8.7)	-1.3 (6.9)	-2.4 (7.4)	1
Aprox.	15.9 (10.6)	11.9 (7.9)	9.1 (6.9)	0.1006	13.9 (6.8)	12.3 (6.1)	7.4 (5.2)	0.0119	-2.0 (10.6)	0.4 (7.1)	-1.7 (7.5)	1
Open	34.6 (18.2)	27.0 (14.1)	29.2 (23.2)	0.6494	35.9 (12.5)	35.9 (11.8)	24.6 (10.5)	0.028	1.3 (19.9)	9.0 (17.2)	-4.6 (21.3)	0.466
No contact	19.7 (9.5)	15.3 (5.5)	14.2 (9.2)	0.1395	20.2 (11.3)	19.8 (5.9)	17.0 (5.7)	1	0.5 (13.6)	4.5 (7.2)	2.9 (8.4)	1

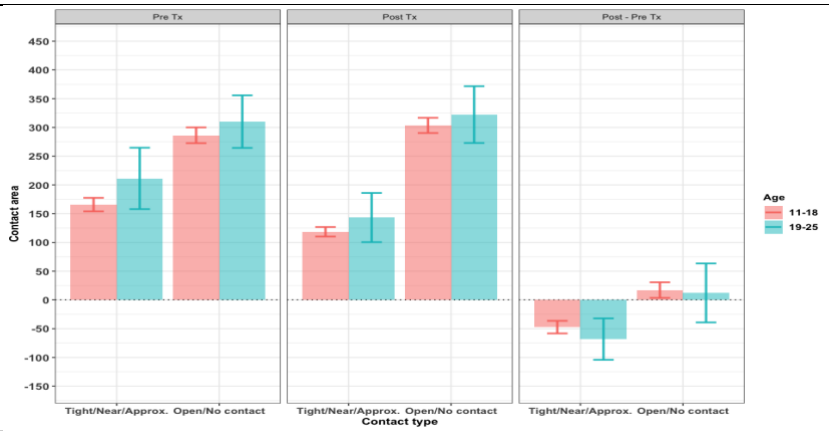
Table 27: Pre-treatment, post-treatment and post-pretreatment differences in amount of posterior contact in patients who underwent different extraction patterns (none, 4 premolars, maxillary premolars(U4s))

	Pre-Tx				Post-Tx				Post-Pre Tx			
	None	Premolars	U4s		None	Premolars	U4s		None	Premolars	U4s	
Contact	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value	Mean (SD)	Mean (SD)	Mean (SD)	Adj. P-value
Tight	9.1 (8.4)	12.6 (12.4)	5.0 (3.4)	0.017	4.7 (4.6)	4.9 (4.2)	2.9 (2.0)	0.2067	-4.3 (8.0)	-7.7 (13.1)	-2.2 (4.0)	0.5523
Near	56.5 (25.8)	62.1 (28.6)	47.1 (14.1)	0.3534	36.2 (16.0)	35.2 (16.9)	27.3 (9.1)	0.1462	-20.2 (23.9)	-26.9 (27.7)	-19.8 (14.5)	1
Aprox.	77.0 (24.7)	81.4 (21.6)	74.3 (15.5)	1	66.2 (22.7)	56.4 (19.2)	48.8 (14.7)	0.027	-10.8 (22.0)	-25.0 (22.0)	-25.4 (20.3)	0.0631
Open	157.9 (41.0)	168.9 (30.6)	158.0 (26.4)	1	177.4 (42.4)	147.0 (26.6)	138.0 (20.9)	0.0002	19.5 (47.3)	-21.9 (31.4)	-20.0 (27.2)	0.0002
No contact	81.2 (27.7)	75.7 (14.0)	80.0 (22.3)	1	97.8 (32.0)	79.0 (17.6)	78.1 (16.6)	0.0127	16.5 (18.0)	3.3 (15.9)	-1.9 (14.4)	0.0017

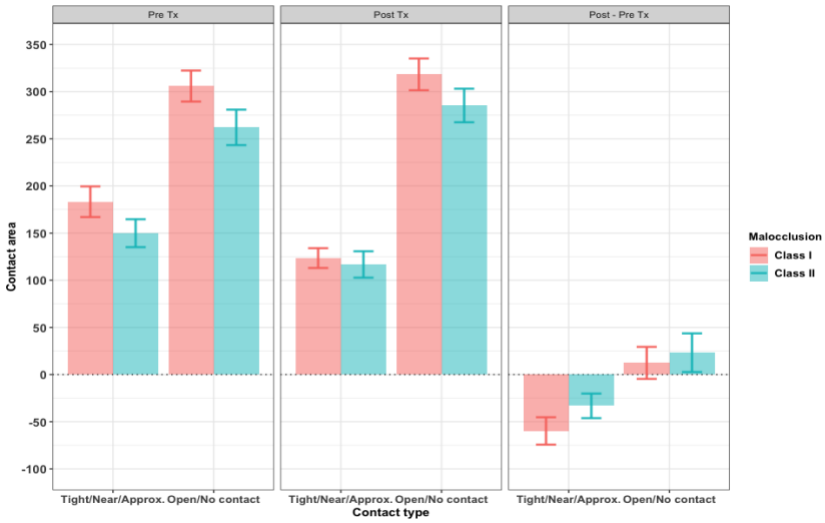
Table 28: Pre-treatment, post-treatment and post-pretreatment differences in AMOUNT of tight+near+approximating contacts and open+no contacts between various groups

