Evaluating Changes in the Inter-Occlusal Space During Orthodontic Retention Stage

Veronica M. Toro

A thesis

Submitted in partial fulfillment of the

Requirements for the degree of

Master of Science in Dentistry

University of Washington

2018

Reading Committee:

Anne-Marie Bollen, Chair

Burcu Bayirli

Roozbeh Khosravi

Mohammed Masoud

Program Authorized to Offer Degree:

Orthodontics

University of Washington

Abstract

Evaluating Changes in the Inter-Occlusal Space During Orthodontic Retention Stage

Veronica M. Toro

Chair of the Supervisor Committee:

Anne-Marie Bollen, Professor and Program Director

Department of Orthodontics

Introduction: The purpose of the study was to measure the post-treatment changes in the inter-occlusal space one month and three months after comprehensive orthodontic treatment: settling. 3D images acquired during retention were used. The effects of the patients' demographics and retention protocols on settling were analyzed. **Methods:** Consecutively finished orthodontic patients were invited to participate in the study. Intraoral scans were obtained at debond, 1-month and 3-months after debond. A 3D Software was used to evaluate the inter-occlusal changes between the upper and lower teeth in a range of distance of -0.6mm to 2mm. A heat map of the surface area was created. Two main categories and six subgroups of height distance were created. The dental arch was also divided into anterior and posterior segments. The changes in the Total Surface Area within Range, area for each category, anterior and posterior portions, the differences between occlusal coverage and no occlusal coverage retainers, age, and gender were compared at all time points. **Results:** 90 patients were enrolled in the study. The *Total Surface Area within Range* increased in the first month. The surface area of teeth in the -0.6mm to 0.25mm category stayed constant while the *0.25mm to 2mm* range also increased. Similar changes were seen from 1

month to 3 months, but were not statistically significant. The same pattern was observed for the anterior and posterior segments. The increase in occlusal contacts was found in the group of patients wearing retainers without occlusal coverage. In patients wearing retainers with occlusal coverage, the changes were not statistically significant. Gender did not show a correlation with inter-occlusal changes after orthodontic treatment. Adolescents showed a statistically significant increase in *Total Surface Area within Range* and *0.25mm to 2mm* category, while Adults did not. However, there is no statistically significant difference between them. **Conclusions:** During the first month after the removal of orthodontic appliances, patients show an increase in the total occlusal surface area. This increase is primarily from changes in the inter-occlusal space between teeth that have more than 0.25 mm distance between the upper and lower dentition. The contact surface area of teeth within the -*0.6mm to 0.25mm* range between the upper and lower teeth remains constant over the three-month period. Anterior and posterior teeth exhibit similar changes throughout the 3-month period. Retainers without occlusal coverage allow changes in the inter-occlusal contacts, while retainers with occlusal coverage do not. A bigger sample size is needed to confirm a relationship with age.

TABLE OF CONTENT

List of Figures……7

List of Tables……..8

Acknowledgment……..9

1. INTRODUCTION 10

2. MATERIALS AND METHODS 14

2.1. STUDY DESIGN 14

2.2. PARTICIPANTS, ELIGIBILITY CRITERIA, AND DATA COLLECTION 14

2.3. METHODS 14

2.3.1. Intra-oral Scans 14

2.3.2. Measurements on the scans 15

2.4. VERIFICATION OF MEASUREMENT ERROR AND TECHNICAL ERROR 16

2.4.1. Power Calculations 17

2.5. DATA ANALYSIS 17

3. RESULTS 18

3.1. SAMPLE POPULATION CHARACTERISTICS 18

3.1.1. Demographics and baseline data 19

3.2. VERIFICATION OF MEASUREMENT ERROR AND TECHNICAL ERROR 20

3.3. CONTACT SURFACE AREA INCREASES DURING THE EARLY STAGE OF ORTHODONTIC RETENTION. 21

3.3.1. Overall Total Surface Area within Range increases in the first month of retention. 21

3.3.2. The changes in the contact surface area happen in regions with a distance over 0.25mm..... 21

3.3.3. Total Surface Area within Range increases in both anterior and posterior segments during retention stage. 21

3.4. INFLUENCE OF GENDER AND AGE. 23

3.4.1. Gender did not influence the changes in Total Surface Area within Range during early retention stage. 23

3.4.2. Age did not influence the changes in Total Surface Area within Range during early retention stage, even though a trend was found. 23

3.5. THE TYPE OF RETAINER INFLUENCES THE CHANGES IN THE *TOTAL SURFACE AREA WITHIN RANGE* DURING THE EARLY RETENTION STAGE. 23

3.5.1. Occlusal coverage retainers prevent tooth movement during early stage of settling 23

3.5.2. Retainers influence the changes in the anterior and posterior teeth during retention stage 24

4. DISCUSSION 27

4.1. WHEN DOES SETTLING OCCUR? 27

4.2. WHERE DOES SETTLING OCCUR? 28

4.3. IS THERE A DIFFERENCE IN THE SETTLING PROCESS BETWEEN ANTERIOR AND POSTERIOR TEETH? 29

4.4. DOES THE RETAINER PROTOCOL INFLUENCE THE SETTLING PROCESS? 29

4.5. DOES RETAINER PROTOCOL INFLUENCE THE SETTLING PROCESS IN THE ANTERIOR AND POSTERIOR TEETH DIFFERENTLY? 30

4.6. DO PATIENTS' AGE AND GENDER AFFECT SETTLING? 30

4.7. LIMITATIONS 31

4.8. FUTURE STUDIES 31

LIST OF FIGURES

Figure 1 Heat Maps created on GOM Inspect software marking the area on the occlusal table of the lower arch that is within a range of -0.6mm and 2mm of distance from the upper arch: A. T0 – Debond. B. T1 – 1 month after debond. C. T2 – 3 months after debond

Figure 2 Participants' Flowchart

Figure 3 Significant increase in the Total Surface Area within Range and the 0.25mm to 2mm category is seen from T0 to T1. The -0.6mm to 0.25mm category stayed constant. B. In the six subcategories, the 0.25mm to 0.5mm and 0.5mm to 1mm categories showed a significant increase from T0 to T1. C. and D. Anterior and posterior teeth showed the same pattern of increase in Total Surface Area within Range and the 0.25mm to 2mm category.

Figure 4 51 had no-occlusal coverage retainers, 18 had occlusal coverage retainers. A. Significant increase in the Total Surface Area within Range and the 0.25mm to 2mm category from T0 to T1. B. Decrease in the Total Surface Area within Range and the -0.6mm to 0.25mm category is seen from T0 to T1, but these changes were not significant.

Figure 5 Figure 5 51 patients with no-occlusal coverage retainers, while 18 had occlusal coverage retainers. A. Significant increase in the Total Surface Area within Range and the 0.25mm to 2mm category is seen from debond to 1 month. B. Decrease in the Total Surface Area within Range and in both categories of contacts was found, but these changes were not significant. **C**. Significant increase in the Total Surface Area within Range of the posterior teeth from T0 to T1 and from T0 to T2 was found. The 0.25mm to 2mm category also experienced a significant increase from time point to time point. **D.** The group with occlusal coverage retainers showed a decrease in the Total Surface Area within Range as well as the two categories of contacts. As with the anterior teeth, these changes were not statistically significant.

LIST OF TABLES

Table 1 Demographics and baseline data

Table 2 Demographics and baseline data of dropouts

ACKNOWLEDGEMENTS

The author would like to acknowledge and express her sincere gratitude to the University of Washington, the Department of Orthodontics, and the UW Orthodontic Alumni for providing the resources and funding for this project. Special thanks to Dr. Anne-Marie Bollen, Dr. Burcu Bayirli, Dr. Masoud Mohamed, Dr. Roozbeh Khosravi and Dr. Charles Speakerman for their time, guidance, confidence and support.

1. INTRODUCTION

One of the many goals of orthodontic treatment is to achieve a functional occlusion. An "ideal functional occlusion" is considered to be the occlusal relationship between the upper and lower dentition with the highest amount of occlusal contacts for chewing and incising.

At the time of removal of the orthodontic appliances, maximum intercuspation is sought but not always obtained. The prevailing opinion is that the majority of the patients will have increased occlusal contacts sometime after the removal of the fixed appliances. This process is called settling. Hoybjerg et al., in their paper *Evaluation of 3 retention protocols using the American Board of Orthodontics cast and radiograph evaluation*, defines settling as the natural vertical and horizontal movement of teeth into functionally stable inter-occlusal contacts after orthodontic treatment.[1]

Several studies have demonstrated that, in general, there is an increase in the occlusal contacts of teeth in 3 months to a year after orthodontic appliances are removed. According to Razdolsky and Sadowsky, there may be occlusal changes due to settling up to 21 months after orthodontic treatment.[2] Haydar et al.'s study demonstrated that within three months there is an increase in the number of contacts on the second molars and a decrease in the number of contacts on the first molars. They explain that it is due to a continued eruption of teeth and the contacts get balanced.[3] Durbin and Sadowsky also demonstrated an increase in the posterior teeth's contacts but also showed that there might be a decrease in the anterior teeth's contact during three months after debonding.[4] Gazit and Lieberman confirmed that there is a 56% increase in the number of contacts after one year by using a photocclusion technique.[5] According to these authors, the increase in the number of occlusal contacts improves the fitting of the teeth during the retention stage.

During the retention stage of the orthodontic treatment orthodontists strive to eliminate or prevent relapse, which are movements of teeth that negatively affect the occlusion and dental alignment, but hope to allow settling.[6] There are multiple possible retainers that can help orthodontists achieve these goals, but the most commonly prescribed, according to Basciftci et al., are the Hawley wrap-around retainer, the fixed bonded retainers, the transparent overlay (commonly known as an Essix retainer), and the tooth positioners.[6] The differences in the design between each of these retainers could cause differences in tooth movement. Several studies have been conducted comparing different retention protocols and their results regarding settling. Basciftci et al. evaluated the changes in occlusal contacts after a year of retention with maxillary and mandibular wrap around Hawleys and maxillary Jensen plates with mandibular canine-to-canine fixed lingual retainers. They concluded that in both groups there was an increase in the occlusal contacts, but especially in the one with the two removable Hawleys.[6] Sauget et al. compared the occlusal contacts between patients using Hawley retainers versus patients using clear overlay retainers (Essix). They demonstrated that there is a significant difference in occlusal contacts between these two types of retainers after three months of retention. "From T2 (retainer delivery) to T3 (3 months of retention) the number of total contacts and posterior contacts increased significantly more in the Hawley group than the clear overlay group.".[7] Durbin and Sadowsky reported more settling in the patients with active positioners than in patients with passive Hawley retainers, while Haydar and co-workers stated no difference.[3,4] Bauer et al. compared the Hawley retainer with the Perfector and Hawley retainer and found no significant difference between them.[8] Lastly, Demir et al. compared the retention characteristics of the Essix retainer with the Hawley retainer. They concluded that the retention characteristics between these two retention protocols are similar.[9]

In the above quoted literature, most of the techniques used to evaluate the settling process were similar to each other and can be considered as more visual techniques instead of actual measurements. Basciftci et al., Durbin et al., Haydar et al., Razdolsky et al., and Sauget et al. used the same technique for data recording. [2,3,4,6,7] They took alginate impressions in all of the patients at the two times points and a minimum of two inter-occlusal registrations with polyether rubber impression material. The inter-occlusal registrations were positioned either on a radiographic viewing screen or held to the daylight to identify the occlusal contacts and the near contacts. Perforations were registered as occlusal contacts and transferred onto the study models with red marks, while the near contacts were the areas in the inter-occlusal registration that only had changed in color and registered onto the study models with black. Durbin et al. did not attempt to investigate areas of near contacts. Haydar et al. then took standard pictures of the occlusal view of the models as marked, with the help of a setup that made it possible to standardize all the photographs. [3] Contacts on the first time point photograph were traced on acetate paper and superimposed on the second registration photograph for each tooth separately.

