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Effect of Centric Interference on Canine Tooth Wear

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Effect of Centric Interference on Canine Tooth Wear

by

Andrey Gaiduchik

A Thesis submitted in partial satisfaction of
the requirements for the degree
Master of Science in Orthodontics and Dentofacial Orthopedics

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Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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I would also like to thank my wife, Aneta, and my daughter Mila for motivating and supporting me. To my parents, thank you for pushing me.

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ABBREVIATIONS

3D	Three dimensional
ABO	American Board of Orthodontics
ANB	Angle formed by A point, Nasion and B point
CO	Centric occlusion
CPI	Condylar positioning instrument
CR	Centric relation
CTW	Individual canine tooth wear
df	Degrees of freedom
DL	Distolingual cusp
E/M/H	Easy, medium, and hard from difficulty of bite registration
EMG	Electromyography
F	Female
GERD	Gastroesophageal reflux disease
ICC	Intra-class correlation
LL	Lower left
LLU	Loma Linda University
LR	Lower right
M	Male
MIP	Maximum intercuspation position
SSRI	Selective serotonin reuptake inhibitor
stl	Stereolithography
T1	Time-point 1

T2	Time-point 2
T4	Time-point 4
TFH	Total face height
TMD	Temporomandibular dysfunction
TMJ	Temporomandibular joint
TTW	The addition of all canine analyzed per timepoint
TW	Tooth wear
TWI	Tooth wear index
UL	Upper left
UR	Upper right
VDO	Vertical dimension of occlusion

ABSTRACT

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by

Andrey Gaiduchik

Master of Science, Graduate Program in Orthodontics and Dentofacial Orthopedics
Loma Linda University, September 2018
Dr. V. Leroy Leggitt, Chairperson
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Purpose: The aim of this study was to determine the long term effect of a centric interference on canine tooth wear (CTW) and on centric occlusion (CO) and maximal intercuspation (MIP) variance.

Materials and Methods: Thirty subjects, 11 males and 19 females, were selected based on inclusion and exclusion criteria. Changes in enamel volume were studied between the end of orthodontic treatment (T2) and at least seven years post treatment (T4). All models were scanned using a high resolution desktop scanner, (OrthoInsight 3D Scanner™, MotionView LLC). T4 models were articulated using a Panadent® Articulator and evaluated for dental interferences and CO/MIP variance using the incisal pin locator. The canines were evaluated for volumetric CTW from T2 to T4 using Geomagic Control (3D Systems, South Carolina 2014). Intraclass correlation test was used to evaluate repeatability. A Chi-Square correlation test was used to evaluate the relationship between interference and CTW. A Spearman-rho test was used to evaluate the relationship between CTW and CO/MIP discrepancy.

Results: The presence of a posterior interference, indicated by an initial contact in CO, was present in all subjects. Sixty-seven percent of subjects showed greater CTW opposite the side of the interference, which was not statistically significant ($p=0.114$). There was a relationship between an interference on the left side and CTW on the opposite side ($p=0.039$) but no relationship between a right interference and CTW ($p=0.308$). CO/MIP discrepancy had a moderate correlation with TW ($rho=0.558$, $p=0.001$). The mean CTW/year was 0.13 ± 0.16 mm^3. Males had $0.22 \pm .21$ mm^3 and females had 0.07 ± 0.16 mm^3 of CTW/yr, which was a statistically significant difference ($p=0.008$). Sixty percent of the centric interferences were due to the maxillary second molar.

Conclusions: No statistical relationship was found between centric interferences and CTW. There was a relationship between a left centric interference and CTW, but no relationship between a right centric interference and CTW. There was a moderate relationship between CTW and CO/MIP discrepancy. There was a statistically significant difference in CTW between males and females. Most of the interferences were due to the disto-lingual cusp of the maxillary second molars.

CHAPTER ONE

REVIEW OF LITERATURE

Introduction

The evaluation of orthodontic treatment finishing, occlusion, and stability has been discussed in the literature. For most orthodontists, a final treatment outcome goal includes a correction to Andrew's Six Keys to be considered a "good" finish. During the treatment, orthodontists would monitor patients for caries risk, dental sensitivity, periodontal diseases, joint sensitivity, and pathologies to reach the final goal of a good occlusion. There is support in the literature that defines the optimal joint position as another measure of an excellent finish.[8, 28] This would be the physiologic goal of treatment. Some have suspected that when static occlusion is not in line with physiologic goals, then dental and muscular symptoms could increase. Despite an optimal static occlusion, dental interferences may still exist that would cause some physiologic compensation of function to avoid the interference. The neuromuscular system would direct the mandible to the opposite canine that would lead to some identifiable asymmetrical tooth wear.[4, 16] Although tooth wear has been measured in the literature, it has not been measured in relation with a dental interference.

Tooth Wear

Loss of tooth structure is considered permanent, irreversible and problematic in that it affects aesthetics and occlusion. Normal tooth wear occurs continuously throughout the aging process, though the observed effects vary greatly from one person to another.[4] Tooth wear affects the area of the tooth by 1) tooth to tooth contact on proximal, occlusal and incisal surfaces. This takes place during mastication, swallowing, and bruxism. Another way tooth wear can occur is by 2) tooth abrasion. Tooth abrasion is the mechanical and pathological wearing of the tooth that occurs through brushing and clenching.[4] 3) Tooth erosion is the final type. This is primarily caused through chemical wear, such as eating acidic foods or GERD. The International Classification of Diseases, published by the World Health Organization (WHO), described tooth wear as a tooth disease. Once the process occurs, it requires treatment if it is severe enough.

Some treatments due to excessive tooth wear require restoring the vertical dimension of occlusion. Loss of VDO can be a significant problem for some people. Hand et al. found that in a sample of 520 subjects, 84.2% had enamel attrition, 72.9% had dentin attrition, and 4.2% had severe attrition.[29] Sivasithamparam et al. found that 11.6% of 448 adult patients had either near-pulpal exposures or pulp exposures.[7]

Tooth wear during or after orthodontic treatment has been discussed in the literature, however the definitive casual relationship is yet to be determined. One study showed that attrition in adults is correlated with attrition in mixed dentition though it was not determined to be predictable.[3] Patients who had attrition during orthodontic treatment were more likely to have more attrition 20 years post treatment, regardless of their finished occlusion at the end of orthodontic treatment. Out of this study, they found that patients had more tooth wear as they aged. The authors in this study used TWI's to evaluate tooth wear. Although a categorical scoring system can be reliable with some calibration, there are many disadvantages to it because there is no quantifiable information about the tooth wear.

