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Incisor Contact in Optimal Occlusion

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INCISOR CONTACT IN OPTIMAL OCCLUSION

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ABSTRACT

The objective of the present study was to grade the overjet of untreated plaster dental study casts with optimal occlusion utilizing the American Board of Orthodontics (ABO) Objective Grading System (OGS). Currently no data set exists for incisor contact norms in optimal occlusion. **Materials and Methods:** 140 Plaster dental study casts possessing optimal occlusion were utilized for this study. Study casts used were obtained from the office of Dr. Lawrence F. Andrews in San Diego, CA. The majority of the study models were those used in determining Andrews Six Keys to Normal Occlusion. Overjet was graded according to the ABO OGS with each incisor being given a grade of 0, 1, or 2 for a total of 8 point deductions possible per pair of study casts. **Results:** Only 4 of the 140 (3%) study casts measured received no point deductions, implying that all incisors were in contact. 123 study casts (88%) had all incisors within 1mm of contact. 528 incisors (94%) out of the total sample of 560 were also within 1mm of contact. **Conclusion:** Currently the goal for overjet in cases brought before the American Board of Orthodontics is to have all incisors in contact. The results of the study suggest that the overwhelming majority of optimally occluding non orthodontically treated patients do not have their incisors touching, but are within 1mm of contact. The data acquired in this study can be used when determining final treatment goals for incisor contact.

Keywords: Overjet, Optimal Occlusion, Incisor contact, Central Incisor, Lateral Incisor

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CHAPTER 1

INTRODUCTION

For well over 100 years the orthodontic profession has strived to achieve excellence in treatment results. Beginning with Edward Angle, the interdigitation of the teeth has been paramount when treating orthodontic patients. Close scrutiny of treatment outcomes has become the mantra of the profession.

In 1999, the Objective Grading System (OGS) was implemented by the American Board of Orthodontics (ABO)[1, 2] as the official grading scale to evaluate orthodontic treatment results. The purpose of the OGS was to allow both examiners and examinees an objective and reliable method for the grading of orthodontic casts and panoramic radiographs. The 8 occlusal scoring categories of the ABO OGS were alignment, marginal ridges, bucco-lingual inclination, occlusal relationships, occlusal contacts, overjet, interproximal contacts, and root angulation.

The area of interest this study attempts to examine is within the category of overjet. Currently the OGS goal is to have all incisors in contact following the completion of orthodontic treatment. If this is not present, considerable point deductions are given to the examinee during the board examination process. To date, no study has described incisor contact and its relationship to overjet in a large sample of non-orthodontically treated patients with optimal occlusion.

Specific aims of the study

Previous research studies have been unable to accurately document incisor contact in non-treated orthodontic normals. In order to achieve optimal orthodontic treatment results it is imperative that optimal goals be used from sound research data. Unfortunately, no data currently exists in regards to the critique of incisor contact. This study looks to first gather patient study models that have not received orthodontic treatment, and would also not benefit from orthodontic treatment. The study will then develop averages for anterior incisor tooth contact in the optimal untreated patient. It is expected that the data collected in this study can be used as a benchmark for final treatment goals in regard to anterior incisor contact and final overjet in orthodontically treated patients.

Null Hypothesis

There is no significant difference between incisor contact of the untreated optimal occlusion and that expected of by the American Board of Orthodontics.

CHAPTER 2

LITERATURE REVIEW

Occlusal contact

A balanced occlusal contact is important in all aspect of dentistry because it helps maintain function, stability of tooth position and the surrounding periodontium. Teeth usually make contact during mastication, bruxism and swallowing. Several factors should be considered when measuring occlusal contacts: size, distribution, location and number of occlusal contacts.

A small occlusal area is an area covering a point on the buccal or lingual incline of a cusp or a peak of a cusp[3]. If the contact area covers more than one third of the outer buccal or lingual surface or more than one half of the inner buccal or lingual surface of a cusp, it is considered a large contact area. According to Ross a smaller contact area is more efficient and less destructive than a large contact area[3].

Symmetrical distribution of occlusal contacts help distribute forces more evenly between the teeth. It is more favorable to have the mandibular molars in contact with the buccal peaks than having asymmetrical distribution of contact areas in which the molars are occluding buccal peaks, central grooves and the lingual peaks.