Gazit and Lieberman, and Hoybjerg et al. used slightly different techniques. [1,5] Gazit and Lieberman took occlusal registrations at debonding and three months after debond using an occlusal wafer. The wafer was then projected on a polariscope and analyzed the light, medium and heavy contacts. Hoybjerg utilized the study models at debonding and the study models of 1-year post-retention and evaluated them using the cast and radiograph evaluation (CRE) which used to be the objective grading system created by the American Board of Orthodontics. [1]

The existing literature indicates that after orthodontic treatment some movements occur that cause an increase in the overall occlusal contacts: settling. But despite all of the studies, no information is available on the specific movements that are occurring, their timing, and what

influences settling (the type of teeth, type of retainer and patient age and gender). Prior studies have relied on visual techniques like bite registrations and pictures, ABO's CRE, and photocclusion, but now new technology is available that allows to study 3D movements of teeth and to get specific measurements to address these questions.

The purpose of the study is to measure the post-treatment change in the inter-occlusal space one month and three months after orthodontic comprehensive treatment using 3D image analyses. The effect of the patients' demographics as well as retention protocols on the changes in occlusal contacts was analyzed.

2. MATERIALS AND METHODS

2.1. Study design

This prospective study compared changes in the inter-occlusal space using 3D images of patients at T0 (debond day), T1 (1 month after debonding), and T2 (3 months after debonding). Institutional Review Board (IRB) approval was obtained from the University Human Subjects Division before initiating the study procedures on June 22, 2016.

2.2. Participants, eligibility criteria, and data collection

All patients with full permanent dentition from the University Orthodontic Clinic whose fixed orthodontic appliances or Invisalign attachments were removed from June 2016 to September 2017 were approached to participate in the study. Excluded were patients who underwent Orthognathic surgery during their Orthodontic treatment, had unfinished or discontinued treatments for reasons such as missed appointments and poor compliance, third molars were going to be extracted or another dental/oral surgery was needed post treatment that could influence landmarks during the observation period, as well as those patients requiring prosthetic treatment of missing teeth during the study period.

The age, gender, orthodontic treatment performed, type of retainers and retention protocol was collected for each patient.

2.3. Methods

2.3.1. Intra-oral Scans

Each patient underwent an intra-oral scan with the same second generation of iTero (Align Techonology, Inc. San José, CA) digital scanner at the University of Washington Orthodontic Clinic at the three time points (T0 – debond; T1 – 1 month; T2 – 3 months). All patients were

scanned in supine position and asked to bite in their most comfortable position or Maximum Intercuspation. All intra-oral scans were exported from *www.mycadent.com* as a single STL file (maxilla and mandible in occlusion). The files were imported into the GOM Inspect software for analysis (GOM Precise Industrial 3D Metrology; Braunschweig, Germany).

2.3.2. Measurements on the scans

At each time point, a heat map was created in GOM inspect software marking the area on the occlusal table of the lower arch that had -0.6mm to 2mm distance from the upper arch (Figure 1). -0.6mm was the lowest collision value that was detected in this study. Collisions are created because the computer systems do not stop the images from moving through each other once the models have made contact. [10] According to Yoon et al, "Collision can be redefined as an adherence between two objects." They state that in these areas, there are no gaps or spaces between the objects for all points of view.[11]

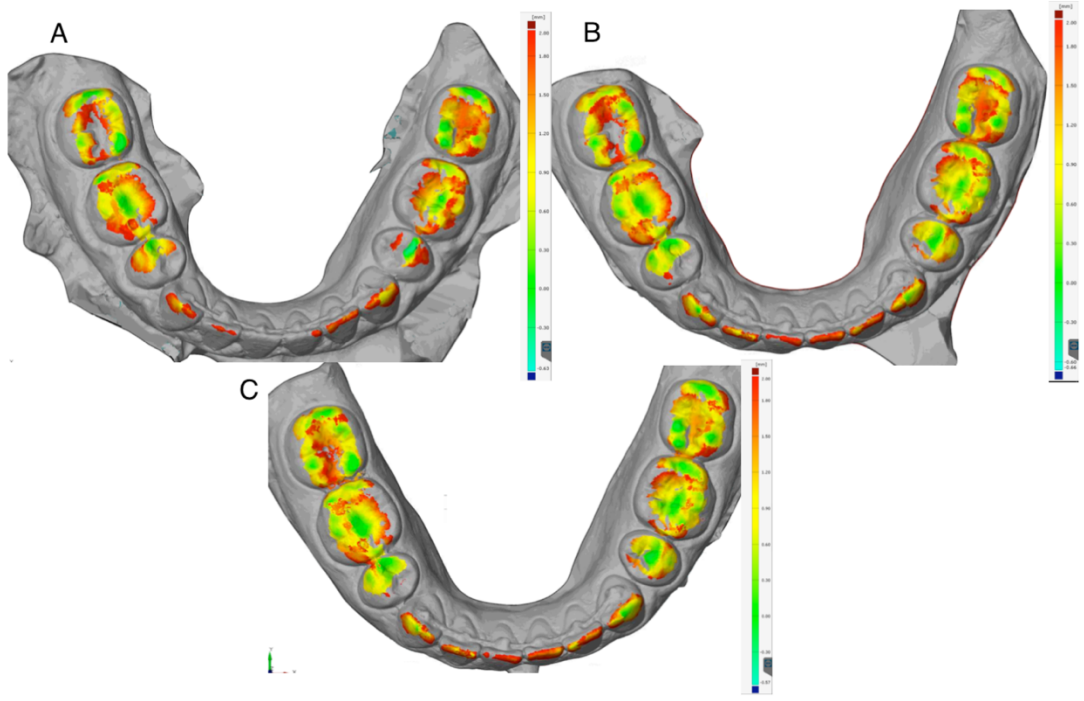


Figure 1 Heat Maps created on GOM Inspect software marking the area on the occlusal table of the lower arch that is within a range of -0.6mm and 2mm of distance from the upper arch: A. T0 – Debond. B. T1 – 1 month after debond. C. T2 – 3 months after debond

Within the color spectrum, the "blue/green" colors indicated heavy occlusal contacts, while "orange/red" colors indicated shallow to no occlusal contact but within the range. A *Total Surface Area within Range* including all color areas was measured at each time-point. This *Total Surface Area within Range* was divided into two categories: Contacts (*-0.6mm to 0.25mm* range) and No contacts (*0.25mm to 2mm* range). In addition, the two categories were subdivided into six types of occlusal contacts: -0.6*mm to 0mm, 0mm to 0.1mm, 0.1mm to 0.25, 0.25mm to 0.5mm, 0.5mm to 1mm, and 1mm to 2mm*. The *Total Surface Area within Range* and the area for each category and subcategory at each time point were compared.

The occlusal tables were divided into anterior (canine to canine) and posterior (premolars to molars bilaterally) segments. The *Total Surface Area within Range*, the two categories, and six subcategories were measured for each segment.

2.4. Verification of Measurement Error and Technical Error

To verify the measurement error, 10 cases were randomly selected, and the same measurements were made on the maxillary arch instead of the mandibular arch. Also, three months after the initial measurements, 20 cases were randomly selected and re-measured by the investigator. *Total Surface Area within Range* and *-0.6mm to 0mm* subgroup at T1 were re-measured. They were compared with the initial measurement to verify intra-examiner and measurement error.

In order to verify for possible Technical Error due to bite registration, three patients were scanned twice and bite registrations were recorded. Scans were imported into GOM Inspect and the *Total Surface Area within Range* was measured. Mean and Standard deviation for the two time-points were calculated. Paired t-test was done to compare them.

2.4.1. Power Calculations

A post-hoc power calculation for *Total Surface Area within Range*, the *-0.6mm to 0.25mm* and the *0.25mm to 2mm* was done using the sample size of 71 and the standard deviation of the change from debond (T0) to 3 months (T2). For the *Total Surface Area within Range,* an 18 unit difference can be detected with 90% power. For the *-0.6mm to 0.25mm* a 10 unit difference can be detected with 90% power, while a 16 unit difference can be detected with 90% power for the *0.25mm to 2mm* category.

2.5. Data Analysis

For each time point, the mean and the standard error of the mean were calculated for the *Total Surface Area within Range*, the two main categories and the six subcategories of types of contacts. A paired t-test was done for each group and the *Total Surface Area within Range* to compare the changes.

A paired t-test was done to examine and compare the increase in occlusal contacts in the anterior and posterior segments. An independent sample t-test was also performed to verify if occlusal coverage retainers and acrylic retainers interfere with settling and if age and gender influence the settling process.

3. RESULTS

3.1. Sample Population Characteristics

A total of 105 sequentially finished patients qualified for the study and were asked to participate. Two patients declined on the day of debond, nine did not show or dropped out after the first scan leaving 94 patients at T1. Eighteen patients did not show or dropped out for the third intraoral scan, resulting in a total of 76 patients with three time-points.

When exporting the models from *www.mycadent.com*, nine patients had to be removed from the study because of inadequate intraoral scans (i.e., fingers attached to teeth), four of them only had T0 and T1 scans, while 5 of them had all three time points. The final analysis was done for 90 patients with debond and one month IO Scans, and 71 patients with three time-points. See Figure 2 for a flowchart of the patients during the study period.

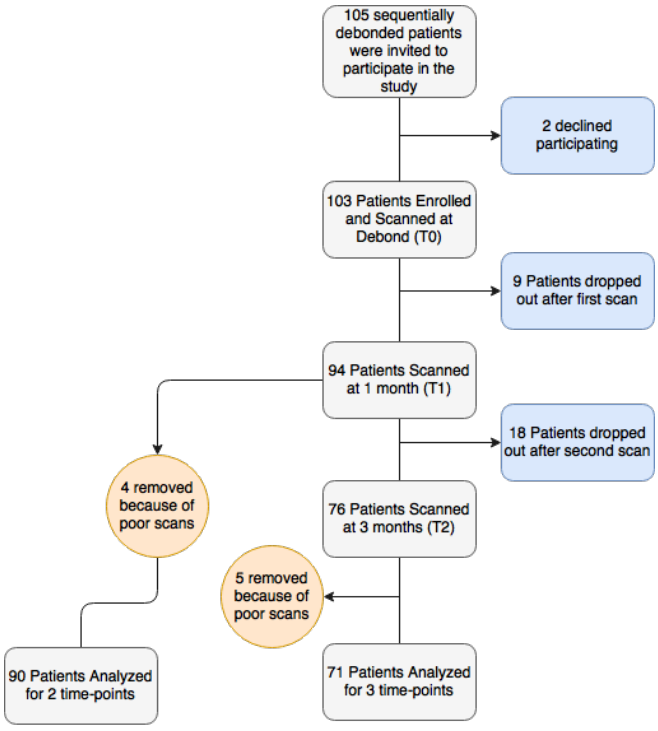


Figure 2 Participants' Flowchart

3.1.1. Demographics and baseline data

Table 1 shows the patients' demographic data and the retainer protocol data for the 90 analyzed patients. Most of the patients were female and adolescent, 66% and 69% respectively. 66% of the 90 patients were prescribed a no occlusal coverage retainer (i.e., Hawley or Wrap retainers), while 24% were prescribed an occlusal coverage retainer (i.e., Essix retainers). 10% of the participants had a combination of both types of retainers. In the occlusal coverage retainer group, 72% of the patients had upper and lower Essix retainers, while 28% had upper Essix retainers only. 42% and 41% had fixed retainers plus no occlusal coverage retainers and occlusal coverage retainers, respectively. Fixed retainers were not taken into consideration for the division of the groups since that would have diluted the groups significantly.

Table 1 Demographics and baseline data

Table 1. Demographics and baseline data			
		N	**%**
Gender			
	Female	59	66%
	Male	31	34%
Age			
	Adolescents (F<18; M<21)	62	69%
	Adults (F≥18, M≥21)	28	31%
Retainer Protocol			
	No occlusal Coverage Retainers	59	66%
	Occlusal Coverage Retainers	22	24%
	Combination of No Occlusal Coverage and Occlusal Coverage	9	10%

All patients were instructed to wear their retainers full time from debond to 1 month. 93% of the patients were instructed to continue full time wear from 1 month to 3 months. Retainer wear was not measured or controlled in any way.

In table 2, the demographics and baseline data for the dropout patients are shown. No significant difference was noticed between the dropouts and the analyzed patients.