Another study evaluated occlusal wear of anterior teeth in orthodontic patients with different retainers up to five years of post treatment.[24] Dental casts were analyzed before treatment, after treatment, and five years post-treatment using a grading scale. The authors concluded that there was an increase in tooth wear for all teeth, regardless of the retainer, but the amount of tooth loss was clinically negligible. However, an increase in intercanine width during treatment was associated with a slower progression of tooth wear. Other studies evaluated the association between orthodontic treatment and tooth wear, and concluded that orthodontic treatment did not lead to increased tooth wear.[26]

Methods were developed to evaluate the progression and quantity of tooth wear.[22] In a cohort study, Rodriguez et al. discovered TW was 0.03 mm^3 per year, using Geomagic Qualify 11. The authors concluded that tooth wear was slow in this cohort, suggesting that tooth wear may be cyclical in nature or inactive in this population.

Pintado et al. investigated the enamel loss in 18 young adults (dental students between 22 and 30 years old) for two years using a profiling system on epoxy replicas of the teeth.[6] Their results showed that the mean volume loss for canine was 0.087 mm^3 per year. Park et. al., using Rapidform XOR3, evaluated cuspids from start of treatment (T1) to the end of treatment (T2) and discovered a mean volume of tooth wear on 224 canines to be 2.0 mm^3 over a 35.5 month period of treatment.[23]

For some individuals, the tooth wear may be negligible, while others may require intervention and treatment. Because tooth wear is multifactorial, understanding as much as possible about the etiology could be beneficial to the patient’s long term overall health.

Significance of CO and MIP

One of the areas of controversy in orthodontics is the topic of centric relation and occlusion. Andrew's Six Keys has often been the final occlusal goal.[30] Traditional and orthognathologic orthodontists differ as to what the optimal final orthodontic treatment should look like.[9, 12, 13]

Gnathology oriented orthodontists aim to have centric occlusion coincide with maximum intercuspation, whereas, traditional orthodontists tend to use hand held models, and favor treatment goals that include the attainment of the best occlusal relationship with the framework of optimal dentofacial esthetics, function and stability through the function of MIP.[8, 30]

To understand the differing philosophies, it is best to first establish a consensus for the definitions in use:

Centric relation is defined as a musculoskeletal stable position of the joint, that is anatomically determined, repeatable and reproducible. The Academy of Prosthodontists defines CR as "The maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the condyle in the anterior-superior position against the slopes of the articular eminence." This position is independent of tooth contact.[31, 32]

Maximum intercuspation (MIP) is a dentally determined position. The condylar position is determined by the maximal dental contacts, with tooth morphology determining the position of the mandible.[9, 11] Academy of Prosthodontists defines MIP as "the complete intercuspation of the opposing teeth independent of condylar position, sometimes referred to as the best fit of the teeth regardless of the condylar position."[31]

Centric occlusion is defined by the Academy of Prosthodontist as “the occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximal intercuspal position.”[31, 32]

With this in mind, gnathalogical orthodontists believe that orthodontists should treat patients to a desirable physiologic goal,[11] which is believed to provide long term stability of the joints and occlusion, healthy muscles and joints, and improved function and esthetics.[9] The treatment of orthodontics has evolved from just Andrews’ Six Keys to that of “coordination of tooth position with jaw function.”[11] Dr. Andrews proposed static occlusal goals for orthodontic treatment, where guidelines are given for the position of teeth. Dr. Roth further added keys that contributed to the physiological goals that related to the occlusal goals.[11] The goal of gnathological orthodontists was for the mandible to seat ideally in MIP, without condylar deflection from CR due to interferences.[32] If occlusal interferences existed, causing a deflection of condyles away from CR in MIP, then there was “an imbalance between the inferior lateral pterygoid and elevator muscles, which triggered muscle hyperactivity leading to development of TMD.”[32] Any disharmony was believed to contribute to the development of TMD.[32, 33]

Traditional orthodontists strive for the best occlusal relationship in regards to function, esthetics, and stability at MIP.[30] Rinchuse and Kandasamy presented opposing views with regards to placing the condyles into CR and MIP.[12, 13, 34] One of the reasons behind this is that they believed there is not enough evidence, and that gnathologic orthodontists proposed goals based on clinical experience.[34] Because TMD is a multifactorial issue and occlusion is just one of the issues, it was concluded that TMJ’s not in CR would not lead to TMD.[34]

To register a patient in centric relation, it is necessary to mount the patient's models in an articulator using a proper bite registration.[9-11, 28, 32, 33, 35] Most studies that review CO and MIP and TMJ positions, made a bite registration in MIP, an additional bite registration in CR, and a facebow registration. The casts are mounted with the CR bite registration. The widely held belief that the patient's accommodated neuromusculature system guides the mandible into occlusion, avoiding any existing interferences because the intercuspal position is dominant over the condylar position.[8, 16] So, it was also necessary to deprogram the neuromusculature prior to a bite registration.[11, 28, 33] In a prospective study, Cordray examined 596 patients to evaluate the 3D arch displacement and condylar displacement between CO and MIP.[11] After mounting the models, he observed that the dental discrepancy in CO was significantly different from MIP, with more posterior contacts (94%), increased overjet, decreased overbite, midline differences, and Angle classification changes. He found a significant difference between occlusion when dictated by the teeth vs when it was dictated by the condyles.[11]

Discrepancies in CO and MIP can occur in the cephalometric analysis as well.[35] Tracings were compared from a MIP tracing with those converted to a centric relation tracing. There were 68 patients who had a CO/MIP discrepancy of 2 mm or greater in either direction, measured in the condyles. They recommended that for a correct orthodontic diagnosis the mandible should be placed in centric relation.

There have been several studies published to show the discrepancy between CO and MIP.[9, 11, 19, 36, 37] In these studies, only Cordray[11] and Karl[19] utilized neuromuscular deprograming prior to a bite registration. Deprogramming is considered important because the neuromusculature may change the closure of the mandible if there is an occlusal interference.[33] There are several useful methods that aid in deprogramming, they include[16, 18, 19]: 1) having the patient bite anteriorly on a cotton roll, 2) anterior Lucia jig, and 3) a leaf gauge.[33] Costea found in their study that 85% of the patients had vertical and 87.5% had horizontal discrepancy for both condyles, and 87.5% had a significant condylar displacement in at least one of the three planes.[9] They suggested that treatment should consider the condyles before treatment to establish the correct diagnosis.

In a similar study, the authors investigated the relationship between CO/MIP discrepancy and TMD in pre-treated orthodontic patients with signs and symptoms of TMD.[32] In their study, they used 107 pre-treated orthodontic patients and a control group of 70 patients that were asymptomatic. They found that 72.9% in the experimental group and 11.4% in the control group had a positive CO/MIP discrepancy. Patients with a CO/MIP discrepancy had a significant relationship with TMD signs and symptoms.