Occlusal contact location can be distributed into two types according to the direction of the force. Vertical forces along the long axis of the teeth will happen in the buccal peaks of the mandibular posterior teeth and the central groove area of the maxillary teeth. Lateral forces will happen along the inner inclines of the mandibular

posterior teeth and the outer buccal incline of mandibular teeth. In the maxillary teeth, lateral forces happen in the inner buccal and inner lingual surfaces[3]. Lateral forces are usually less tolerable than the vertical forces because they are against thinner cortical bone (buccal, lingual and interproximal bone[3].

Variation in the average number of occlusal contact per subject has been reported in literature. This could be due to the thickness of the occlusal registration strips used to measure the occlusal contact. If it was very thick, a sensory perception will be initiated and occlusal forces might be generated. An occlusal registration strip should plastically deform with a thickness less than 21 μm[4]. McDevitt used a 40 μm thick marking paper to measure the number of occlusal contacts and found an average of 11 occlusal contact per subject including anterior teeth[5]. On the other hand, Ehrlich used a 28-gauge green casting wax to measure the number of occlusal contacts and found an average of 79 occlusal contacts per subject excluding anterior teeth us.[6] Both researchers have reported having most of the occlusal contact in the molar areas and even more specifically on the first molar. More than one third of McDevitt's sample had no anterior contact. Increased number of occlusal contacts don't necessarily indicate a normal occlusion. In a study done by Watanabe-Kanno, it was found that Class II division (div) I patients had slightly more occlusal contacts than Class I.[7] A significant difference was found on the lower first premolar with the Class II div I having a higher occlusal contact area. This finding could be because lower first premolars usually have smaller lingual cusps in comparison with the buccal cusp and this fact was highly observed in the group of patients who had a Class I molar relationship.

Angle Malocclusion Classification

Edward H. Angle was credited with creating the first system to evaluate tooth alignment. In 1899 Angle wrote the following:

"The shapes of the cusps, crowns, roots, and the very structure are all designed for the purpose of making occlusion the one grand object, in order that they may best serve the purpose for which they were designed,--namely, the cutting and grinding of the food. Examined carefully, it will be seen that there can be no "irregularities" of the teeth if they are in perfect occlusion, but that all must be regular and even, each contributing to the support of the others, and all in perfect harmony."[8]

His criteria are still widely used today by both orthodontist and general dentist. The first molar was the key tooth to grade the teeth and he referred to this as the 'Key to occlusion'.[8] Class I occlusion is when the mesiobuccal cusp of the upper first molar occludes with the mesiobuccal groove of the lower first molar and the teeth are aligned in the line of occlusion.[9] Class I malocclusion is when the the mesiobuccal cusp of the upper first molar occludes with the mesiobuccal groove of the lower first molar and the teeth are slightly out of alignment. If the lower first molar is distal to the upper molars the teeth are in Class II malocclusion. If the lower first molar is mesial to the upper first molar, the teeth are in Class III malocclusion. However, his classification doesn't include the position of teeth in vertical and horizontal planes, and can't be applied when the first molar is missing because it is the key to occlusion.[8] Angle believed that the first molar was crucial to the occlusal scheme and was strongly against extraction. In 1904 Angle said, before the Academy of Stomatology: "Then will their careless sacrifice surely be

regarded as a punishable crime, for I believe that, generally speaking, the loss of a first lower molar is really a far greater damage to the physical economy, as a whole, than would be the loss of a finger."[10] Throughout his life, Angle was against the extraction of teeth and felt optimal occlusion could not be obtained with extraction treatment.

Lischer Malocclusion Classification

Lischer used the lower first molar to describe the malocclusion and referred to a Class I malocclusion as Neutrocclusion, Class II as Distocclusion and Class III as Mesiocclusion. His classification also described individual teeth also in all three planes of space: Labioversion, linguvesion, distoversion, mesioversion, supraversion, and infraversion. His classification included also rotation of a tooth around its long axis referred to as torsiversion.[11] If a tooth was transposed he called it transversion.[11] His classification was thought to be more detailed and precise than Angle's original classification.

Dewey's Malocclusion Classification

Dewey believed that each cusp in the dentition was as important as the mesiobuccal cusp of the upper first molar and more than one tooth should be taken into consideration when classifying teeth.[12] He used Lischer's terminologies to refer to the malocclusions because they were more descriptive than Angle's terminologies, therefore using the nomenclature Class I, II and III.