Table 2 Demographics and baseline data of dropouts

Table 2. Demographics and baseline data of dropouts			
		N	**%**
Gender			
	Female	16	59%
	Male	11	41%
Age			
	Adolescents (F<18; M<21)	19	70%
	Adults (F≥18, M≥21)	8	30%
Retainer Protocol			
	No occlusal Coverage Retainers	15	56%
	Occlusal Coverage Retainers	6	22%
	Combination of No Occlusal Coverage and Occlusal Coverage	6	22%

3.2. Verification of Measurement Error and Technical Error

There was no significant difference between the measurements of the occlusal contacts on the mandibular or maxillary dental arch. After re-measuring 20 randomly selected cases and comparing them, there was no significant difference between them. The Dahlberg's formula was computed giving 0.41 for Total Surface Area within Range and 0.044 for Collisions.

After scanning twice and measuring the Total Surface area within Range for 3 patients to verify the possible technical error, there was no significant difference between the two time-points (p-value = 0.51).

3.3. Contact Surface Area increases during the early stage of orthodontic retention.

3.3.1. Overall Total Surface Area within Range increases in the first month of retention.

Figure 3A shows the changes in the overall contact surface area (-0.6mm to 2mm) at each time points. For the *Total Surface Area within Range,* there was a statistically significant increase from debond (T0) to 1 month (T1) ($p = 0.00008$) and from 1 month to 3 months (T2) ($p = 0.050$). The changes from T0 to T2 were also statistically significant ($p = 0.00005$). The *0.25mm to 2mm* category had a statistically significant increase between each time point ($p = 0.000001$, $p= 0.049$, and $p = 0.000001$, respectively).

3.3.2. The changes in the contact surface area happen in regions with a distance over 0.25mm

In the six subgroups of types of contacts, only the *0.25mm to 0.5mm* and *0.5mm to 1mm* categories increased significantly from T0 to T1 ($p=0.0035$ and $p=0.0000$, respectively). The total changes from T0 to T2 ($p=0.0012$ and $p=0.0000$, respectively) were also statistically significant. The *-0.6mm to 0mm* and the *1mm to 2mm"* categories decreased while the *0.1mm to 0.25mm* category increased; none were statistically significant ($p>0.05$). The *0mm to 0.1mm* category stayed constant through the 3 months period (Figure 3B).

3.3.3. Total Surface Area within Range increases in both anterior and posterior segments during retention stage.

For the anterior teeth (canine to canine), a statistically significant increase in the *Total Surface Area within Range* ($p=0.00034$) and in the *0.25mm to 2mm* category ($p=0.0020$) from T0 to T1 was measured (Figure 3C). The changes in the *-0.6mm to 0.25mm* range were not statistically

significant. The same pattern was seen in the subgroups of types of contacts in the anterior teeth (See Appendix A).

This pattern seen in the anterior teeth was also seen in the posterior segments (Figure 3D). The *Total Surface Area within Range* and the *0.25 to 2mm* category had statistically significant increases from T0 to T1 ($p = 0.0011$ and $p = 0.00001$, respectively). The *-0.6mm to 0.25mm* category stayed almost constant throughout the three-month period. In the subgroups of types of contacts, the same pattern was reflected except for a significant decrease in the *-0.6mm to 0mm* category ($p = 0.45$). This category has a significant change when looking at it independently, but was not enough to change the overall *-0.6mm to 0.25mm* category (See Appendix A)

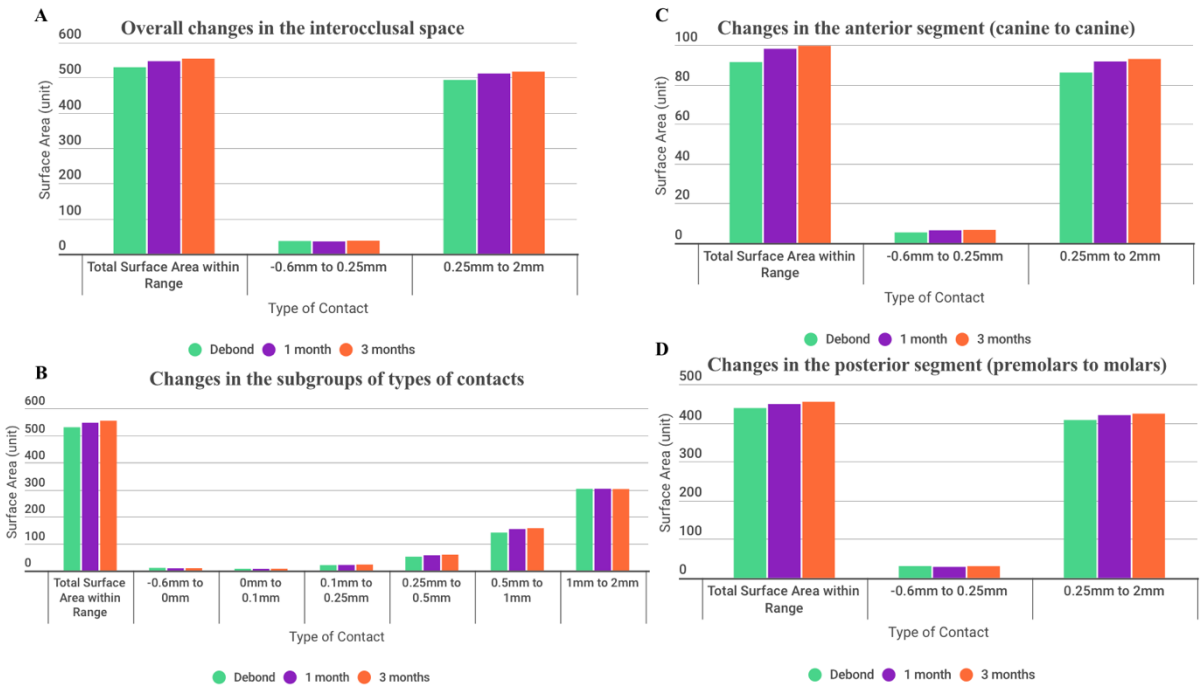


Figure 3 Significant increase in the Total Surface Area within Range and the 0.25mm to 2mm category is seen from T0 to T1. The -2mm to 0.25mm category stayed constant. B. In the six subcategories, the 0.25mm to 0.5mm and 0.5mm to 1mm categories showed a significant increase from T0 to T1. C. and D. Anterior and posterior teeth showed the same pattern of increase in Total Surface Area within Range and the 0.25mm to 2mm category.

3.4. Influence of gender and age.

3.4.1. Gender did not influence the changes in *Total Surface Area within Range* during early retention stage.

There are no statistically significant differences at any time-point between females and males (See Appendix B).

3.4.2. Age did not influence the changes in *Total Surface Area within Range* during early retention stage, even though a trend was found.

There are no statistically significant differences between adolescents and adults in the *Total Surface Area within Range*, the two categories and the subcategories in the three-month period. When looking at the two groups separately, the adolescent group showed a statistically significant increase in the *Total Surface Area within Range* and the *0.25mm to 2mm* range, while the adults did not have any statistically significant change (See Appendix C).

3.5. The type of retainer influences the changes in the *Total Surface Area within Range* during the early retention stage.

3.5.1. Occlusal coverage retainers prevent tooth movement during early stage of settling

Of the 59 patients using retainers with no occlusal coverage, 51 completed the study. The increase from T0 to T1 in the *Total Surface Area within Range* ($p=0.00002$), the *-0.6mm to 0.25mm* category ($p = 0.03$) and *0.25mm to 2mm* ($p = 0.00001$) was statistically significant (Figure 4A). The change from T1 to T2 in the *0.25mm to 2mm* category was also statistically significant ($p = 0.038$).

18 patients out of the 22 instructed to use retainers with occlusal coverage completed the three time points. In this group, the *Total Surface Area within Range* and *-0.6mm to 0.25mm* decreased

between each time-point but were not statistically significant. The change from T0 to T1 in the *-0.6mm to 0.25mm* category had a p-value of 0.06, being the closest category to a significant change (Figure 4B).

When comparing the changes of these two retainer groups, a statistically significant difference in the *Total Surface Area within Range* (p=0.006), and in the *-0.6mm to 0.25mm* category (p = 0.02) from T0 to T1 was found (Appendix D).

The third group of retainer protocol was comprised of 9 patients, of which only 2 were evaluated at all time points. For this reason, statistical analysis was only done for the 9 patients comparing T0 to T1; none of the changes were statistically significant.

For details on the six subgroups of types of contacts, see Appendix E.

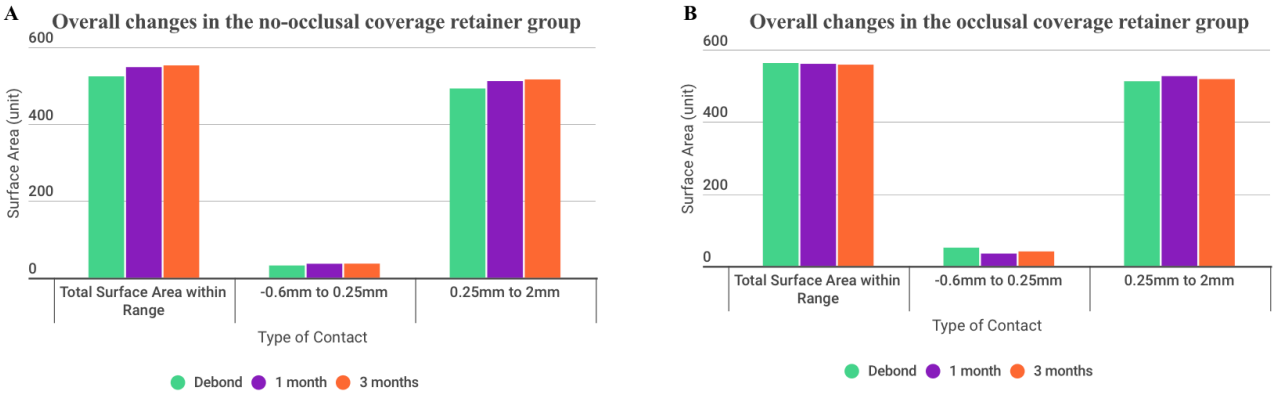


Figure 4 51 had no-occlusal coverage retainers, 18 had occlusal coverage retainers. A. Significant increase in the Total Surface Area within Range and the 0.25mm to 2mm category from T0 to T1. B. Decrease in the Total Surface Area within Range and the -0.6mm to 0.25mm category is seen from T0 to T1, but these changes were not significant.

3.5.2. Retainers influence the changes in the anterior and posterior teeth during retention stage

In patients wearing retainers without occlusal coverage, the anterior teeth had a statistically significant increase in the *Total Surface Area within Range* (p = 0.00051) and the *0.25mm to 2mm*

category ($p = 0.002$) from T0 to T1 (Figure 5A). On the other hand, in the group of retainers with occlusal coverage, a decrease in the *Total Surface Area within Range* and both ranges was found (Figure 5B). Nonetheless, the changes in the anterior teeth were not statistically significant at any time-point nor category.

When comparing the results of both types of retainers, a statistically significant difference was found in the change of the *Total Surface Area within Range* from T0 to T1 ($p = 0.011$) and the *0.25mm to 2mm* category ($p = 0.03$). This difference indicates that the group of retainers without occlusal coverage allow a significantly positive change in a 3-month period compared to the retainer group with occlusal coverage (Appendix F).

In the posterior teeth, retainers had a similar effect as in the anterior teeth. The retainer group without occlusal coverage showed a statistically significant increase in the *Total Surface Area within Range* and the *0.25mm to 2mm* from T0 to T1($p = 0.0002$, $p = 0.001$), and from T0 to T2 ($p = 0.0007$, $p = 0.002$) (Figure 5C). The group with occlusal coverage retainers showed a decrease in the *Total Surface Area within Range* as well as in the two categories of contacts. As with the anterior teeth, these changes were not statistically significant (Figure 5D).

When comparing the results of the influence the type of retainers in the posterior teeth, a statistically significant difference was found in the change of the *Total Surface Area within Range* from T0 to T1 ($p = 0.008$). This difference indicates that the group of retainers without occlusal coverage allow a significantly positive change in the first month compared to the retainer group with occlusal coverage. A significant difference was also found in the *-0.6mm to 0.25mm* category from T0 to T1 ($p = 0.04$) (Appendix F).