In contrast, some evidence has been suggested that MIP does not have to be coincident with CO and that discrepancies can range up to 4 mm.[34] Ramfjord suggested that patients could tolerate discrepancies of 1.5 mm horizontally and 1.5 mm vertically and 0.5 mm transversely.[30] This suggests that instead of having one position of the joint, there may be a range to normal physiologic function.

Interferences

As mentioned, tooth wear has been linked to many factors. Clark et al have reported that interferences, such as high fillings or premature contacts, could lead to periodontal and pulpal issues.[1] Some patients with interferences, experienced jaw muscle pain, clicking, disruption of smooth jaw function, and local tooth pain. However, it could not be proven that interferences caused bruxism.[1] Ramjford showed that there was an individual tolerance level that would determine if patients would have pain in the presence of an interference.[30]

Some studies show that patients have an adaptive behavior towards experimental interferences, while others do not.[5] Bell evaluated artificial interferences between subjects with and without a history of TMD. Subjects with a history of TMD reported stronger symptoms with the presence of an interference, compared to those without. There was more sensitivity towards occlusal discomfort and chewing difficulties. People have varying degrees of adaptive capabilities, and those with a history of TMD, may have more difficulty.[5]

Methods of Analyzing Tooth Wear

Analyzing tooth wear has always been difficult due to the inability of extrapolating quantifiable data. Previously, tooth wear has been assessed clinically using TWI's.[3, 7, 29] Severe tooth wear can be assessed clinically, however the quantity could not be determined. With the advent of various software applications, it is possible to evaluate quantitative tooth wear digitally using 3D analysis. Pintado et al. used AnSur Software[6] and Rodriguez et al. used Geomagic Qualify 11.[22]

Park et al. also examined tooth wear using a 3D reverse engineering software (Rapidform XOR3, INUS Technology, Seoul, Korea).[23] Volumetric changes in canines from T1 to T2 were evaluated by superimposing the buccal and lingual surfaces of the scanned teeth. The superimposed teeth were reconstructed into solid objects and the volume difference was calculated.

The use of 3D software analysis has been used by various industries. There are many uses for 3D analysis in dentistry that have been utilized by Suresmile®, Invisalign, RMO Dental Monitoring™ and other companies to analyze dental tooth movements. Geomagic is a 3D software that has been used to control, design and inspect manufacturing in industries such as automotive, aerospace, and recently healthcare. One of the applications of this software could be used to analyze dentition, specifically tooth wear. By taking two similar digital objects, it is possible to evaluate subtle differences. No other studies have been found evaluating tooth wear due to centric interferences.

CHAPTER TWO

EFFECT OF CENTRIC INTERFERENCE ON CANINE TOOTH WEAR

Abstract

Purpose: The aim of this study was to determine the long term effect of a centric interference on canine tooth wear (CTW) and on centric occlusion (CO) and maximal intercuspation (MIP) variance.

Materials and Methods: Thirty subjects, 11 males and 19 females, were selected based on inclusion and exclusion criteria. Changes in enamel volume were studied between the end of orthodontic treatment (T2) and at least seven years post treatment (T4). All models were scanned using a high resolution desktop scanner, (OrthoInsight 3D Scanner™, MotionView LLC). T4 models were articulated using a Panadent® Articulator and evaluated for dental interferences and CO/MIP variance using the incisal pin locator. The canines were evaluated for volumetric CTW from T2 to T4 using Geomagic Control (3D Systems, South Carolina 2014). Intraclass correlation test was used to evaluate repeatability. A Chi-Square correlation test was used to evaluate the relationship between interference and CTW. A Spearman-rho test was used to evaluate the relationship between CTW and CO/MIP discrepancy.

Results: The presence of a posterior interference, indicated by an initial contact in CO, was present in all subjects. Sixty-seven percent of subjects showed greater CTW opposite the side of the interference, which was not statistically significant (p=0.114). There was a relationship between an interference on the left side and CTW on the opposite side (p=0.039) but no relationship between a right interference and CTW (p=0.308). CO/MIP discrepancy had a moderate correlation with TW (rho=0.558, p=0.001). The mean CTW/year was 0.13±0.16 mm^3. Males had 0.22±.21 mm^3 and females had 0.07±0.16 mm^3 of CTW/yr, which was a statistically significant difference (p=0.008). Sixty percent of the centric interferences were due to the maxillary second molar.

Conclusions: No statistical relationship was found between centric interferences and CTW. There was a relationship between a left centric interference and CTW, but no relationship between a right centric interference and CTW. There was a moderate relationship between CTW and CO/MIP discrepancy. There was a statistically significant difference in CTW between males and females. Most of the interferences were due to the disto-lingual cusp of the maxillary second molars.

Introduction

Tooth wear can occur by attrition (physical), abrasion (mechanical) or erosion (chemical), which has been linked to several factors including stress related clenching, bruxism, supraocclusal restorations and malpositioned teeth.[1-4] Various studies have shown that the effects of dental interferences and premature contacts are associated with increased dental symptoms, but tooth wear was not one of the factors examined .[1, 5] Previous studies have shown that all individuals exhibit tooth wear to varying degrees and that different factors contribute to overall TW.[5, 6] Severe tooth structure loss may require restoration.[7]

Most authors consider Andrew's Six to be the standard in establishing a static, esthetic, and stable occlusion. Some authors have stated that along with static goals there should be functional goals for occlusal relationships that results in a centric relation joint position with.[8] If there was a discrepancy between CO and MIP, occlusion differed from the MIP or the CO position. [9, 10] Although some authors believe that centric relation should be the goal of occlusal treatment,[8, 11] other authors have described the CR as subjective.[12, 13]

In cases where a discrepancy existed between CO and MIP, the result was a dental interference.[1] If the subjects had coincident CO and MIP, occlusions were shown to be stable for a longer time.[14, 15] These patients showed little tooth wear and no interferences. However in cases with posterior interferences, the patients would avoid these interferences, using contact guidance on the anterior teeth.[16, 17] The neuromuscular system would direct the mandible to the canine opposite of the interference, which resulted in increased canine tooth wear. Eventually, the tooth wear would progress to the anterior and posterior teeth resulting in an unaesthetic and unstable occlusion. If these observations were correct, it may be possible to treat occlusion to prevent increased tooth wear and that discourages tooth wear as the patient ages.[15] However, there have not been long term studies to evaluate the effects of dental interferences.

Null Hypothesis

There is no relationship between canine tooth wear and contralateral centric interferences.