Angle's Class I malocclusion was subclassified into five categories:

- Class I type 1: the molars are in Angle's Class I and the anterior teeth are crowded.[12] In this category the teeth are typically inclined lingually and the patient could benefit from expansion.
- Class I type 2: the molars are in Angle's Class I and the anterior teeth are protrusive.[12] This category usually corresponds with a mouth breathing problem.
- Class I type 3: the molars are in Angle's Class I and the anterior teeth are inclined lingually and might be in anterior crossbite.[12] The patient might have underdevelopment of the maxilla and protrusive lower lip.
- Class I type 4: the molars are in Angle's Class I with a posterior crossbite.[12]
- Class I type 5: the molars are in Angle's Class I but the molars have mesially drifted.[12]

Class II malocclusions were sublcassified into 2 categories:

- Distocclusion with labioversion is the equivalent of Class I div I
- Distocclusion with linguoversion of upper anterior teeth is the equivalent of Class Ii div II.

Class III malocclusions were divided into three types according to the position and alignment of anterior teeth.

- Class III type 1: the anterior teeth are fairly aligned.[12]
- Class III type 2: the lower anterior teeth are crowded but lingual to the upper anterior teeth.[12]
- Class III type 3: the upper teeth are crowded and lingual to the lower teeth.[12]

Occlusal Index

In 1971, Dr. Chester Summers introduced a guide of occlusal evaluation and termed it the, “Occlusal Index”.[13] The term “index of occlusion” was first mentioned by the World Health Organization in a report given in 1966. The report stated that an index of occlusion should possess three characteristics: First, the index should be reliable in that it would contain both inter- and intra-examiner reproducibility at different times; Second, the report stated that the index must be valid in that it would describe measurements exactly as the examiners desired to be measured. Third, the index should be valid “during time” and take into consideration normal occlusal development.[14]

Summers stated that a good occlusal index should fulfill the following criteria: It can be expressed in a single number, is equally sensitive throughout the scale, is an accurate representation of the stage of the disease, can be statistically analyzed, is reproducible, requires minimum judgement, could be used on a larger population, detects a progress or regression in a group and should be valid during time[13]. Summer’s Occlusal Index has proved to follow most of these criteria and had the least amount of bias.[15] Summer felt that the word “malocclusion” was an imprecise word, improperly used in a precise way.[13]

Summer made sure that the index could be used in any dentition (Primary, Mixed and Permanent Dentition). He measured 9 criteria: Dental age, Molar relation, overbite, overjet, posterior crossbite, posterior open bite, tooth displacement, midline relation and congenitally missing maxillary incisors. One of the advantages of the Occlusal Index is the high reliability and reproducibility except in mixed dentition which showed moderate reliability.[16] On the other hand, the Occlusal Index has different coding sheets

according to the developmental age of the patient which can sometimes make it slightly complicated. This has led to dissatisfaction with the index due to the time consuming and tedious process of completing the index[1].

The Peer Assessment Rating Index

In 1987 the British Orthodontic Standards Working Party had a series of meetings to create an Index that could measure malocclusion at any point during treatment. Over two hundred casts representing different stages of treatment were simultaneously evaluated by 10 orthodontists by projecting the cases on a screen. These meetings resulted in the formulation of the Peer Assessment Rating Index (PAR).[17] A lower score represented better tooth alignment. Subtracting the pre-treatment PAR score from the post-treatment PAR score could show the improvement of a case. The PAR index has 11 components that are added up for a total PAR score. These criteria are: 1- upper right segment, 2- upper anterior segment, 3-upper left segment, 4-lower right segment, 5-lower anterior segment, 6-lower left segment, 7-right buccal occlusion, 8-overjet, 9-overbite, 10-centerline and 11-left buccal occlusion. Components 1 to 6 include spacing, crowding and impacted teeth. The buccal occlusion components include the position of the teeth in three planes of spaces and is scored to the last distal molar (1^{st}, 2^{nd} and 3rd molars). An overjet of 0-3 mm scored 0 which means that the upper anterior teeth don't have to touch the lower anterior teeth. The PAR index has showed an excellent intra-examiner and inter-examiner reliability. Right and left buccal segments have a slightly lower reliability score.[17] Right and left buccal occlusion have the lowest inter-examiner reliability score (R=0.75) and this could be because the interdigitation of the cast can change slightly due

to the way it was held each time. In another study, Buchanan showed that the PAR index had excellent reliability whether it was in mixed or permanent dentition.[16] The PAR index is thought to be an easy way to measure the alignment of teeth throughout the course of treatment and is used frequently throughout European countries.