Analysis of the subcategories of contacts was done for the anterior and posterior teeth with the two types of retainers. For details, view Appendix F.

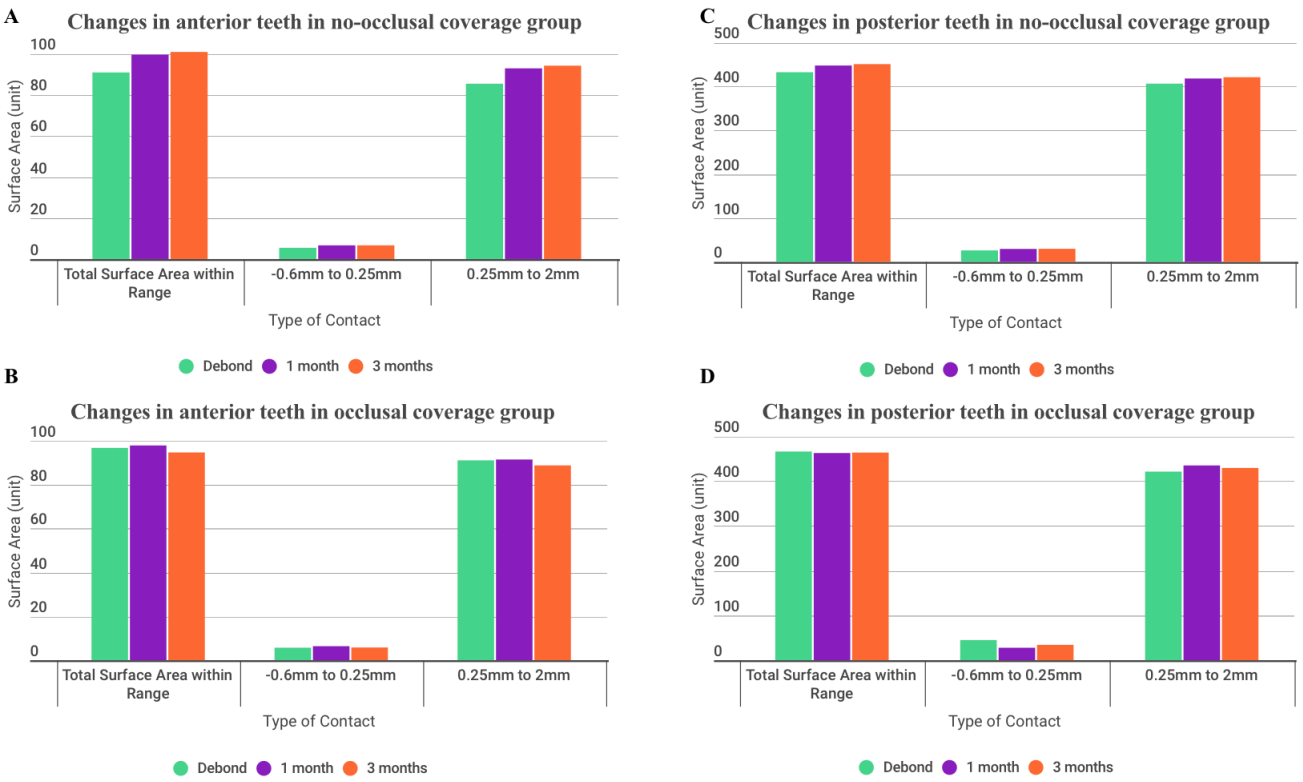


Figure 5 Figure 5 51 patients with no-occlusal coverage retainers, while 18 had occlusal coverage retainers. A. Significant increase in the Total Surface Area within Range and the 0.25mm to 2mm category is seen from debond to 1 month. B. Decrease in the Total Surface Area within Range and in both categories of contacts was found, but these changes were not significant. ***C****. Significant increase in the Total Surface Area within Range of the posterior teeth from T0 to T1 and from T0 to T2 was found. The 0.25mm to 2mm category also experienced a significant increase from time point to time point.* ***D.*** *The group with occlusal coverage retainers showed a decrease in the Total Surface Area within Range as well as the two categories of contacts. As with the anterior teeth, these changes were not statistically significant.*

4. DISCUSSION

Changes in the inter-occlusal space after the removal of orthodontic appliances, or "settling," have been studied for many years. While the concept of settling is well accepted, many questions about this phenomenon remain unanswered. This study evaluated dental movements using three-dimensional technology.

4.1. When does settling occur?

Başçiftci et al., Hoybjerg et al., and Razdolsky et al., evaluated and compared records taken at debond and one year or more after removal of the orthodontic appliances. [1,2,6] They all found increase in the occlusal contacts. However, none of them established the timing as there was a large period between the time-points. Haydar et al. and Durbin et al., found an increase in occlusal contacts between the time of debond and 3-months after debond.[3,4]

In this study, records were taken at debond, 1-month and 3-months after removal of appliances, with the hypothesis that most of the settling happens in the early stage of retention. The methodology of the GOM Inspect Software did not allow us to measure the surface area of the entire occlusal table due to the inclusion of gingival tissues in the heat map. Therefore, the range being studied was limited to -0.6mm to 2mm between the maxillary and mandibular teeth. This area was defined as the *Total Surface Area within Range*. There were areas of the occlusal table at all three time-points that were outside of this range. The significant increase ($p<0.05$) in *Total Surface Area within Range* from debond to 1 month indicates that areas that were initially outside of the study's range (more than 2mm of space between the upper and lower dentition) entered this range. These results coincide with previous studies showing that there is a definite increase in the total surface area in the range studied. It also showed that most of the changes

occur in the first month after the removal of orthodontic appliances. The increase continued to happen during the 1-month to 3-month period, but none of them were statistically significant.

With this in mind, a clinician can consider taking final records one month after the removal of the orthodontic appliance. At this point, most of the positive changes would have already happened.

4.2. Where does settling occur?

Previous studies were not able to divide the inter-occlusal space into categories to evaluate where most of the changes occurred. Previous methods used to study the changes in the inter-occlusal space were mainly visual. Basciftci et al., Durbin et al., Haydar et al., Razdolsky et al., and Sauget et al. took alginate impressions and inter-occlusal registrations with polyether rubber impression material. [2,3,4,6,7] The inter-occlusal registrations were positioned either on a radiographic viewing screen or held to the daylight to identify the occlusal contacts and the near contacts. Durbin et al. did not attempt to investigate areas of near contacts.[4] Haydar et al. took standard pictures of the occlusal view of the marked models and traced on acetate paper the contacts on the first-time point photograph and superimposed on the second registration photograph for each tooth separately. [3]

Gazit and Lieberman, and Hoybjerg et al. used slightly different techniques.[1,5] Gazit and Lieberman took occlusal registrations and projected them on a polariscope to analyze the light, medium and heavy contacts.[5] Hoybjerg evaluated study models at debond and 1-year post-retention using the cast and radiograph evaluation (CRE) by the American Board of Orthodontics.[1]

In this study, 3D technology provided us with detailed records of the changes that took place. The total surface area within range was divided into two main categories based on the distance

between the two arches: *-0.6mm to 0.25mm* and *0.25 mm to 2mm*. It was also divided into six sub-groups to determine where the movements occurred. The results showed that areas at a distance of more than 0.25mm from occlusal contact change the most during a 3-month retention period. It also showed that the amount of surface area within a distance less than 0.25mm from the occlusal table stays constant throughout the three months period.

4.3. Is there a difference in the settling process between anterior and posterior teeth?

In contrast to Durbin et al.'s study, but similar to Razdolsky et al., this study showed that there is a significant increase in the total surface area within range in anterior and posterior segments from debond to 1-month retainer checks.[2,4] Due to the number and the size of teeth, most of the surface area under the range (-0.6mm to 2mm) was comprised by the posterior segment, but positive changes were noticed in both segments.

4.4. Does the retainer protocol influence the settling process?

Durbin et al. analyzed the difference between Conventional retainers (Hawley Retainers with or without biteplates) and Positioners, believing and demonstrating that positioners allow more positive changes than conventional retainers; Haydar et al. showed no significant difference between these two groups of retainers.[3,4] Occlusal coverage retainers (i.e., Essix), no-occlusal coverage retainers (i.e., Hawley), and fixed retainers are the most common protocols used today. In this study, three groups of retainers were compared: Occlusal Coverage Retainers, No-Occlusal Coverage Retainers, and a Combination of both. Fixed retainers were not taken into consideration. Since practitioners were not instructed what type of retainer each patient should have, there was a significant variation in the number of patients in each group. This difference resulted in the exclusion of the group of the combination of both types of retainer due to a small sample.

Sauget et al. and Hoybjerg et al. analyzed the effect of Hawley Retainers, Essix and fixed retainers in the settling process.[1,7] Our study agrees with both previous studies that no-occlusal coverage retainers allow positive changes in the inter-occlusal space, while the occlusal coverage retainers do not. We found that with occlusal coverage retainers the *-0.6mm to 0mm* sub-group experience a significant decrease from debond to 1 month. This change can be due to the intrusion effect of the occlusal coverage retainers

4.5. Does retainer protocol influence the settling process in the anterior and posterior teeth differently?

Sauget et al. established that the retainer protocol influences the settling process of the anterior and posterior teeth.[7] In this study, anterior and posterior teeth showed a significant increase in *Total Surface Area within Range* when looking at the no-occlusal coverage retainer group. In the occlusal coverage retainer group, none of the segments experienced any significant change. Even though the changes in the occlusal coverage retainer group were not significant, the decrease from debond to 1 month in the posterior teeth for *-0.6mm to 0.25mm* and *0.25mm to 2mm* categories had p-values of 0.07. It is possible that with an increase in the sample size of patients with occlusal coverage retainer, the posterior teeth would have shown a significant change.

4.6. Do patients' age and gender affect settling?

No significant difference was found between female and male patients in settling at any time-point in any of the categories.

We found that adolescent patients had a statistically significant increase in the *Total Surface Area within Range* and in the *0.25mm to 2mm* category from debond to 1 month. Adults did not experience any significant change. Age has some effect on settling, but when the effect of age for

the different categories was compared, none were significantly different. The observed trend that age may influence settling needs to be evaluated in a study with a bigger sample size of adult patients.

4.7. Limitations

The software GOM Inspect utilizes a mathematical model and an arbitrary unit to measure Surface Area. While the clinical significance of the surface area unit is not known, this measure allowed us to evaluate changes over time and compare changes between different groups.

This study did not focus on the changes in occlusal contact of specific contact areas. The differences at specific time points of the total surface area within range were compared, not the long-term changes of each specific area. For example, we did not establish if a heavy contact at the time of debond would be present at later time points. While the amount of surface area of contacts remained similar over time, we were not able to determine whether this is because initial contacts remain in place, or are replaced by contacts on other teeth.

Another limitation of the study is the lack of information on patient compliance with retainer wear. Lastly, there was a large difference in the size of the two groups of retainer types, age, and gender. Randomization could be taken into consideration for future studies to control these variables.

4.8. Future studies

This study found that the amount of surface area in the contacts category stayed the same throughout the 3 months, but we were not able to evaluate if the location of these contacts were the same or if they were changing. A study superimposing the models from the three time-points

would help us verify if the position of the contacts changes throughout the 3 months. It would also be interesting to look at specific tooth movements such as tipping, extrusion, intrusion, and torque.

A study with a more balanced sample of patients and retainer protocols would help to evaluate the possible influence of age and gender in settling. It would also confirm the findings seen in this study in relation to the occlusal coverage retainers preventing changes in the inter-occlusal space.

Lastly, in this study the quality of the finishing of the cases was not taken in consideration. It may be surmised that well finished cases would have less settling than cases that were finished well. A study evaluating how patients are finished and how settling is influenced by it should be performed.

This study confirms that there is an increase in the total surface in occlusal contact during the retention stage. The majority of the changes occur during the first month after the removal of orthodontic appliances. The changes take place between teeth that are not close to one-another. The amount of surface area in the contact range (-0.6 to 0.25 mm inter-occlusal distance) does not change during the first 3 months post debonding. Anterior and posterior teeth exhibit similar changes. Retainers with Occlusal Coverage prevent settling. There is no effect of gender on inter-occlusal changes after orthodontic treatment. There may be more settling in adolescent than in adults, but bigger sample size is needed to evaluate it.