Methods and Materials

Patient Selection

Approval for this study was granted by an Institutional Review Board (#5170224). Thirty subjects were evaluated more than seven years after the finish of orthodontic treatment (T4). The post treatment orthodontic records (T2) of potential subjects were prescreened for inclusion criteria before being scheduled for data collection. Subjects were selected based on their willingness to participate in the study and on inclusion/exclusion criteria (Table 1). Included subjects were at least 18 years old at T4 and with canine Class 1 at T2, ANB angle of 0-4º depicted on a lateral cephalometric tracing at T2, undamaged T2 casts, had at least one molar and one premolar in each quadrant and had completed treatment at least seven years before T4. Exclusion criteria included patients who had any dental adjustments made to the canines after T2, subjects with a removable prosthesis, history of GERD or bulimia, medication history of antidepressants, muscle relaxants or SSRI's, or a history of TMJ treatment.

Records from patients who met the selection criteria were reviewed and the following data recorded: 1) chart number, 2) gender, 3) date of birth, 4) date of T2, and 5) ANB angle.

Data Collection

At the data collection appointment, subjects filled out a questionnaire (Appendix A) that evaluated for any exclusion and were given informed consent (Appendix B). Each subject underwent deprogramming of the mandibular musculature for 10 minutes. The deprogramming consisted of the patient biting horizontally on a cotton roll placed, in a right to left position, directly behind the maxillary anterior teeth with the mandibular anterior teeth passively resting on the cotton roll.[18, 19]

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria
1. T2 Class I canine dental occlusion 2. T2 ANB angle of 0-4º depicted on lateral cephalometric tracing 3. T2 models with undamaged canines 4. At least one molar and one premolar in each quadrant at T2 5. Subject’s age should be at least 18 years old 6. Subjects who completed treatment seven years or more between T2 and T4
Exclusion Criteria
1. Any adjustments made to the canines after T2 by restoration or removal of structure 2. Subject with crowns, veneers or fixed partial dentures on the canines 3. Subject with any removable prosthesis 4. Subject history of GERD or bulimia 5. Health history of usage muscle relaxants or SSRI’s 6. History of TMJ treatment

After deprogramming, an occlusal registration was made using the posterior segments for the registration (Figure 1).[16, 17] The registration was recorded using Panadent trays, manufactured by Panadent Corporation. These trays extended just distal to the first molars. Vanilla Bite material was applied to register the maxillary occlusion. A stop in the mandibular anterior region was constructed with green compound, at the point where the lower incisors contacted the tray. The lower incisors were guided into an anterior stop guided by the clinician.[16-18] This enabled the condyles to move to an anterior superior position determined by deprogramming. The anterior stop was adjusted, so the posterior clearance was approximately 1.5 mm from the tray. The mandibular posterior tooth recording was captured using Vanilla Bite registration material.

The maxillary arch position was captured using an ear bow. Intra-oral photographs were taken in MIP and alginate impressions were made. Refer to Table 2 for a summary of the data collection sequence. The impressions were poured within 10 minutes using orthodontic plaster (Modern Materials®, South Bend, Indiana), using the recommended mixing ratio of 100 grams of plaster with 35 ml of water mixed with a Vac-u-Mixer.

Table 2. Data Collection Sequence

Data Collection Sequence during the Appointment
1. A questionnaire to evaluate for inclusion/exclusion
2. Biting on a cotton roll between the anterior teeth for 10 minutes
3. Occlusal registrations made in CR
4. Ear bow registration
5. T4 alginate impressions and Intraoral photographs

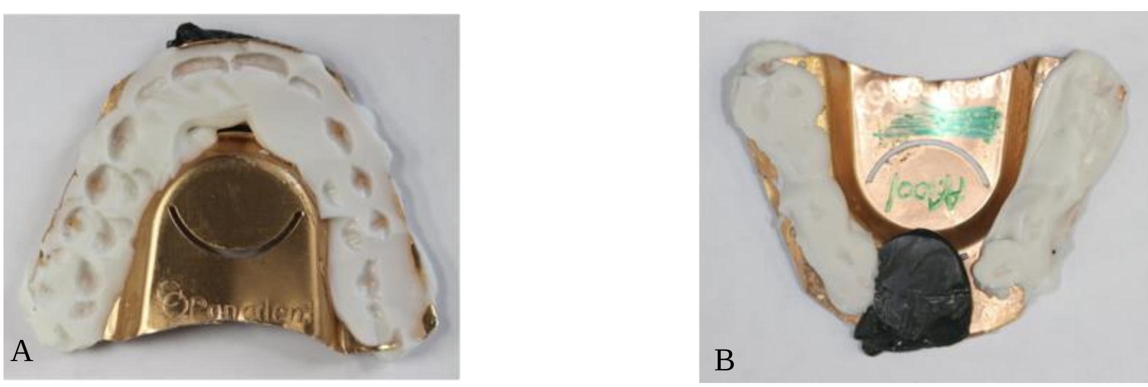

Figure 1. Occlusal Registration Trays. **A)** Maxillary view **B)** Mandibular view. An example of the type of an open centric bite registration.

Lab Protocol

The models from T2 and T4 were compared for possible distortion. First molar crown B/L widths were measured on T2 and T4 models with digital calipers with an accuracy of +/- 0.02 mm (VINCA Digital Caliper DCLA-0605, Clockwise Tools, Valencia, CA). A suggested clinically acceptable range is between 0.09-0.24 mm.[20] If distortion error was greater than this suggested range, another set of impressions were made to determine if the distortion error occurred at T4. If the consecutive T4 models matched, then the distortion error was produced during T2 model production.

The accepted T4 casts were scanned using the Ortho Insight 3D scanner. The T4 casts were then mounted on a Panadent articulator using a Panadent Ear Bow and the CR registration. To determine centric occlusion, the centric pin was left in the locked position, the incisal pin raised and the occlusal registration removed. The superior arm of the articulator was then gently lowered to the mandibular cast where the first point of contact recorded using 0.021 mm Accufilm. If contacts occurred on both sides, 0.012 mm Shimstock was used to determine first point of contact. The position of this contact point and the corresponding tooth number was recorded.

To determine the CO/MIP discrepancy, the centric pin on the articulator was unlocked and the casts were gently hand articulated into MIP on the articulator. The incisal pin was then “dropped” and tightened onto the incisal guide table to record MIP position. The articulator was locked back into the CR position while the pin remained in its locked position at MIP. While the casts were touching in CO, the distance the incisal pin was from the incisal guide table was recorded. Vanilla Bite was applied to the incisal guide table and the maxillary arm of the articulator was lowered into a small amount of the Polyvinylsiloxane (PVS) registration material. The deepest portion of this registration was measured with digital calipers and recorded three different times, then averaged to document the difference between CO and MIP.