Andrews Six Keys of Occlusion

In 1972 Dr. Lawrence F. Andrews an orthodontist in San Diego, California published a paper titled "The Six Keys to Normal Occlusion". In his research, he first gathered dental study models of 120 patients that he felt would not benefit from orthodontic treatment and exhibited optimal occlusion.[18-20] Andrews stated that specific criteria of the models that were gathered and what they displayed were as follows: "(1) had never had orthodontic treatment, (2) were straight and pleasing in appearance, (3) had a bite which looked generally correct, and (4) in my judgment would not benefit from orthodontic treatment." [18] Dr. Andrews thought that the molar classification first introduced by Angle was not sufficient to describe a malocclusion and that more in depth study need be obtained in order to ascertain what characteristics were found in this large group of untreated individuals. Andrews validated his six keys when he compared them to 1,150 treated cases by the nation's most skilled orthodontists of the time from 1965 to 1971. When speaking of these 1,150 cases using the six keys Andrews stated, "…learning to what degree the six characteristics were present and whether the absence of any one permitted prediction of other error factors, such as the existence of spaces or of poor posterior occlusal relations."[18]

The six characteristics that were found by Andrews during his study of non-treated optimal study models were as follows:

1. **Molar relationship**: The distal surface of the distobuccal cusp of the upper first permanent molar must occlude with the mesial surface of the mesiobuccal cusp of the lower second molar. Without this relationship, the remaining posterior occlusion will have a difficult chance falling into a solid occlusion
2. **Crown Angulation** (tip): The gingival portion of the long axes of all crowns should be oriented more distal than the incisal portion. This will also help allow for proper interdigitation of the dentition.
3. **Crown Inclination** (Torque or labiolingual/buccolingual inclination): This angle is described as the angle formed by a 90 degree line to the occlusal plane and a line tangent to the bracket site. Andrews discovered patterns of root torque based on specific teeth within the dental arches.

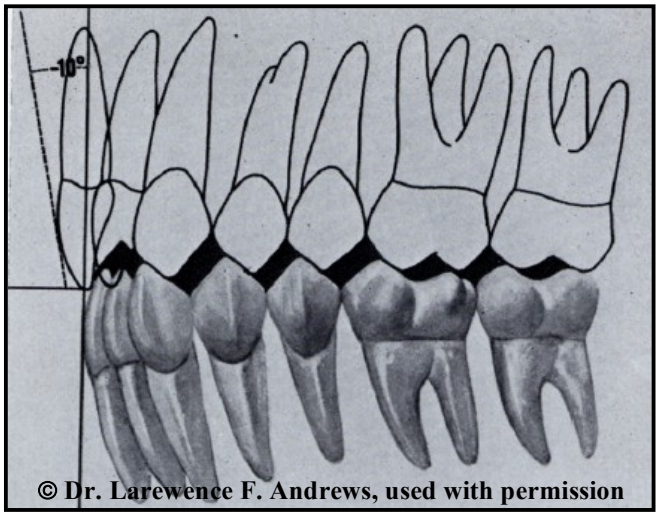

FIGURE 1. Improper torque as described by Andrews[19]

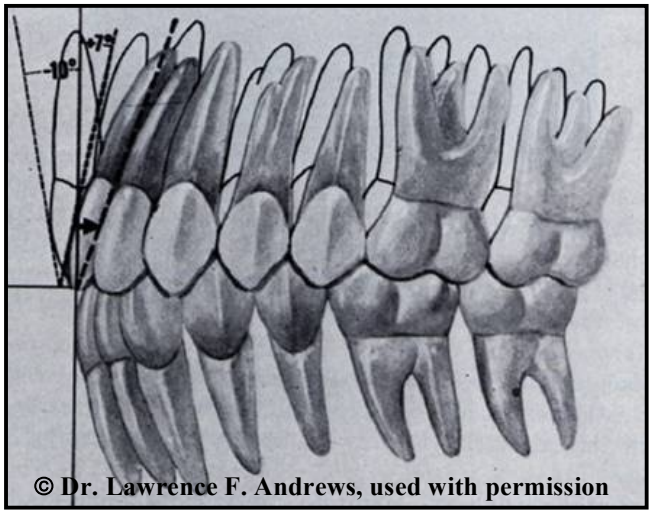

FIGURE 2. Proper root torque allowing optimal inter-digitation[19]