BIBLIOGRAPHY

1. Hoybjerg, A. J., Currier, G. F., & Kadioglu, O. (2013). Evaluation of 3 retention protocols using the American Board of Orthodontics cast and radiograph evaluation. American Journal of Orthodontics and Dentofacial Orthopedics, 144(1), 16-22.
2. Razdolsky, Yen, Cyril Sadowsky, and Ellen A. BeGole. 1989. "Occlusal Contacts Following Orthodontic Treatment: A Follow-up Study." *The Angle Orthodontist* 59 (3): 181–85.
3. Haydar, B., S. Ciğer, and P. Saatçi. 1992. "Occlusal Contact Changes after the Active Phase of Orthodontic Treatment." *American Journal of Orthodontics and Dentofacial Orthopedics: Official Publication of the American Association of Orthodontists, Its Constituent Societies, and the American Board of Orthodontics* 102 (1): 22–28.
4. Durbin, D. S., and C. Sadowsky. 1986. "Changes in Tooth Contacts Following Orthodontic Treatment." *American Journal of Orthodontics and Dentofacial Orthopedics: Official Publication of the American Association of Orthodontists, Its Constituent Societies, and the American Board of Orthodontics* 90 (5): 375–82.
5. Gazit, Esther, and Myron A. Lieberman. 1985. "Occlusal Contacts Following Orthodontic Treatment." *The Angle Orthodontist* 55 (4): 316–20.
6. Başçiftçi, Faruk Ayhan, Tancan Uysal, Zafer Sari, and Ozgur Inan. 2007. "Occlusal Contacts with Different Retention Procedures in 1-Year Follow-up Period." *American Journal of Orthodontics and Dentofacial Orthopedics: Official Publication of the American Association of Orthodontists, Its Constituent Societies, and the American Board of Orthodontics* 131 (3): 357–62.
7. Sauget, Earl, David A. Covell Jr., Roger P. Boero, and William S. Lieber. 1997. "Comparison of Occlusal Contacts with Use of Hawley and Clear Overlay Retainers." *The Angle Orthodontist* 67 (3): 223–30.
8. Bauer, Elizabeth M., Rolf Behrents, Donald R. Oliver, and Peter H. Buschang. 2010. "Posterior Occlusion Changes with a Hawley vs. Perfector and Hawley Retainer." *The Angle Orthodontist* 80 (5): 853–60.
9. Demir, Abdullah, Hasan Babacan, Ruhi Nalcacı, and Tolga Topcuoglu. 2012. "Comparison of Retention Characteristics of Essix and Hawley Retainers." *Korean Journal of Orthodontics* 42 (5): 255–6

10. Xia, J.J., Chang, Y., Zhou, X. 2010. "Automated Digital Dental Articulation." *Medical image computing and computer-assisted intervention* 13(Pt 3): 278-286.

11. Yoon, T., and Jung, K. 2009. "Fast 3D Collision Detection Algorithm using 2D Intersection Area." *World Academy of Science, Engineering and Technology* (36): 721-724.

12. Andrews, L. F. (1972). The six keys to normal occlusion. American Journal of Orthodontics, 62(3), 296-309.

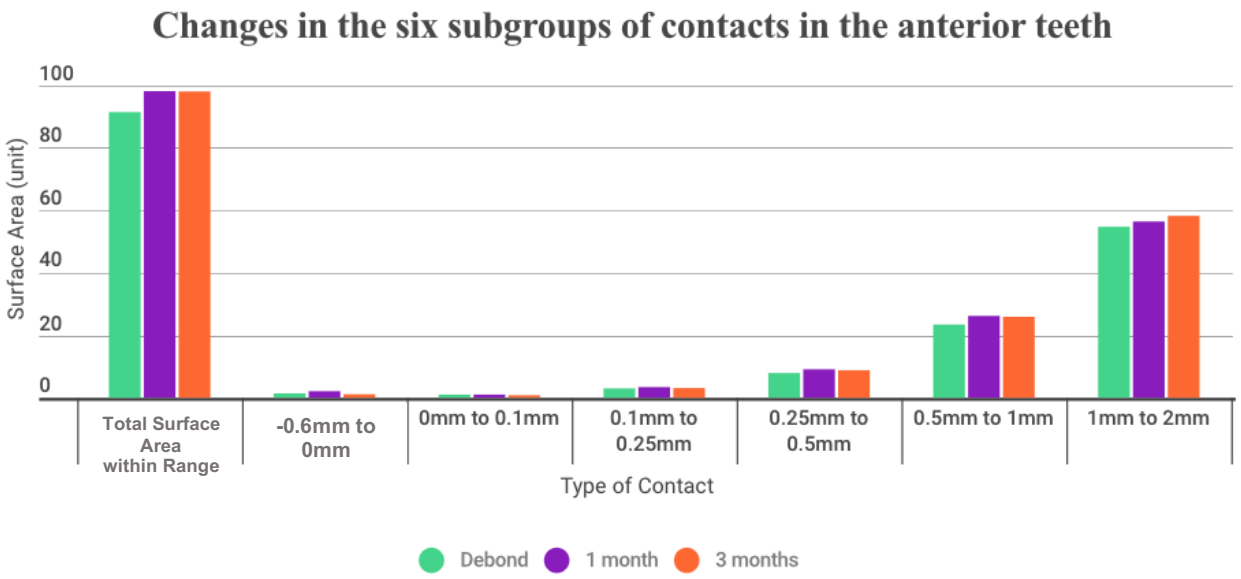
13. Graber, L. W., Vanarsdall, R. L., & Vig, K. W. 2005. "Orthodontics: Current principles & techniques" (4th ed.). Philadelphia, PA: Elsevier/Mosby.

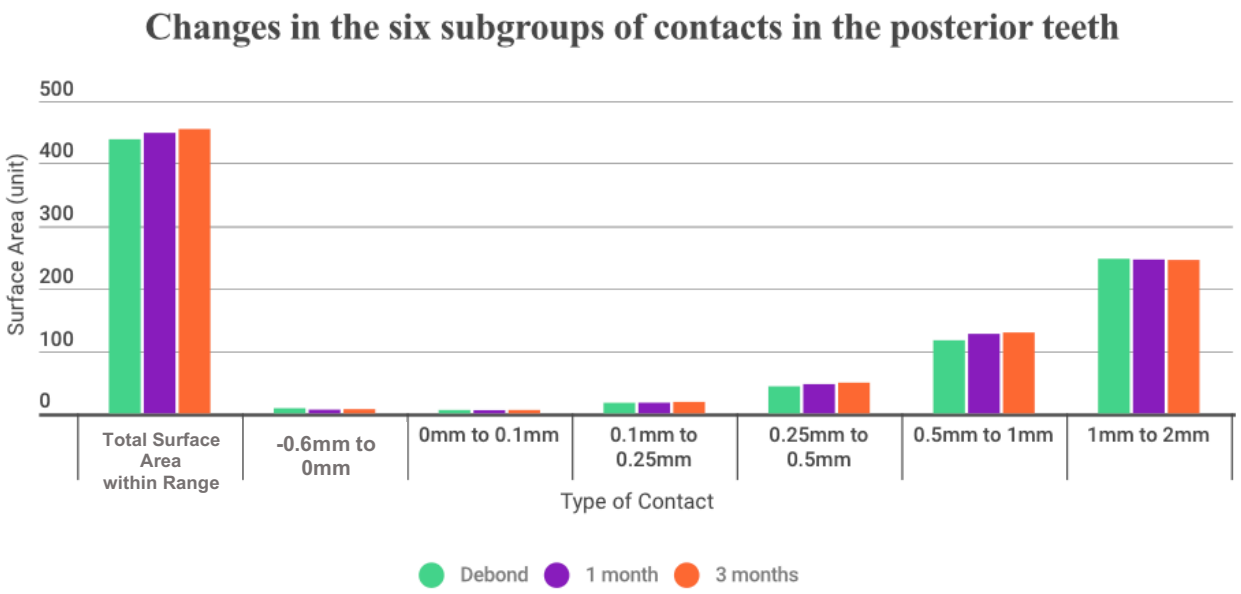
14. Morton, Sandra, and Hans Pancherz. 2009. "Changes in Functional Occlusion during the Postorthodontic Retention Period: A Prospective Longitudinal Clinical Study." *American Journal of Orthodontics and Dentofacial Orthopedics: Official Publication of the American Association of Orthodontists, Its Constituent Societies, and the American Board of Orthodontics* 135 (3): 310–15.

15. Sullivan, B., M. D. Sc., T. J. Freer, B. D. Sc., D. Vautin, M. D. Sc., K. E. Basford, and M. Lit. St. n.d. "Occlusal Contacts: Comparison of Posttreatment Patients, and Untreated." http://ac.els-cdn.com.offcampus.lib.washington.edu/002239139190167U/1-s2.0-002239139190167U-main.pdf?_tid=49b3f6e8-be50-11e5-8433-00000aacb35d&acdnat=1453168954_4066948136b049ee3d994e077b06c16a.

16. Proffit, W. R., & Fields, H. W. 2013. "Contemporary orthodontics" (5th ed.). St. Louis: Mosby.

APPENDIX A


Changes in the six subgroups of contacts in the anterior teeth
100
80
60
40
20
0
Surface Area (unit)
Total Surface Area within Range
-0.6mm to 0mm
0mm to 0.1mm
0.1mm to 0.25mm
0.25mm to 0.5mm
0.5mm to 1mm
1mm to 2mm
Type of Contact
Debond
1 month
3 months


Changes in the six subgroups of contacts in the posterior teeth
500
400
300
200
100
0
Surface Area (unit)
Total Surface Area within Range
-0.6mm to 0mm
0mm to 0.1mm
0.1mm to 0.25mm
0.25mm to 0.5mm
0.5mm to 1mm
1mm to 2mm
Type of Contact
Debond
1 month
3 months

APPENDIX B

Table 3. Data analysis for the effect of gender in the overall inter-occlusal changes									
		Female			Male			Difference between gender groups	
Category	**Dif**	**N**	**Mean Dif (95% CI)**	**p**	**N**	**Mean Dif (95% CI)**	**p**	**Mean Dif (95% CI)**	**p**
Total Surface Area within Range	T1-T0	59	16.6 (6.7 – 26.5)	**0.0014***	31	18.0 (2.5 – 33.6)	**0.024***	-1.5 (-19.6 – 16.7)	0.87
	T2-T1	48	7.3 (-1.42 – 16)	0.099	23	6.2 (-6.08 – 18.5)	0.31	1.1 (-13.7 – 15.9)	0.88
	T2-T0	48	24.4 (11.9 – 36.9)	**0.00028***	23	21.7 (-1.1 – 44.6)	0.061	2.7 (-23.0 – 28.3)	0.83
-0.6mm to 0.25mm	T1-T0	59	-3.6 (-9.3 – 2.1)	0.21	31	3.3 (-7.8 – 14.5)	0.54	-7.0 (-19.4 – 5.4)	0.26
	T2-T1	48	-0.8 (-5.6 – 4.1)	0.75	23	5.2 (-3.5 – 13.8)	0.23	-5.9 (-15.7 – 3.8)	0.22
	T2-T0	48	-2.8 (-8.5 – 3.0)	0.34	23	8.9 (-6.3 – 24.1)	0.24	-11.7 (-27.8 – 4.4)	0.15
0.25mm to 2mm	T1-T0	59	20.2 (11.3 – 29.1)	**0.00003***	31	14.7 (0.0 – 29.4)	0.050	5.5 (-11.5 – 22.5)	0.52
	T2-T1	48	8.1 (1.1 – 15.0)	**0.024***	23	1.1 (-9.8 – 11.9)	0.84	7.0 (-5.7 – 19.7)	0.27
	T2-T0	48	27.2 (16.1 – 38.3)	**0.00001***	23	12.8 (-7.2 – 32.8)	0.20	14.3 (-8.2 – 36.9)	0.20