	Pretreatment (T1)	Post-treatment (T2)	T2-T1 difference/change
Gender			

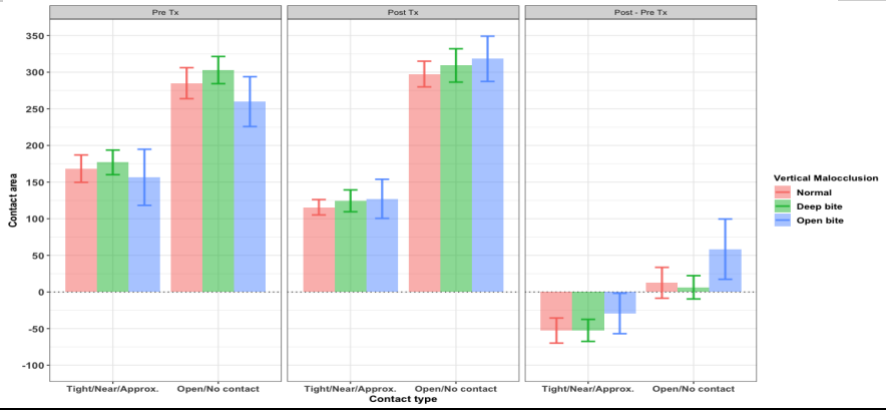
Age



Initial Angle malocclusion



Initial vertical malocclusion



Extractions

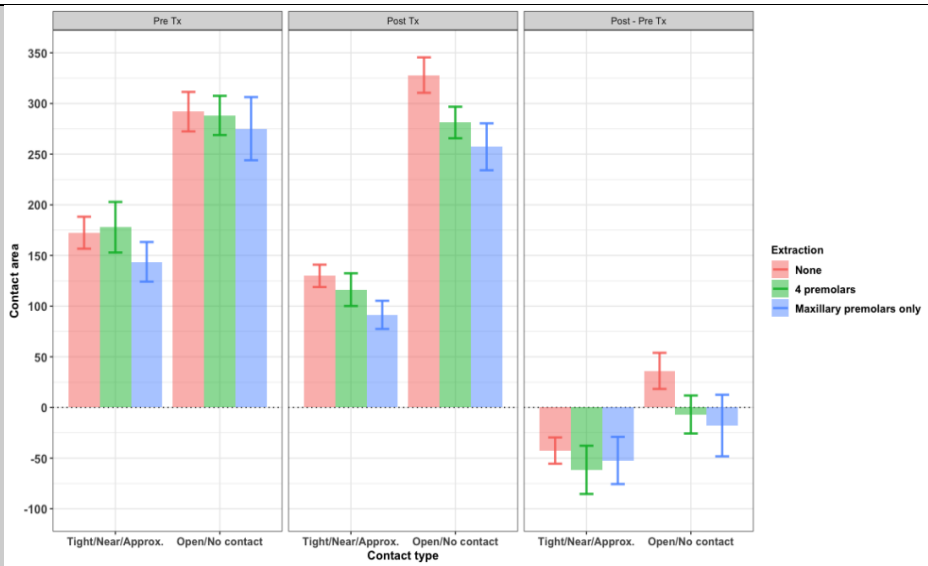


Table 29 Summary of any correlation between total contact change and percentage or PAR score improvement. Correlation = Spearman rank correlation coefficient, Lower and upper = 95% confidence interval for the spearman rank correlation coefficient, Lower and Upper= 95% confidence interval for the Spearman rank correlation coefficient

Contact	Correlation	Lower	Upper	P-value
Total	0.10	-0.10	0.29	0.3374
Tight	-0.09	-0.29	0.11	0.3632
Near	-0.17	-0.36	0.03	0.0935
Approx.	-0.02	-0.22	0.18	0.8288
Open	0.18	-0.02	0.37	0.0767
No	0.13	-0.07	0.32	0.208
Tight (%)	-0.08	-0.27	0.12	0.4500
Near (%)	-0.22	-0.41	-0.03	0.0277
Approx. (%)	-0.05	-0.25	0.15	0.6462
Open (%)	0.24	0.04	0.42	0.021
No (%)	-0.01	-0.21	0.20	0.9594

Table 30: Summary of any correlation between anterior contact change and percentage or PAR score improvement.

Contact	Correlation	Lower	Upper	P-value
Total	0.19	-0.01	0.38	0.0571
Tight	0.09	-0.11	0.28	0.3906
Near	0.06	-0.14	0.26	0.5534
Approx.	0.12	-0.09	0.31	0.2623
Open	0.24	0.04	0.42	0.0182
No	0.24	0.04	0.42	0.0207
Tight (%)	0.11	-0.10	0.30	0.3043
Near (%)	-0.03	-0.23	0.17	0.7561
Approx. (%)	-0.07	-0.26	0.14	0.5238
Open (%)	0.14	-0.06	0.33	0.1777
No (%)	-0.03	-0.23	0.17	0.7746

Table 31: Summary of any correlation between posterior contact change and percentage or PAR score improvement.

Contact	Correlation	Lower	Upper	P-value
Total #2	-0.01	-0.21	0.19	0.9225
Tight	-0.12	-0.31	0.09	0.2592
Near	-0.17	-0.36	0.03	0.0885
Approx.	-0.06	-0.26	0.14	0.5709
Open	0.09	-0.11	0.28	0.3927
No	0.03	-0.17	0.23	0.7557
Tight (%)	-0.11	-0.3	0.09	0.2866
Near (%)	-0.20	-0.38	0.00	0.0545
Approx. (%)	-0.06	-0.26	0.14	0.553
Open (%)	0.20	0.00	0.38	0.0516
No (%)	0.01	-0.19	0.21	0.8909