4. **Rotation**: Andrews reported that teeth should be free of undesirable rotations. If a tooth is not in its correction rotation, it creates a situation where arch length is inadequate or excessive. This in turn is not amenable to correct occlusion.
5. **Tights contacts**: Contact points should be tight without spacing. Spacing between teeth often creates arch length discrepancies and does not allow for proper interdigitations of occlusion. Tights contacts are always desirable unless a Bolton discrepancy is present or open contacts are intentional.[21-23]
6. **Occlusal Plane**: Andrews noted that in nonorthodontic normals that the occlusal plane was generally flat to a slight curve of Spee. With a flat curve of Spee intergiditation is often the most optimal.

Andrews six keys of normal occlusion led the way for a more thoughtful and objective review of treatment results. What was not present in this evaluation was a scoring methodology of grading treatment results that could be used by examiners.

The principles of optimal occlusion outlined by Andrews are still used today in many postgraduate orthodontic programs throughout the world.

ABO Objective Grading System

It wasn't until 1994 that the American Board of Orthodontics began searching for a more objective way of grading patient's orthodontic treatment results. [1] Following the ABO exam in 1995 examiners used 15 criteria to assess orthodontic treatment results of 100 cases and found that 85% of the errors in final results resulted from 7 areas as follows: alignment, marginal ridges, buccolingual inclination, overjet, occlusal relationships, occlusal contacts and root angulation. One year later, a second field test was used to determine whether the examiners were able to reproduce similar inter-examiner scores. Using 300 sets of final casts and panoramic radiographs examiners again found that the majority of errors resulted in the 7 areas found the year prior. In order to help increase inter-examiner reliability a subcommittee recommended that a measurement tool be created. This led to the advent of the ABO measurement gauge pictured below.

FIGURE 3. American Board of Orthodontics (ABO) measurement gauge.

In 1997, using the newly developed measurement gauge and 832 dental casts and panoramic radiographs, the modified grading system was once again evaluated and the same 7 areas of inaccuracy were once again found to prevail. During this grading, the examiners were first introduced to the measurement gauge and examiners were pre-calibrated to achieve greater reliability of the measurements. An eighth area of critique was also added to include interproximal contacts into the grading system. Following this test, the measurement gauge was modified to improve accuracy of measurements between examiners.

Finally, in 1998, examiners used one last field test to evaluate the model grading system. The main goals of this final test were to determine a valid passing score for the examination and to achieve improved calibration between examiners. After nearly 5 years of testing the ABO officially introduced the use of the model Grading System during the February ABO clinical examination in 1999. The 8 occlusal scoring categories of the ABO OGS were alignment, marginal ridges, buccolingual inclination, occlusal relationships, occlusal contacts, overjet, interproximal contacts, and root angulation (Figure 4).

Alignment

The first criterion is alignment. With alignment, the ABO is evaluating the incisal edges of the maxillary anterior teeth, and the incisal edges/labial-incisal surfaces of the mandibular teeth. For the posterior teeth, the guides for the maxillary dentition are the mesiodistal central grooves and the mandibular buccal cusps of the molars and premolars (Table 1). The purpose for these grading areas in alignment is that they are easily identifiable and also represent the posterior areas of occlusion. All four field tests showed

that approximately 80% of all mistakes in alignment resulted from the maxillary and mandibular lateral incisors.

Table 1. Alignment Scoring

	Discrepancy	Points Deducted
	0.5-1.0 mm	1 Per tooth
	>1.0 mm	2 per tooth

Marginal Ridges

Marginal ridges of posterior teeth should all be at the same level. Some exceptions to this would be if the patient had existing restorations, attrition and/or periodontal bone loss (Table 2). The rationale for this assessment is that generally speaking, if marginal ridges are even, then the cementoenamel junctions and bone levels of adjacent teeth will coincide. Additionally, even marginal ridges also enable proper occlusal contacts during mastication. Field tests showed that the most common area of error was between the upper first and second molar with the second most common site of error being the lower first and second molars.