Table 4. Data analysis for the effect of gender in the six subgroups of types of contacts									
		Female			Male			Difference between groups	
Category	**Dif**	**N**	**Mean Dif (95% CI)**	**p**	**N**	**Mean Dif (95% CI)**	**p**	**Mean Dif (95% CI)**	**p**
Total Surface Area within Range	T1-T0	59	16.6 (6.7 – 26.5)	**0.0014***	31	18.0 (2.5 – 33.6)	**0.024***	-1.5 (-19.6 – 16.7)	0.87
	T2-T1	48	7.3 (-1.42 – 16)	0.099	23	6.2 (-6.08 – 18.5)	0.31	1.1 (-13.7 – 15.9)	0.88
	T2-T0	48	24.4 (11.9 – 36.9)	**0.00028***	23	21.7 (-1.1 – 44.6)	0.061	2.7 (-23.0 – 28.3)	0.83
-0.6mm to 0mm	T1-T0	59	-2.6 (-5.1 – -0.1)	**0.043***	31	0.5 (-4.5 – 5.5)	0.83	-3.1 (-8.6 – 2.4)	0.26
	T2-T1	48	-0.9 (-2.9 – 1.1)	0.39	23	0.9 (-3.6 – 5.5)	0.67	-1.8 (-6.7 – 3.1)	0.46
	T2-T0	48	-2.4 (-5.2 – 0.4)	0.088	23	1.9 (-5.3 – 9.1)	0.60	-4.3 (-11.9 – 3.4)	0.26
0mm to 0.1mm	T1-T0	59	-0.7 (-1.7 – 0.2)	0.13	31	0.7 (-2.5 – 3.9)	0.68	-1.4 (-4.7 – 1.9)	0.40
	T2-T1	48	-0.1 (-1.0 – 0.7)	0.77	23	0.8 (-1.0 – 2.5)	0.38	-0.9 (-2.8 – 1.1)	0.36
	T2-T0	48	-0.7 (-1.8 – 0.4)	0.21	23	1.7 (-1.6 – 4.9)	0.30	-2.3 (-5.7 – 1.0)	0.17
0.1mm to 0.25mm	T1-T0	59	-0.3 (-3.0 – 2.4)	0.82	31	2.2 (-2.6 – 7.0)	0.36	-2.5 (-7.9 – 2.9)	0.36
	T2-T1	48	0.2 (-2.3 – 2.7)	0.86	23	3.5 (-0.33 – 7.3)	0.072	-3.2 (-7.72 – 1.2)	0.15
	T2-T0	48	0.03 (-2.1 – 2.8)	0.79	23	5.4 (-2.1 – 12.9)	0.15	-5.1 (-12.9 – 2.8)	0.20
0.25mm to 0.5mm	T1-T0	59	3.9 (-0.3 – 8.1)	0.067	31	6.6 (1.6 – 11.7)	**0.012***	-2.7 (-9.2 – 3.8)	0.41
	T2-T1	48	2.6 (-1.2 – 6.4)	0.181	23	3.9 (-4.2 – 12.1)	0.33	-1.4 (-10.2 – 7.5)	0.76
	T2-T0	48	6.6 (2.1 – 11.1)	**0.0047***	23	8.3 (-1.5 – 18.1)	0.092	-1.7 (-12.3 – 8.9)	0.75
0.5mm to 1mm	T1-T0	59	14.2 (7.9 – 20.5)	**0.00003***	31	10.8 (1.7 – 19.9)	**0.021***	3.4 (-7.5 – 14.3)	0.53
	T2-T1	48	6.2 (1.2 – 11.2)	**0.016***	23	-1.4 (-9.5 – 6.6)	0.72	7.6 (-1.7 – 16.9)	0.11
	T2-T0	48	19.1 (11.5 – 26.7)	**0.00001***	23	11.2 (-1.1 – 23.6)	0.073	7.9 (-6.4 – 22.1)	0.27
1mm to 2mm	T1-T0	59	2.1 (-4.7 – 8.9)	0.55	31	-2.7 (-13.2 – 7.8)	0.60	4.8 (-7.6 – 17.1)	0.44
	T2-T1	48	-0.7 (-7.62 – 6.3)	0.84	23	-1.4 (-16.5 – 13.7)	0.84	0.8 (-15.6 – 17.2)	0.93
	T2-T0	48	1.4 (-7.8 – 10.7)	0.75	23	-6.7 (-25.5 – 12.1)	0.47	8.2 (-12.5 – 28.8)	0.43

APPENDIX C

Table 5. Data analysis for the effect of age in the overall inter-occlusal changes									
		Adolescents (M <21; F<18)			Adults (M≥21; F≥18)			Difference between age groups	
Category	**Dif**	**N**	**Mean Dif (95% CI)**	**p**	**N**	**Mean Dif (95% CI)**	**p**	**Mean Dif (95% CI)**	**p**
Total Surface Area within Range	T1-T0	62	16.6 (6.7 – 26.5)	**0.0014***	28	18.0 (2.5 – 33.6)	**0.024***	-1.5 (-19.6 – 16.7)	0.87
	T2-T1	49	7.3 (-1.42 – 16)	0.099	22	6.2 (-6.08 – 18.5)	0.31	1.1 (-13.7 – 15.9)	0.88
	T2-T0	49	24.4 (11.9 – 36.9)	**0.00028***	22	21.7 (-1.1 – 44.6)	0.061	2.7 (-23.0 – 28.3)	0.83
-0.6mm to 0.25mm	T1-T0	62	-1.2 (-5.4 – 3.1)	0.59	28	-1.4 (-16.2 – 13.5)	0.85	0.2 (-15.2 – 15.6)	0.98
	T2-T1	49	2.3 (-2.5 – 7.0)	0.35	22	-1.3 (-10.43 – 7.9)	0.77	3.5 (-6.6 – 13.7)	0.48
	T2-T0	49	1.3 (-4.9 – 7.6)	0.67	22	0.4 (-14.9 – 15.6)	0.96	1.0 (-15.3 – 17.3)	0.90
0.25mm to 2mm	T1-T0	62	21.3 (12.8 – 29.8)	**0.000001***	28	11.6 (-4.4 – 27.6)	0.15	9.7 (-8.2 – 27.6)	0.28
	T2-T1	49	4.9 (-1.6 – 11.4)	0.133	22	7.8 (-4.9 – 20.5)	0.22	-2.9 (-16.9 – 11.2)	0.68
	T2-T0	49	25.8 (14.3 – 37.3)	**0.00004***	22	15.2 (-4.3 – 34.7)	0.12	10.6 (-11.7 – 32.8)	0.34

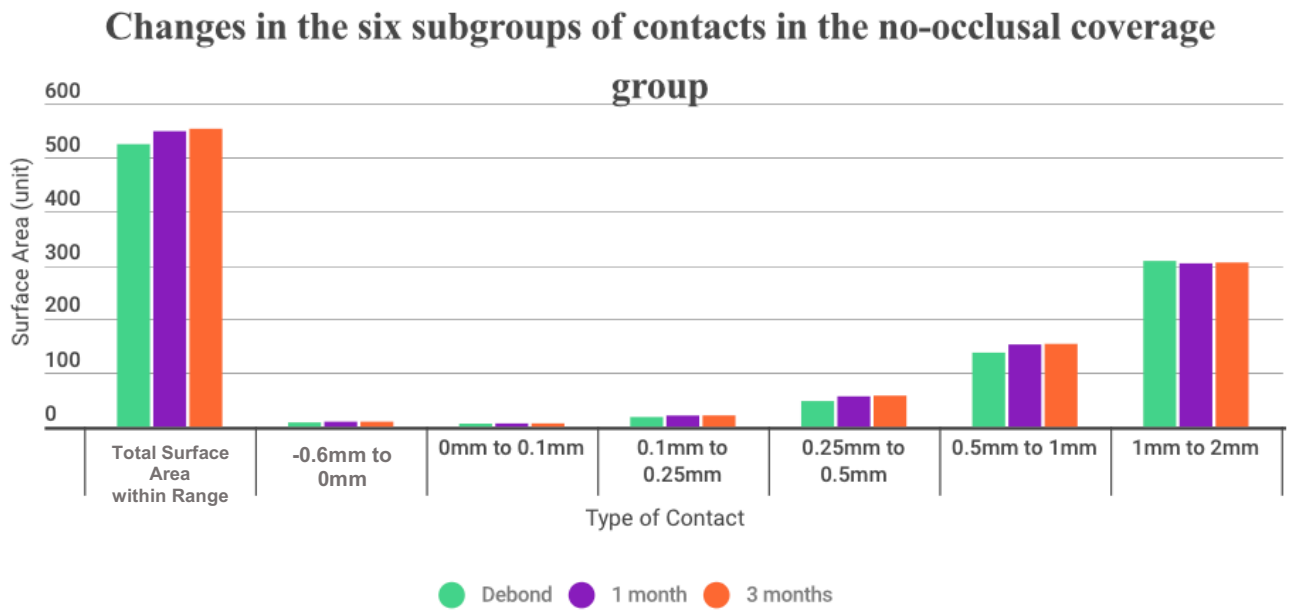
Table 6. Data analysis for the effect of gender in the six subgroups of types of contacts									
		Adolescents (M <21; F<18)			Adults (M≥21; F≥18)			Difference between groups	
Category	**Dif**	**N**	**Mean Dif (95 CI)**	**p**	**N**	**Mean Dif (95 CI)**	**p**	**Mean Dif (95 CI)**	**p**
Total Surface Area within Range	T1-T0	62	20.2 (10.0 – 30.3)	**0.0002***	28	10.3 (-4.2 – 24.7)	0.15704	9.9 (-7.5 – 27.3)	0.26
	T2-T1	49	7.2 (-1.71 – 16.1)	0.111	22	6.5 (-5.12 – 18.1)	0.258	0.7 (-13.6 – 15.0)	0.92
	T2-T0	49	27.1 (13.2 – 41.1)	**0.00028***	22	15.6 (-2.2 – 33.4)	0.08348	11.6 (-10.6 – 33.7)	0.30
-0.6mm to 0mm	T1-T0	62	-1.8 (-4.1 – 0.5)	0.12	28	-0.9 (-6.8 – 4.9)	0.75	-0.9 (-7.1 – 5.3)	0.78
	T2-T1	49	0.7 (-1.6 – 3.1)	0.52	22	-2.6 (-6.2 – 1.1)	0.16	3.3 (-0.9 – 7.5)	0.12
	T2-T0	49	-0.7 (-4.1 – 2.7)	0.69	22	-1.8 (-7.9 – 4.3)	0.56	1.1 (-5.8 – 8.0)	0.75
0mm to 0.1mm	T1-T0	62	-0.3 (-1.0 – 0.4)	0.41	28	-0.1 (-3.9 – 3.7)	0.94	-0.2 (-4.0 – 3.7)	0.93
	T2-T1	49	0.4 (-0.3 – 1.1)	0.22	22	-0.4 (-2.6 – 1.7)	0.69	0.8 (-1.4 – 3.1)	0.45
	T2-T0	49	0.1 (-0.8 – 1.1)	0.80	22	0.0 (-3.7 – 3.7)	0.98	0.2 (-3.6 – 3.9)	0.93
0.1mm to 0.25mm	T1-T0	62	0.9 (-0.9 – 2.8)	0.31	28	-0.3 (-7.0 – 6.4)	0.92	1.3 (-5.7 – 8.2)	0.71
	T2-T1	49	1.1 (-1.1 – 3.2)	0.32	22	1.7 (-3.3 – 6.7)	0.49	-0.6 (-6.0 – 4.8)	0.82
	T2-T0	49	1.9 (-0.6 – 4.4)	0.14	22	2.2 (-5.8 – 10.1)	0.58	-0.3 (-8.5 – 8.0)	0.95
0.25mm to 0.5mm	T1-T0	62	6.2 (2.6 – 9.7)	**0.0010***	28	1.9 (-5.0 – 8.8)	0.5703	4.2 (-3.5 – 11.9)	0.27
	T2-T1	49	2.7 (-1.8 – 7.2)	0.227	22	3.6 (-2.6 – 9.8)	0.240	-0.9 (-8.3 – 6.6)	0.82
	T2-T0	49	8.0 (2.8 – 13.2)	**0.0031***	22	5.3 (-2.8 – 13.3)	0.1855	2.7 (-6.7 – 12.1)	0.56
0.5mm to 1mm	T1-T0	62	-0.1 (-6.2 – 6.0)	0.97	28	1.6 (-11.1 – 14.4)	0.80	-1.8 (-15.7 – 12.2)	0.80
	T2-T1	49	-2.0 (-9.8 – 5.8)	0.61	22	1.5 (-11.5 – 14.4)	0.82	-3.4 (-18.3 – 11.4)	0.64
	T2-T0	49	-2.6 (-12.2 – 7.1)	0.60	22	1.8 (-16.6 – 20.3)	0.84	-4.4 (-24.9 – 16.1)	0.67
1mm to 2mm	T1-T0	62	15.3 (9.3 – 21.3)	**0.000001***	28	8.1 (-1.8 – 17.9)	0.10442	7.2 (-4.2 – 18.6)	0.21
	T2-T1	49	4.2 (-1.1 0 9.5)	0.117	22	2.7 (-4.9 – 10.4)	0.467	1.5 (-7.7 – 10.6)	0.75
	T2-T0	49	20.3 (12.7 – 28.0)	**0.000001***	22	8.1 (-3.7 – 19.9)	0.16792	12.2 (-1.6 – 26.0)	0.081