Tooth Wear Measurements

All the 3D models were imported into 3D Systems Geomagic Control 2014, and evaluated for estimated volumetric changes in the canine crowns. 120 pairs of canines (T2 and T4) were segmented from the digital models of 30 patients (Figure 2). The canines at T2 and T4 were initially superimposed using the middle thirds of the labial and lingual surfaces for references, and then a better fit was established with a global registration (Figure 3). The software calculates thousands of points between the two models and finds a best-fit that would have the smallest standard deviation between the points of T2 and T4 canines (Figure 4). To calculate the volume, the 3D canine had to be reconstructed as a solid object. The final volume was a calculation of the constructed 3D object. Therefore, three boundary planes were used to construct a 3D solid object. The planes allowed for the two models to have identical sides, with the only difference being on the incisal. The mesial and distal planes were created parallel to the long axis of the canine of about 1.5 mm from the mesial and distal contact points (Figure 5AB). The gingival plane was perpendicular to the mesial and distal planes and cut off at the incisal third of the canine (Figure 5C). The surfaces were then filled and the volumetric differences between T2 and T4 canines were calculated (Figure 5D).

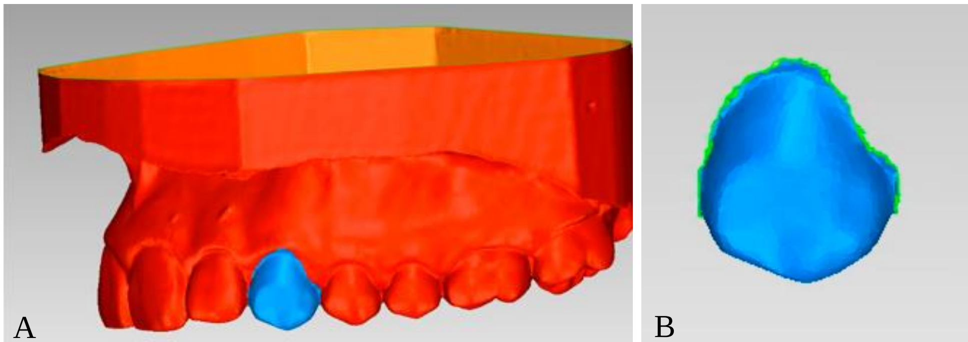

Figure 2. Geomagic Canine Segmentation. **A)** The tooth to be examined, needs to be sectioned on the software. Blue is the selected area. **B)** The remaining section after the rest of the model was removed.

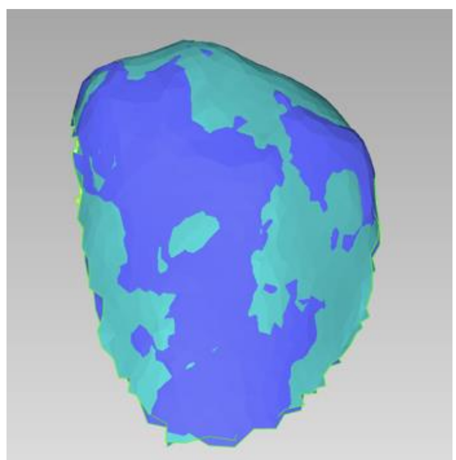

Figure 3. Geomagic Global Registration. Canines from T2 and T4, represented by different colors, are superimposed with a best fit, showing areas of overlapping tooth surfaces.

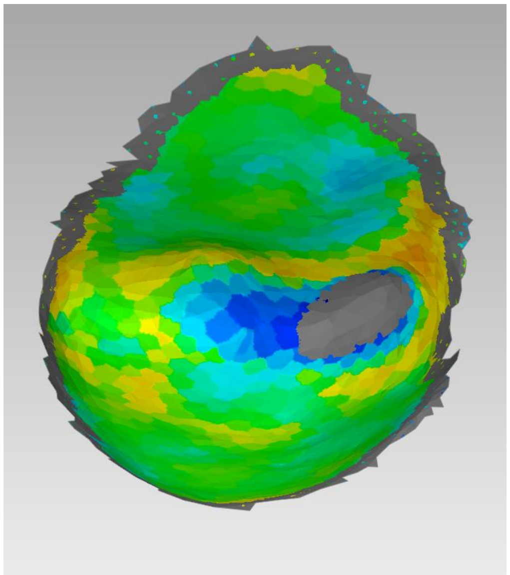

Figure 4. Geomagic 3D Superimposition Color Map. Image is of T2 canine with green showing no change, blue/purple – volume loss, yellow/red – volume increase.

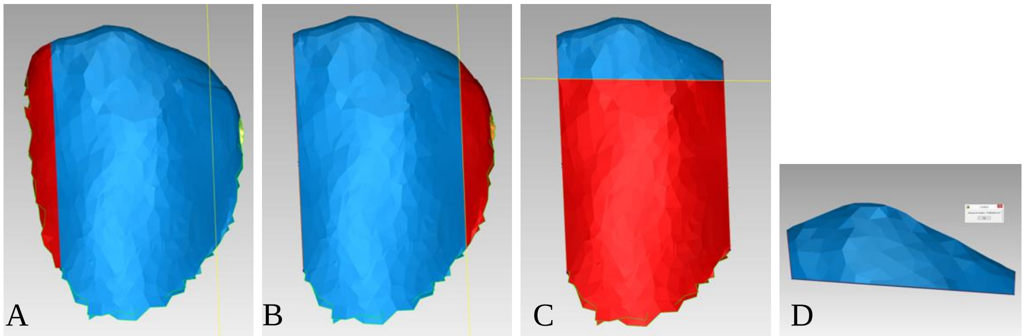

Figure 5. Geomagic Creating Boundaries. Process for creating even boundaries around T2 and T4. **A)** and **B**) Creating mesial and distal boundaries where the red is sectioned. **C)** Gingival boundary is created with **D)** the remaining incisal portion left over and the volume is calculated.

Statistical Analysis

SPSS^{TM} 25.0 (SPSS Inc., Chicago, IL) and Microsoft® Excel were used for statistical analysis. The reliability of casts were analyzed with an intraclass correlation test. To evaluate the method error, ten patients were selected, and CTW analysis were repeated with a one week washout interval. The reliability of CTW measurements was also analyzed using an intraclass correlation test.

A Chi-square correlation test was used to test for the relationship between centric interference and CTW. A Wilcoxon signed-rank test was used to analyze the tooth wear and the side of interference. Spearman's Rho correlation analysis was used to evaluate CTW and CO/MIP discrepancy. Mann-Whitney U Test analysis was used to assess the relationship between CTW and gender. For all statistical analyses, the significance level was set at alpha=0.05.

Results

Reliability

First molar B/L width measurements showed showed excellent agreement between T2 and T4 casts with an average correlation coefficient of 0.95 and a mean difference and standard error of 0.05±0.02 mm.[20] (Table 3)

All tooth wear measurements were repeated on 10 subjects and intra-class correlation tests showed excellent agreement between original and repeated measurements at an overall ICC of 0.99. The mean difference and standard error were 0.017±0.02 mm^3.

Table 3. Agreement Between T2 and T4 First Molar Measurements.