Table 2. Marginal Ridges[a]

	Discrepancy	Points Deducted
	0.5-1.0 mm	1 per interproximal contact
	>1 mm	2 per interproximal contact

[a]Canine premolar transition not scored
Distal of lower first premolars not included in scoring

Buccolingual Inclination

Buccal cusps of contralateral mandibular molars should contact and the lingual cusps should be within 1mm when assessed using the flat surface of gauge extending from right and left posterior teeth (figure 4).

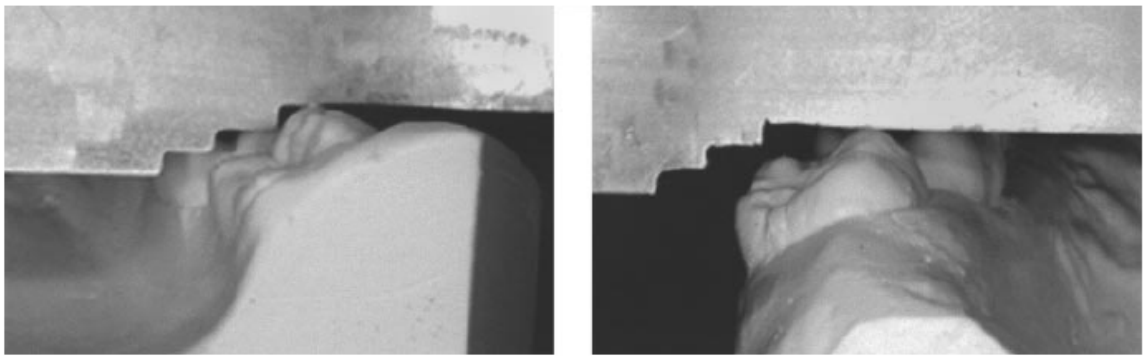

Figure 4. Buccolingual Inclination[1]

The lingual cusps of maxillary posterior contralateral teeth should contact and the buccal cusps should be within 1mm of the surface of the straight edge. The maxillary and mandibular second molars are most likely to cause point deductions in grading. Mandibular first premolars and distal cusps of second molars are not scored.

Table 3. Buccolingual Inclination

	Discrepancy	Points Deducted
	0-1 mm	No points
	1-2 mm	1 per posterior tooth
	>2mm	2 per posterior tooth

Occlusal Relationship

It was Dr. Edward H. Angle that first described the different types of posterior occlusion.[8] The foundation of occlusal relationships defined by Dr. Angle is still used today by the American Board of Orthodontics (Table 4). In ideal occlusion, it is said that the maxillary canine cusp tip should line up (within 1mm) of the embrasure between the lower canine and first premolar.[1] The maxillary premolars and first molars should also be aligned with a cusp-to-embrasure inter-occlusal relationship with the lower premolars and first molars.

Table 4. Occlusal Relationship[a]

Discrepancy	Points Deducted
0-1 mm	No points
1-2 mm	1 per maxillary tooth
>2 mm	2 per maxillary tooth

[a]Canine through the second molar are scored

Overjet

Overjet is assessed while viewing the models from a labiolingual relationship. In order to accurately evaluate it, models must be trimmed correctly at the backs of the bases of the models. The anterior-posterior relationship of the anterior teeth and the transverse relationship of the posterior teeth are evaluated in this manner (Table 5). The lingual cusps of maxillary posterior teeth and the buccal cusps of mandibular posterior teeth should be in line with the center of the occlusal surfaces. In the anterior region, it is expected that all lower incisors and canines will contact maxillary incisors. Grading is determined by the mandibular buccal cusps and maxillary incisors.

It is important to note that the examiner may adjust points if excessively acute angles are seen between the maxillary and mandibular incisors or a significant overlap of incisal edges. Field tests have shown that the most common areas of error are between the maxillary and mandibular incisors and the second molars

Table 5. Overjet[a]

	Discrepancy	Points Deducted
	0-1 mm	1 per maxillary tooth
	>1mm	2 per maxillary tooth

[a]Mandibular anterior teeth should contact maxillary anterior teeth

Occlusal Contacts

Posterior occlusion is evaluated by measuring occlusal contacts. One objective of orthodontic treatment is to obtain maximum intercuspation of the teeth. Functioning cusps include the maxillary molar and premolar lingual cusps and the mandibular molar and premolar cusps (Table 6). The most common area for problems is seen between upper and lower second molars. One important note is that small or diminutive cusps not in contact will not be scored (including all mandibular first premolars' lingual cusps).