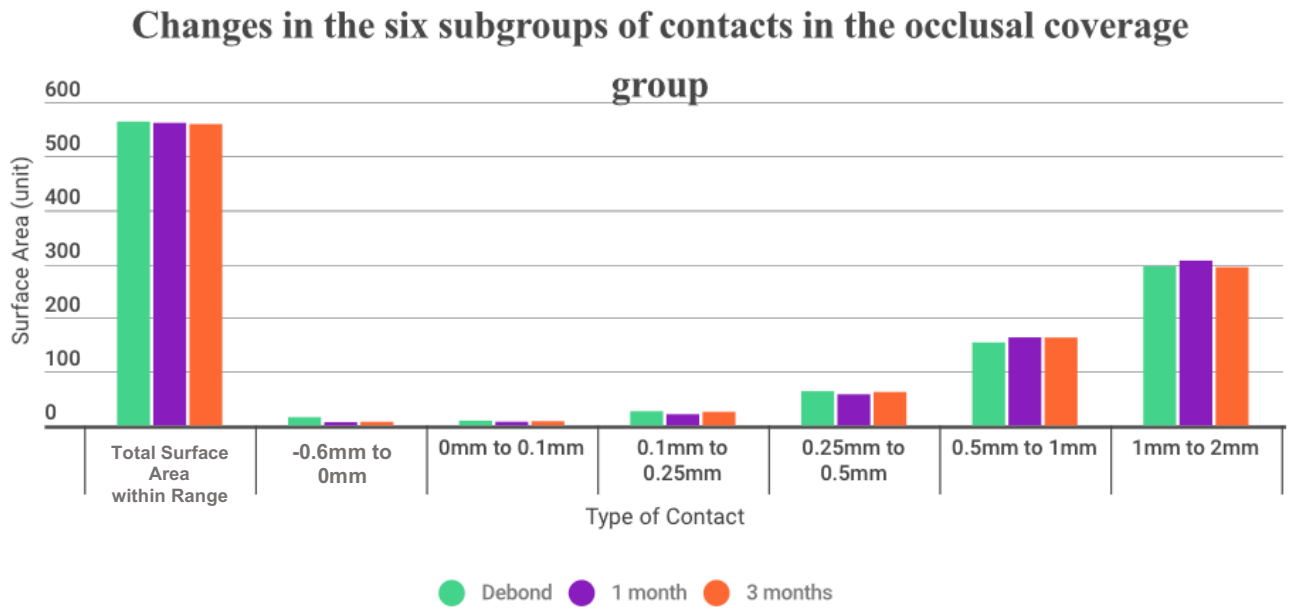
APPENDIX D

Table 7. Data analysis of the effect of retainer protocol in the changes in the inter-occlusal space									
	No Occlusal Coverage Retainers				**Occlusal Coverage Retainers**			**Difference between Groups**	
Category	**Dif.**	**N**	**Mean Dif. (95% CI)**	**p**	**n**	**Mean Dif. (95% CI)**	**p**	**Mean Dif. (95% CI)**	**p**
Total Surface Area within Range	T1-T0	59	23.9 (13.5-34.3)	**0.00002***	22	-2.2 (-17.3 – 13.)	0.77	26.1 (8.1 – 44.2)	**0.006***
	T2-T1	51	8.4 (0.28 – 17.1)	0.057	18	3.1 (-8.82 – 15.0)	0.59	5.4 (-9.0 – 19.8)	0.46
	T2-T0	51	30.4 (17.4 – 43.4)	**0.00002***	18	1.3 (-19.3 – 21.8)	0.90	29.1 (5.3 – 52.9)	**0.018***
-0.6mm to 0.25mm	T1-T0	59	4.6 (0.5 – 8.8)	**0.03***	22	-16.4 (-33.7 – 0.9)	0.06	21.0 (3.3 – 38.8)	**0.02***
	T2-T1	51	0.7 (-4.5 – 5.9)	0.79	18	3.1 (-5.5 – 11.7)	0.46	-2.4 (-12.2 – 7.4)	0.62
	T2-T0	51	5.2 (-0.6 – 9.8)	**0.03***	18	-11.6 (-32.5 – 9.4)	0.26	16.8 (-4.5 – 38.1)	0.12
0.25mm to 2mm	T1-T0	59	19.3 (10.1 – 28.6)	**0.000***	22	14.2 (-4.3 – 32.8)	0.13	5.1 (-15.4 – 25.5)	0.62
	T2-T1	51	7.8 (0.5 – 15.0)	**0.038***	18	0.0 (-8.8 – 8.8)	1.00	7.8 (-3.4 – 18.9)	0.17
	T2-T0	51	25.2 (13.4 – 37.)	**0.000***	18	12.8 (-7.3 – 33.0)	0.20	12.3 (-10.6 – 35.2)	0.28

Table 8. Data Analysis for the six subgroups changes with Retainer Protocol									
	No Occlusal Coverage Retainers				**Occlusal Coverage Retainers**			**Difference between Groups**	
Category	**Dif.**	**N**	**Mean Dif. (95% CI)**	**p**	**N**	**Mean Dif. (95% CI)**	**p**	**Mean Dif. (95% CI)**	**p**
Total Surface Area within Range	T1-T0	59	23.9 (13.5 – 34.3)	**0.00002***	22	-2.2 (-17.3 – 13.0)	0.77	26.1 (8.1 – 44.2)	**0.006***
	T2-T1	51	8.4 (-0.28 – 17.1)	0.057	18	3.1 (-8.82 – 15.0)	0.59	5.4 (-9.02 – 19.8)	0.46
	T2-T0	51	30.4 (17.4 – 43.4)	**0.00002***	18	1.3 (-19.3 – 21.8)	0.90	29.1 (5.3 – 52.9)	**0.018***
-0.6mm to 0mm	T1-T0	59	1.4 (-0.9 – 3.7)	0.23	22	-9.0 (-15.1 - -2.9)	**0.006***	10.4 (4.0 – 16.8)	**0.003***
	T2-T1	51	-0.1 (-2.3 – 2.1)	0.91	18	0.0 (-4.9 – 4.8)	0.99	-0.1 (-5.3 – 5.2)	0.98
	T2-T0	51	1.8 (-0.8 – 4.4)	0.17	18	-9.2 (-17.6 - -0.8)	**0.033***	11.0 (2.3 – 19.7)	**0.016***
0mm to 0.1mm	T1-T0	59	0.3 (-3.0 – 1.0)	0.32	22	-1.9 (-6.8 – 3.0)	0.44	2.2 (-2.7 – 7.1)	0.36
	T2-T1	51	0.2 (-0.7 – 1.2)	0.63	18	0.0 (-1.8 – 1.8)	0.97	0.3 (-1.7 – 2.3)	0.79
	T2-T0	51	0.5 (-0.4 – 1.3)	0.28	18	-1.2 (-5.9 – 3.5)	0.59	1.7 (-3.1 – 6.4)	0.47
0.1mm to 0.25mm	T1-T0	59	2.9 (0.8 – 4.9)	**0.007***	22	-5.5 (-13.1 – 2.0)	0.14	8.4 (0.7 – 16.2)	**0.035***
	T2-T1	51	0.6 (-2.06 – 3.2)	0.66	18	3.2 (-0.49 – 6.8)	0.085	-2.6 (-6.98 – 1.8)	0.24
	T2-T0	51	2.9 (0.7 – 5.2)	**0.010***	18	-1.2 (-11.3 – 8.9)	0.81	4.1 (-6.2 – 14.5)	0.41
0.25mm to 0.5mm	T1-T0	59	8.7 (5.0 – 12.3)	**0.00001***	22	-5.7 (-12.0 – 0.6)	0.074	14.4 (7.2 – 21.6)	**0.0002***
	T2-T1	51	3.1 (-1.4 – 7.6)	0.178	18	2.6 (-3.8 – 9.0)	0.40	0.5 (-7.2 – 8.1)	0.90
	T2-T0	51	9.6 (4.8 – 14.3)	**0.0002***	18	-2.2 (-10.7 – 6.4)	0.60	11.7 (2.1 – 21.3)	**0.018***
0.5mm to 1mm	T1-T0	59	-4.5 (-10.2 – 1.2)	0.12	22	10.4 (-5.4 – 26.3)	0.18	-15.0 (-31.6 – 1.7)	0.08
	T2-T1	51	0.8 (-7.59 – 9.2)	0.85	18	-5.2 (-16.3 – 0.34)	0.34	6.0 (-7.54 – 19.6)	0.38
	T2-T0	51	-1.9 (-11.6 – 7.8)	0.69	18	3.5 (-17.2 – 24.2)	0.73	-5.4 (-27.9 – 17.0)	0.62
1mm to 2mm	T1-T0	59	15.1 (8.7 – 21.6)	**0.00001***	22	9.5 (-1.6 – 20.6)	0.09	5.6 (-7.0 – 18.3)	0.37
	T2-T1	51	3.9 (-1.2 – 8.9)	0.13	18	2.6 (-4.9 – 10.0)	0.48	1.3 (-7.5 – 10.1)	0.77
	T2-T0	51	17.5 (9.8 – 25.3)	**0.00003***	18	11.5 (-1.7 – 24.7)	0.083	6.0 (-9.0 – 21.0)	0.42

APPENDIX E


Changes in the six subgroups of contacts in the no-occlusal coverage group
600
500
400
300
200
100
0
Surface Area (unit)
Total Surface Area within Range
-0.6mm to 0mm
0mm to 0.1mm
0.1mm to 0.25mm
0.25mm to 0.5mm
0.5mm to 1mm
1mm to 2mm
Type of Contact
Debond
1 month
3 months


Changes in the six subgroups of contacts in the occlusal coverage group
600
500
400
300
200
100
0
Surface Area (unit)
Total Surface Area within Range
-0.6mm to 0mm
0mm to 0.1mm
0.1mm to 0.25mm
0.25mm to 0.5mm
0.5mm to 1mm
1mm to 2mm
Type of Contact
Debond
1 month
3 months