First Molar	Intra-class Correlation
LL Molar	0.841
LR Molar	0.919
UL Molar	0.969
UR Molar	0.968

Overview

Thirty patients met the selection criteria for this study. Eleven of the subjects were male and nineteen subjects were female. The mean age of the subjects was 27.4±7.3 years with a range of 21 to 46 years. The mean time between T2 and T4 was 9.1±3.5 years with a range of 7 to 21 years post debond.

Forty percent of the subjects had an interference on the right side and 60% of the subjects had an interference on the left side. Sixty percent of the subjects had a posterior interference on the second molar, 23% of the subjects had an interference on the first molar and 17% of the subjects had an interference on a premolar. Eighty-three percent of the subjects with interferences on the second molar, had it on the distolingual cusp of the maxillary second molar, and 43% of the subjects with interferences on the first molar, had it on the DL cusp of the maxillary first molars. The mean CO/MIP discrepancy on the incisal pin was 1.38±1.01 mm with a range of 0.22 to 4.09 mm.

The mean CTW in the entire sample was 1.06±0.18 mm^3 with a mean of 0.13±0.16 mm^3 tooth wear per year. The mean CTW for the right side was 2.34±2.51 mm^3 and the left side was 1.89±2.12 mm^3. The mean total CTW was 4.24±4.55 mm^3 with a range of 0.15 to 18.75 mm^3. The mean CTW was 1.83±.1.81 mm^3 in male subjects and 0.62±.69 mm^3 in female subject. The mean total CTW was 7.31±5.86mm^3 in male subjects 2.46±2.28 mm^3 in female subjects. The mean CTW per year was 0.22±.21 mm^3 in male subjects and 0.07±.16 mm^3 in female subjects. (Table 4) The average CTW of the four canines was as follows: 1.23±1.76 mm^3 at the upper right canine, 1.08±1.48 mm^3 at the upper left canine, 1.15±1.12 mm^3 at the lower right canine, and .081±.92 mm^3 at the lower left canine. (Table 5)

Table 4. Summary of Canine Tooth Wear (mm^3) per Subject

	Male	Female	All
CTW	1.83	0.62	1.06
Total CTW	7.31	2.46	4.24
CTW / Year	0.22	0.07	0.13

Table 5. Summary of Canine Tooth Wear (mm^3) per Side and Tooth

	Right Side CTW		Left Side CTW	
CTW	2.34		1.89	
	UR3	LR3	UL3	LL3
	1.23	1.15	1.08	0.08

Of the 30 subjects, 67% showed greater CTW contralateral to the interference, while 33% showed greater CTW on the same side. All the canines were grouped together for a total of 120 teeth for statistical analysis. In the sample, 83.3% of the canines had less than 2 mm^3 of tooth wear. (Table 6)

Table 6. Individual Canine Tooth Wear (mm^3) Severity Distribution

TW (mm^3)	N=120	% of total sample
0.00-0.99	76	63.3
1.00-1.99	24	20.0
2.00-2.99	9	7.5
3.00-3.99	6	5.0
4.00-4.99	2	1.7
5.00-5.99	1	0.8
6.00-6.99	2	1.7

Correlation Between Interference and Tooth Wear

A Chi-Square correlation test was performed to test the relationship between centric interference and CTW. There was no statistical relationship between centric interference and CTW (Chi-square = 2.5, df=1, p=.114).[21] It was interesting to note that interference was 1.6 times more likely to lead to tooth wear, but a larger sample size is needed to make a statistical association (OR=1.6, 95% CI: 0.84-2.9).

A Wilcoxon signed-rank test was performed comparing the side of the interference with right and left CTW. The left interference had a statistically significant difference between the right and left tooth wear (p=0.039), but the right interference had no statistical significance (p=0.308). The boxplot in Figure 6 illustrates the tooth wear for each side of the interference.

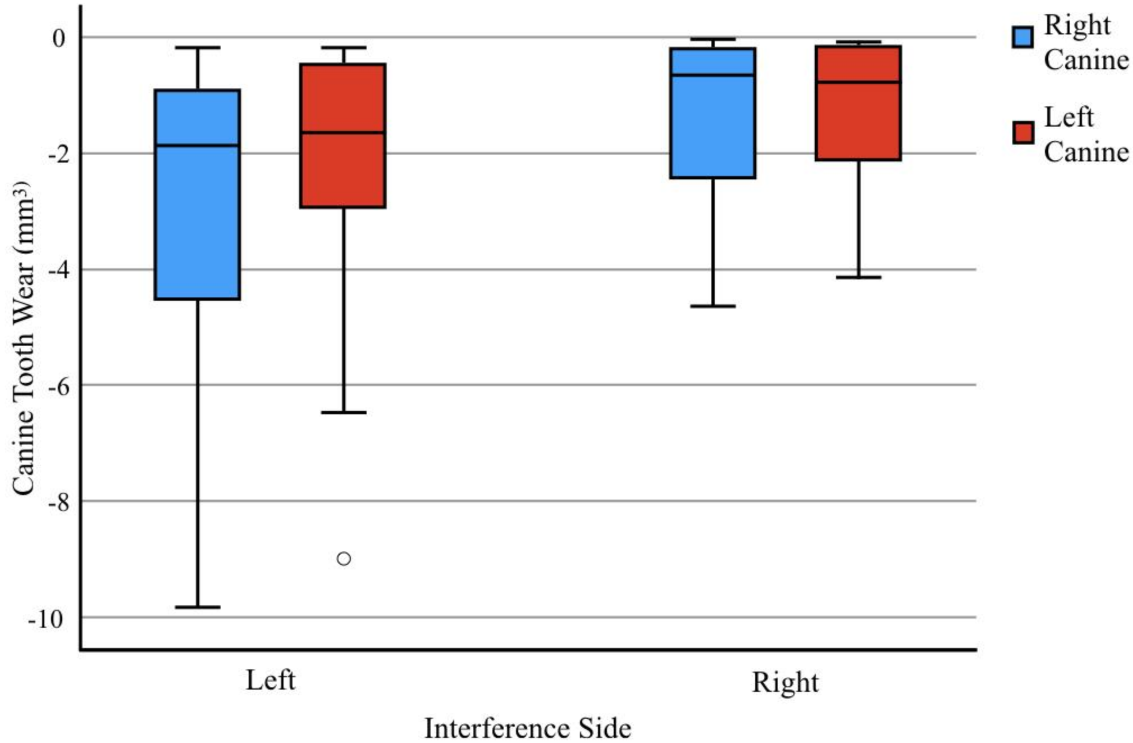

Figure 6. Boxplot of Bilateral Tooth Wear per Side of Interference. The boxplot illustrates the distribution of the tooth wear per side of interference.