Table 6. Occlusal Contacts

	Discrepancy	Points Deducted
	In contact	No points
	0-1 mm	1 per posterior tooth cusp
	1-2 mm	2 per posterior tooth cusp

Interproximal contacts

Tight interproximal contacts serve many purposes including: esthetics, prevention of food impaction and stability of the dental arch (Table 7). In prior ABO field trials, interproximal spacing has not been found to be a common area of examinee error. To account for potential orthodontic metal band spacing following removal of orthodontic appliances, spacing <0.5 mm is not scored.

Table 7. Interproximal Contacts

	Discrepancy	Points Deducted
	0.5-1.0 mm	1 per interproximal contact
	>1.0 mm	2 per interproximal contact

Root Angulation

Using a panoramic radiograph examinees are graded according to root angulation (Table 8). Common areas of problems in past ABO field tests have included the maxillary lateral incisors, canines, and second premolars, as well as the mandibular first premolars. The main rationale for preventing adjacent root convergence is for periodontal health if the patient were susceptible to bone loss in the future.

Table 8. Root Angulation[a]

	Discrepancy	Points Deducted
	Parallel	No Points deducted
	Not parallel[b]	1 per tooth
	Contacting roots	2 per tooth

[a]The canine relationship with adjacent tooth root is not scored

[b]One point is scored if root is close to, but not in contact with adjacent root