APPENDIX F

Table 9. Data Analysis for changes anterior teeth with Retainer Protocol									
	No Occlusal Coverage Retainers				**Occlusal Coverage Retainers**			**Difference between Groups**	
Category	**Dif.**	**N**	**Mean Dif. (95% CI)**	**p**	**N**	**Mean Dif. (95% CI)**	**p**	**Mean Dif. (95% CI)**	**p**
Total Surface Area within Range	T1-T0	59	8.7 (4.0 – 13.4)	**0.00051***	22	1.1 (-5.8 – 8.0)	0.74	7.6 (-0.6 – 15.8)	0.069
	T2-T1	51	2.5 (-1.4 – 6.3)	0.210	18	-1.3 (-7.18 – 4.6)	0.64	3.8 (-3.12 – 10.6)	0.27
	T2-T0	51	11.3 (6.5 – 16.1)	**0.00002***	18	-1.8 (-10.6 – 7.0)	0.67	13.1 (3.3 – 23.0)	**0.011***
-0.6mm to 0.25mm	T1-T0	59	1.2 (-0.5 – 2.9)	0.15	22	0.7 (-1.8 – 3.2)	0.59	0.6 (-2.4 – 3.5)	0.70
	T2-T1	51	-0.3 (-1.7 – 1.2)	0.72	18	0.0 (-3.1 – 3.1)	0.99	-0.3 (-3.6 – 3.1)	0.87
	T2-T0	51	1.4 (-0.4 – 3.1)	0.13	18	-0.6 (-2.7 – 1.6)	0.60	1.9 (-0.8 – 4.6)	0.17
0.25mm to 2mm	T1-T0	59	7.5 (2.8 – 12.1)	**0.002***	22	0.4 (-6.3 – 7.1)	0.89	7.0 (-1.0 – 15.0)	0.08
	T2-T1	51	2.7 (-0.8 0 6.2)	0.130	18	-1.3 (-6.6 – 3.9)	0.60	4.0 (-2.2 – 10.2)	0.19
	T2-T0	51	10.0 (5.4 – 14.6)	**0.0001***	18	-1.3 (-10.4 – 7.9)	0.77	11.2 (1.2 – 21.3)	**0.03***

Table 10. Data Analysis for the six subgroups changes in the anterior teeth with Retainer Protocol									
	No Occlusal Coverage Retainers				**Occlusal Coverage Retainers**			**Difference between Groups**	
Category	**Dif.**	**N**	**Mean Dif. (95% CI)**	**p**	**N**	**Mean Dif. (95% CI)**	**p**	**Mean Dif. (95% CI)**	**p**
Total Surface Area within Range	T1-T0	59	8.7 (4.0 – 13.4)	**0.0005***	22	1.1 (-5.8 – 8.0)	0.74	7.6 (-0.6 – 15.8)	0.07
	T2-T1	51	2.5 (-1.42 – 6.3)	0.210	18	-1.3 (-7.18 – 4.6)	0.64	3.8 (-3.12 – 10.6)	0.27
	T2-T0	51	11.3 (6.5 – 16.1)	**0.00002***	18	-1.8 (-10.6 – 7.0)	0.67	13.1 (3.3 – 23.0)	**0.01***
-0.6mm to 0mm	T1-T0	59	1.0 (-0.3 0 2.2)	0.15	22	0 (-0.8 – 0.9)	0.91	0.9 (-0.6 – 2.4)	0.24
	T2-T1	51	-0.5 (-1.2 – 0.2)	0.19	18	-0.5 (-2.1 – 1.0)	0.48	0.1 (-1.6 – 1.7)	0.94
	T2-T0	51	0.7 (-0.6 – 2.1)	0.29	18	-0.9 (-2.6 – 0.8)	0.28	1.6 (-0.5 – 3.7)	0.13
0mm to 0.1mm	T1-T0	59	-0.1 (-0.5 – 0.3)	0.68	22	0.1 (-0.4 – 0.6)	0.74	-0.2 (-0.8 – 0.5)	0.61
	T2-T1	51	0.1 (-0.2 – 0.5)	0.53	18	0.1 (-0.3 – 0.5)	0.61	0 (-0.5 – 0.5)	1.00
	T2-T0	51	0 (-0.3 – 0.3)	0.97	18	0 (-0.4 – 0.4)	0.93	0 (-0.5 – 0.5)	0.92
0.1mm to 0.25mm	T1-T0	59	0.4 (-0.4 – 1.1)	0.330	22	0.5 (-0.8 – 1.9)	0.41	-0.2 (-1.7 – 1.3)	0.81
	T2-T1	51	0.1 (-0.6 – 0.8)	0.78	18	0.4 (-1.24 – 2.1)	0.59	-0.3 (-2.13 – 1.5)	0.70
	T2-T0	51	0.6 (-0.1 – 1.4)	0.106	18	0.3 (-0.5 – 1.2)	0.43	0.3 (-0.9 – 1.4)	0.64
0.25mm to 0.5mm	T1-T0	59	1.2 (0.2 – 2.3)	**0.02***	22	1.8 (0.1 – 3.5)	**0.04***	-0.5 (-2.5 – 1.4)	0.59
	T2-T1	51	0.6 (-0.6 – 1.7)	0.339	18	0.2 (-1.5 – 1.8)	0.81	0.4 (-1.6 – 2.3)	0.71
	T2-T0	51	1.8 (0.4 – 3.3)	**0.013***	18	1.1 (-0.7 – 2.8)	0.22	0.8 (-1.4 – 3.0)	0.47
0.5mm to 1mm	T1-T0	59	3.4 (1.6 – 5.3)	**0.0005***	22	2.5 (-1.1 – 6.1)	0.16	1.0 (-3.0 – 4.9)	0.63
	T2-T1	51	0.5 (-1.2 – 2.1)	0.59	18	-0.4 (-3.1 – 2.3)	0.76	0.9 (-2.3 – 4.0)	0.58
	T2-T0	51	4.1 (2.0 – 6.2)	**0.0003***	18	0.7 (-3.1 – 4.4)	0.72	3.4 (-0.8 – 7.7)	0.11
1mm to 2mm	T1-T0	59	2.8 (-1.1 – 6.7)	0.16	22	-3.8 (-9.7 – 2.1)	0.20	6.6 (-0.4 – 13.6)	0.06
	T2-T1	51	1.7 (-1.56 – 4.9)	0.30	18	-1.1 (-5.28 – 3.0)	0.57	2.8 (-2.32 – 8.0)	0.27
	T2-T0	51	4.0 (-0.3 – 8.4)	0.07	18	-3.0 (-12.2 – 6.2)	0.51	7.0 (-3.0 – 17.0)	0.16

Table 11. Data Analysis for changes posterior teeth with Retainer Protocol									
	No Occlusal Coverage Retainers				Occlusal Coverage Retainers			Difference between Groups	
Category	**Dif.**	**N**	**Mean Dif. (95% CI)**	**p**	**N**	**Mean Dif. (95% CI)**	**p**	**Mean Dif. (95% CI)**	**p**
Total Surface Area within Range	T1-T0	59	15.3 (7.5 – 23.0.0	**0.0002***	22	-3.3 (-14.6 – 8.1)	0.56	18.5 (5.0 – 32.0)	**0.008***
	T2-T1	51	6.0 (-1.18 – 13.2)	0.100	18	4.4 (-3.51 – 12.3)	0.26	1.6 (-8.8 – 12.0)	0.76
	T2-T0	51	19.1 (8.5 – 29.7)	**0.0007***	18	3.1 (-11.8 – 18.0)	0.67	16.0 (-1.9 – 33.8)	0.08
-0.6mm to 0.25mm	T1-T0	59	3.4 (-0.6 – 7.4)	0.09	22	-17.1 (-35.9 – 1.7)	0.07	20.5 (1.3 – 39.6)	**0.04***
	T2-T1	51	0.9 (-3.6 – 5.5)	0.68	18	3.1 (-5.5 – 11.7)	0.46	-2.1 (-11.7 – 7.4)	0.65
	T2-T0	51	3.9 (-0.3 – 8.0)	0.07	18	-11.0 (-31.8 – 9.7)	0.28	14.9 (-6.2 – 35.9)	0.16
0.25mm to 2mm	T1-T0	59	11.9 (5.0 – 18.7)	**0.001***	22	13.8 (-1.2 – 28.8)	0.07	-1.9 (-18.2 – 14.3)	0.81
	T2-T1	51	5.0 (-0.6 – 10.7)	0.079	18	1.3 (-6.3 – 8.9)	0.72	3.7 (-5.5 – 13.0)	0.42
	T2-T0	51	15.2 (5.7 – 24.8)	**0.002***	18	14.1 (-1.8 – 30.1)	0.08	1.1 (-17.1 – 19.3)	0.90

Table 12. Data Analysis for the six subgroups changes in the posterior teeth with Retainer Protocol									
	No Occlusal Coverage Retainers				Occlusal Coverage Retainers			Difference between Groups	
Category	**Dif.**	**N**	**Mean Dif. (95% CI)**	**p**	**N**	**Mean Dif. (95% CI)**	**p**	**Mean Dif. (95% CI)**	**p**
Total Surface Area within Range	T1-T0	59	15.3 (7.5 – 23.0)	**0.0002***	22	-3.3 (-14.6 – 8.1)	0.56	18.5 (5.0 – 32.0)	**0.008**
	T2-T1	51	6.0 (-1.18 – 13.2)	0.100	18	4.4 (-3.51 – 12.3)	0.26	1.6 (-8.8 – 12.0)	0.76
	T2-T0	51	19.1 (8.5 – 29.7)	**0.0007***	18	3.1 (-11.8 – 18.0)	0.67	16.0 (-1.9 – 33.8)	0.08
-0.6mm to 0mm	T1-T0	59	0.4 (-1.5 – 2.4)	0.65	22	-9.1 (-15.3 - -2.8)	**0.007***	9.5 (3.0 – 16.0)	**0.006**
	T2-T1	51	0.3 (-1.7 – 2.4)	0.74	18	0.5 (-4.3 – 5.3)	0.83	-0.1 (-5.3 – 5.0)	0.95
	T2-T0	51	1.1 (-1.2 – 3.3)	0.34	18	-8.3 (-16.7 – 0.1)	0.053	9.4 (0.7 – 18.0)	**0.035**
0mm to 0.1mm	T1-T0	59	0.4 (-0.2 – 1.0)	0.17	22	-1.9 (-7.2 – 3.3)	0.45	2.4 (-2.9 – 7.6)	0.36
	T2-T1	51	0.1 (-0.7 – 0.9)	0.75	18	-0.1 (-2.1 – 1.9)	0.88	0.3 (-1.8 – 2.4)	0.80
	T2-T0	51	0.5 (-0.3 – 1.2)	0.25	18	-1.2 (-5.9 – 3.5)	0.60	1.6 (-3.1 – 6.4)	0.48
0.1mm to 0.25mm	T1-T0	59	2.5 (0.6 – 4.4)	**0.01***	22	-6.1 (-14.4 – 2.3)	0.15	8.6 (0.1 – 17.1)	**0.048***
	T2-T1	51	0.5 (-1.81 – 2.8)	0.68	18	2.7 (-0.31 – 5.7)	0.08	-2.2 (-5.94 – 1.5)	0.23
	T2-T0	51	2.3 (0.5 – 4.2)	**0.015***	18	-1.5 (-11.3 – 8.3)	0.75	3.9 (-6.1 – 13.8)	0.43
0.25mm to 0.5mm	T1-T0	59	7.5 (4.0 – 10.9)	**0.00006***	22	-7.5 (-14.1 - -0.8)	**0.03***	14.9 (7.5 – 22.3)	**0.0002***
	T2-T1	51	2.5 (-1.6 – 6.6)	0.23	18	2.4 (-3.1 – 8.0)	0.37	0.1 (-6.7 – 6.8)	0.98
	T2-T0	51	7.7 (3.6 – 11.8)	**0.0004***	18	-3.2 (-11.4 – 4.9)	0.42	10.9 (2.0 – 19.9)	**0.019***
0.5mm to 1mm	T1-T0	59	11.7 (6.3 – 17.1)	**0.00006***	22	7.0 (-1.9 – 16.0)	0.12	4.7 (-5.6 – 15.0)	0.36
	T2-T1	51	3.4 (-1.2 – 8.0)	0.14	18	3.0 (-3.8 – 9.7)	0.37	0.5 (-7.5 – 8.5)	0.91
	T2-T0	51	13.4 (6.7 – 20.2)	**0.00020***	18	10.9 (-1.4 – 23.1)	0.08	2.6 (-11.2 – 16.3)	0.70
1mm to 2mm	T1-T0	59	-7.3 (-12.9 - -1.7)	**0.01***	22	14.2 (-0.7 – 29.1)	0.06	-21.6 (-37.3 - -5.8)	**0.01***
	T2-T1	51	-0.9 (-8.22 – 6.5)	0.81	18	-4.1 (-15.7 – 7.6)	0.47	3.2 (-10.28 – 16.7)	0.63
	T2-T0	51	-5.9 (-14.6 – 2.7)	0.17	18	6.5 (-12.1 – 25.0)	0.47	-12.4 (-32.6 – 7.7)	0.22