Relationship of Tooth Wear with Other Factors

Spearman's Rho test was also performed and there was a statistical relationship between CTW and the magnitude of the CO/MIP discrepancy (rho=0.558, p=0.001). Figure 7 illustrates that the relationship between CO/MIP and TTW is very small.

When evaluating gender, a Mann-Whitney U Test showed there was a statistically significant difference between the amount of wear between males and females (p=0.008). Refer to Table 5 for a summary of tooth wear of subjects. There was no relationship between gender and CO/MIP discrepancy (p=0.497).

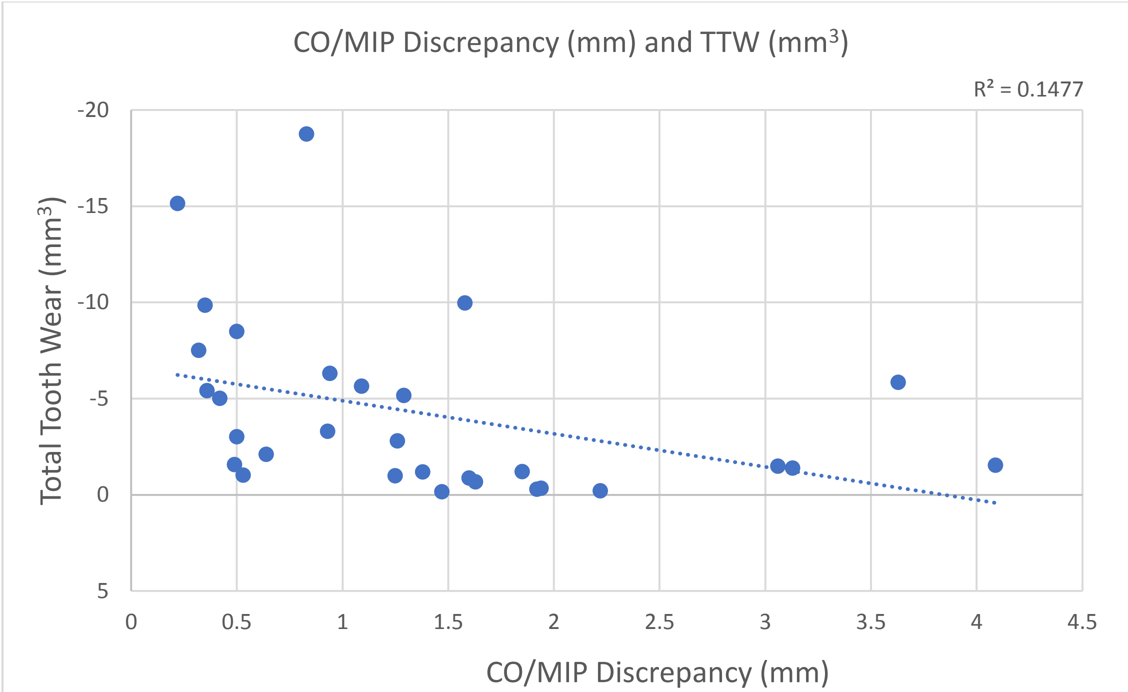

Figure 7. Linear Scatterplot of TTW and CO/MIP Discrepancy. Linear line is a best fit line associated with the data points.

Discussion

There have been many factors associated with TW, including physical, mechanical, or chemical issues.[4] Some patients will have TW greater than expected which may require further restorative treatment.[4, 6, 22] Previous attempts to study tooth wear have been done using a Tooth Wear Index (TWI), which lacks the sensitivity needed for measuring quantitative tooth loss.[3, 23, 24] To overcome this problem, this project incorporated 3D surface superimposition to evaluate dental wear as suggested by Park et al.[23]

This project evaluated whether certain centric interferences cause progression of TW. If it can be determined occlusal interferences contribute to pathologic tooth wear, early reduction of the interference might lead to reduced tooth loss.

During excursive movements, an individual may try to avoid the interference by nonproprioceptive guidance on the anterior teeth, particularly the canine. Another possibility is that a patient with a nocioceptive response to an interference might protect against the canine while coming into full occlusion. Over a period of time, these protective mechanisms might contribute to excess tooth wear on the anterior teeth. As interferences increased in mandibular movements, the posterior teeth would gradually begin to wear as well.[4] Eliminating centric interferences might be an important element in occlusal treatment.

In this study, all of the subjects had an interference as determined by the bite registration protocol, and 67% had an interference with greater CTW contralateral to the side with the interference. More than half the interferences were due to the second molar, especially the disto-lingual cusp. Wood et. al. found that the most common initial point of contact from CR to MIP was also on the most posterior tooth.[25] In orthodontically treated patients, this can be due to inadequate alignment and torque control of the maxillary second molar.

The mean long term CTW in this study was 1.06 mm^3 and 0.13 mm^3/year which is slightly greater than a study done by Rodriguez[22] at 0.030 mm^3 per year and Pintado et al.[6] which was 0.087 mm^3 per year. Park et. al discovered that they had a mean volume loss of 2.00 mm^3 over the course of orthodontic treatment (35.5 months or .67 mm^3/year).[23] The previous studies evaluated TW over 1-2 years. A slight increase in TW per year over a longer period was noted. This increase can be due to several factors, drinking more acidic drinks (coffee, energy drinks) or starting a more stressful part of their life. Previously, TW was described as cyclical, with tooth wear going through a cycle of increased and decreased TW. [22] Therefore, subjects may have gone through a cycle of increased tooth wear.

Statistically, there was no statistical relationship between centric interference and CTW. Although, there was a likelihood that an interference is 1.6 times more likely to lead to TW, this was not statistically significant as some patients showed that an interference has a protective effect. A larger sample size is needed for statistical significance.

When evaluating the distribution of CTW per side of interference, the left side showed statistical significance, possibly due to the larger sample size in subjects with left side interferences. This correlated with increased CTW on the right side.

The difference between CO and MIP was evaluated by measuring the distance of the pin from the table. All the subjects had some variability between MIP and CO. It was thought that with a small discrepancy, the joints were in a more stable position with the occlusion, therefore leading to less TW. As the discrepancy between CO/MIP increased, there would be an increase or decrease in TW. There was a moderate relationship between total CTW and CO/MIP discrepancy. A small positive correlation was seen that as the discrepancy decreased, tooth wear increased. Thirty percent of the subjects had a discrepancy of 0.50 mm. This means that there was a small difference between MIP and CO. Although no conclusions could be made, it is possible that the occlusion was worn down, therefore decreasing the overall discrepancy.

Gender has also been examined for differences in TW.[23, 26] Previously, it was shown that males have more TW than females.[2, 26] Some have discussed the idea that females have lower pain thresholds than males.[27] This might correlate with less TW. This study shows that males had a statistically greater amount of TW than females.

The correlation between tooth wear and interferences cannot be associated as the cause due to the multifactorial effects on tooth wear. However, based on our results, orthodontists should still be cautious of interferences at the end of treatment.

Conclusions

No statistical relationship was found between centric interferences and CTW. There was a relationship between a left side centric interference and CTW, but no statistically significant relationship between a right side centric interference and CTW. There was a moderate relationship between CTW and CO/MIP discrepancy. There was a statistically signficant difference between the amount of tooth wear between males and females. Most of the centric interferences were due to the disto-lingual cusp of the maxillary second molars.

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CHAPTER THREE

EXTENDED DISCUSSION

Study Limitations

This study was a retrospective cross sectional study. Although subjects had an interference at T4, and increased CTW on the contralateral side, it is not clear if the centric interference caused the increase in CTW. It is not known where the joint position was at T2 because there was no CR registration made, therefore we cannot determine the magnitude and progression of the centric interference from T2 to T4.

There are several inherent errors due to the nature of materials and methods in this study. Methods of making and pouring the impressions presents as one of the primary sources of error. Alginate impressions could have some distortion and orthodontic plaster could have some expansion or shrinkage. The orthodontic plaster used in this project had an expansion of 0.18%. Arch width can range by 0.3 mm[38] or -0.174 or 0.912%[39] for the conventional alginate. This could be improved in future studies if the same evaluator takes all registrations and uses a 3D intraoral scanner to avoid distortions.

The CTW measured were small changes, but the possible errors in all the steps could amount to either underestimated or overestimated tooth loss. This was shown when a 3D color map was created in Geomagic. If the segmented teeth were perfect matches, they would have no difference in dimension. Although, the models were scanned with high resolution, there was some data loss in the digital file due to conversion of the actual model into a meshwork of triangles to create the digital file. The OrthoInsight 3D scanner has a resolution of 0.03-0.04 mm, with a standard error of .02 mm. This would have led to an underestimated tooth loss. When performing tooth superimpositions, there was an inherent error in the software as well for generating the alignment. There could also be an error in the method of tooth wear analysis. The standard error for tooth wear analysis was found to be 0.02 mm^3 in this study.

Future Study Directions

The correlations in this study were determined based on the tooth wear that occurred retrospectively from T4. There was no control group in this study. One of the ways to study a group of patients prospectively is to possibly evaluate T1, T2, and T4 records. Before releasing the patients, it would be important to make a CR bite registration at each of these time-points to study the location of the interference and its progression. Another possible future study is to examine the patients of an orthodontist who has made CR bites at different time-points and repeat this project which a different group of patients.

As technology develops, digital tooth wear analysis will most likely be integrated with more digital software. During this study, the author tried to find previous studies evaluating the accuracy of Geomagic Control. A future study could evaluate the accuracy of Geomagic by comparing a gold standard, and comparing it with alginate impressions, and digital scans, and cross referencing the two different impression techniques.

Previous studies have shown that orthodontic treatment or the type of retention does not lead to increased TW.[24, 26] Since this study evaluated patients after a long term, there could be future studies evaluating the stability of the treatment. Although all the patients were Class 1 at T2, some of the occlusions changed slightly at T4. The occlusions at T2 that were finished to a “socked in” Angle Class 1, seemed more stable at T4, and visually exhibited less tooth wear. A future study could evaluate the finishes at T2 and T4, utilizing the ABO Cast Radiograph Evaluation and correlating it to TW.

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APPENDIX A

QUESTIONNAIRE TO PARTICIPATE IN THE STUDY

LOMA LINDA UNIVERSITY

School of Dentistry

Questionnaire to Participate in the Study

Effect of centric interference on canine tooth wear in patients seven years and beyond post orthodontic treatment - a cross sectional study

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Name______________________________________
Date____________________

1. Did you have any fillings, or crowns or adjustments made to any of the front teeth?	YES	NO
2. Do you have a history of bulimia?	YES	NO
3. Do you have a history of GERD?	YES	NO
4. Have you ever taken medication such as: anti-depressants, muscle relaxants or SSRI's?	YES	NO
5. Do you have pain in your jaws?	YES	NO

Signature______________________________

APPENDIX B

INFORMED CONSENT

LOMA LINDA UNIVERSITY

School of Dentistry

Informed Consent

Effect of centric interference on canine tooth wear in patients seven years and beyond post orthodontic treatment - a cross sectional study

Principal Investigator: **Leroy Leggitt, DDS, MS, PhD**
Professor and Chair
Advanced Education Program
Orthodontics and Dentofacial Orthopedics
Contact email: orthodept@llu.edu
Contact number: 909-651-3055

Subject #______________________

1. Purpose and Procedure
    a. You are invited to participate in this research study because you have completed orthodontic treatment here at LLUSD at least 7 years ago.
    b. The aim of this research is to evaluate for any interferences and tooth wear present.
    c. Participation in this study will take approximately 1 hour.
    d. Participation in this study involves photographs, impressions, and a bite registration.
    e. Permission to review dental records.
2. Risks
    a. Participating in this study has minimal possibility of discomfort of the jaws during the impression, bite registration or intraoral photographs.
3. Benefits
    a. Because of the nature of this study, you will not have any health benefits, but you may gain some insight into the retention of your case.

b. While you will not benefit personally, information obtained from this study will benefit humanity by providing evidence for optimal intra-oral health.

4. Participation Rights

a. Participation in this study is voluntary. Your decision whether or not to participate or terminate at any time will not affect your present or future medical care.

5. Confidentiality

a. Your privacy will be protected by using an encrypted hard drive to store information. Your name will not be revealed to anyone.

b. Any published document resulting from this study will not disclose your identity without your permission.

c. Your privacy rights are explained in the attached PHI Authorization.

6. Additional Costs

a. There is no cost to your participating in this study.

7. Reimbursement

a. You will be paid in the form of a gift card of $10 for participating in this study.

8. Impartial Third Party Contact

a. If you wish to contact an impartial third party not associated with this study regarding any question or complaint you may have about the study, you may contact the Office of Patient Relations, Loma Linda University Medical Center, Loma Linda, CA 92354, phone (909) 558-4647 for information and assistance.

9. Informed Consent Statement

a. I have read the contents of the consent form and have listened to the verbal explanation given by the investigator. My questions concerning this study have been answered to my satisfaction. I hereby give voluntary consent to participate in this study. Signing this consent document does not waive my rights nor does it release the investigators, institution or sponsors from their responsibilities. I may call during routine office hours at (909) 558-4616 or during non-office hours at (909) 747-9973 if I have additional questions or concerns.

b. I have been given a copy of this consent form.

c. Subject:

________________________ ___________

Signature of subject Date

10. Investigator’s Attestation:

I have reviewed this consent form with the person signing above. I have explained potential risks and benefits of the study.

___________________________ ___________________ ___________

Signature of investigator Phone Number Date