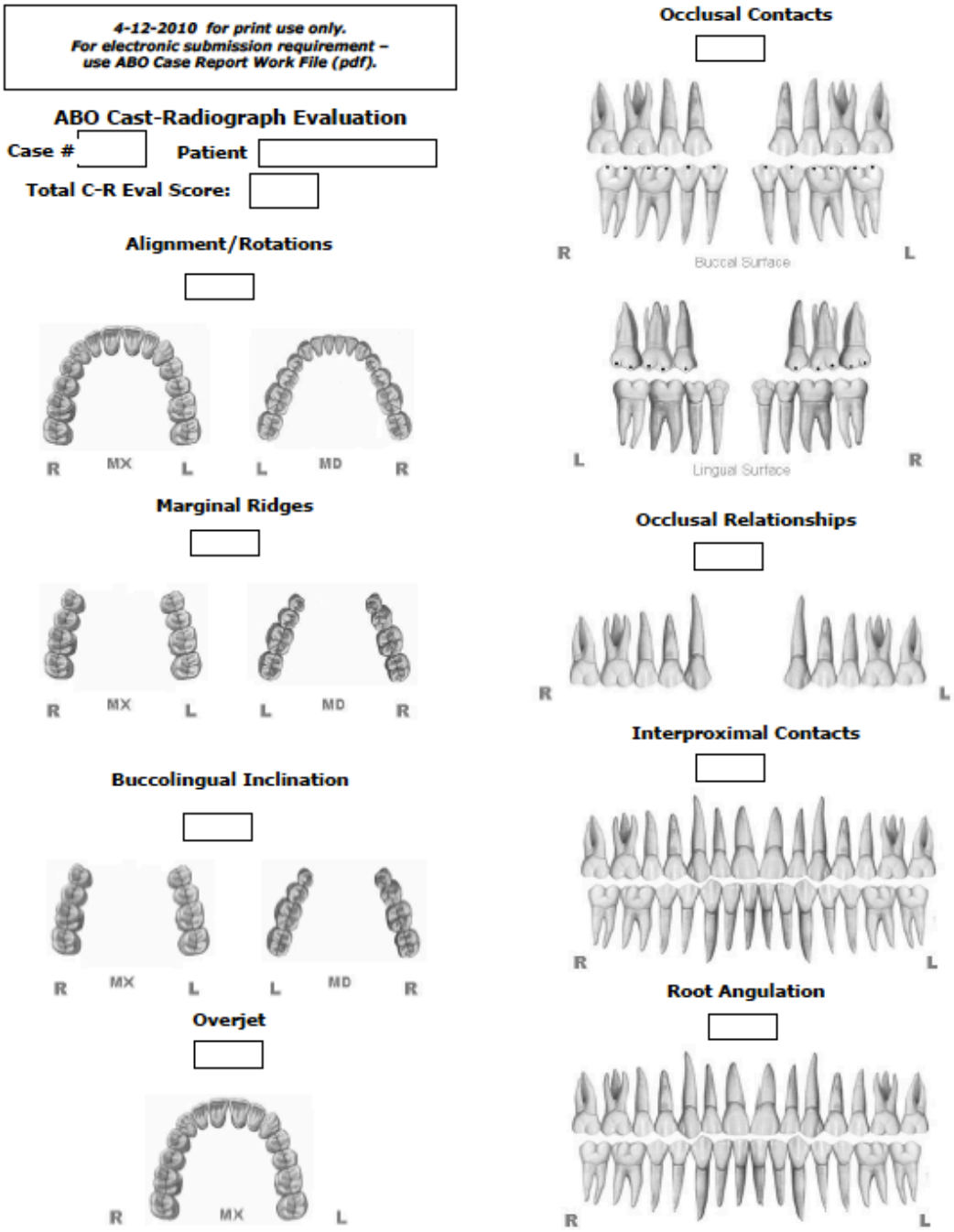

FIGURE 5. Cast Radiograph Grading Worksheet[1]

Cast Grading and Scoring

Following field tests using the ABO Occlusal Grading System a scoring sheet was created. A case report with a score that loses no more than 27 points is considered adequate for submission.[1] After close analysis of the ABO scoring system it was found that a total of 236 point deductions would be possible if one were to have the maximum allowable errors in every grading category. The case report is only a portion of what is needed to successfully become board certified. The ABO also evaluates the candidates records and treatment plans for each submitted case which precede an oral examination.

Incisor Contact and Overjet

One area of the ABO Occlusal Grading System that warrants closer examination is within the grading category of overjet. Previously stated, a candidate may lose a total of 8 points due to inadequate incisor contact.[1] After a thoughtful review of the literature, no patient studies were found to contain an evaluation of incisor contact in the optimally occluding non-orthodontically treated patient. The following questions need answers in order to accept this section of the grading rubric:

1. Why is incisor contact necessary following orthodontic treatment?
2. Are there any adverse effects resulting from incisor contact following orthodontic treatment?
3. What do previous studies teach us about the growth of the mandible during normal maturation and growth?
4. Is it reasonable to allow a total possible 8 point deductions or 30% of the allowed 27 point deductions for a “passing” case report deemed worthy to be brought before the ABO?

In 1972, Bjork published his human implant studies evaluating growth of the human face which have not been replicated since. Bjork's implant studies have shown that when the mandible grows forward relative to the maxilla in the late teens, the mandibular incisor may be displaced lingually.[24] This critical finding suggests that if upper and lower incisors are contacting when treatment is completed then the final result may be compromised with growth and displace the lower incisors lingually.

Okeson reported that in a normal occlusion an absence of contacts on the anterior teeth is not uncommon.[25] Okeson also stated that the one main occlusal requirement of the anterior teeth is to ensure guidance of the mandible during eccentric movements. This term referred to as anterior guidance allows for the posterior to disocclude during movements. Heavy anterior contacts are often extremely harmful to the dentition, displacing the teeth or causing heavy and damaging vibrations known as fremitus that can negatively impact alveolar bone proper surrounding the teeth.[25]

Proffit also spoke of this mandibular growth seen in adolescence and referred to it as, "late mandibular growth". [9] Proffit states, "In patients with a tight anterior occlusion before late mandibular growth occurs, the contact relationship of the lower incisors with the upper incisors must change if the mandible grows forward". These changes however undesirable, cannot be predicted and may have detrimental effects to the patients well-being and occlusion. When late mandibular growth occurs, the following cascade of effects may be seen: The mandible is displaced distally leading to temporomandibular joint disorders; the upper incisors are proclined and displaced forward resulting in spacing; the lower incisors are displaced distally resulting in lower incisor crowding.[9]

CHAPTER 3

MATERIALS AND METHODS

This is a descriptive study investigating the inter-arch incisor contact of 140 dental casts (560 maxillary incisors) The study sample was obtained from the Andrews Foundation (San Diego, CA) using Dr. Lawrence Andrews' collection of untreated patient study models. The study included males and females ranging in age from 11 to 71 years old. All patients study models were collected from 1960 to present and procured by Dr. Larry Andrews (San Diego, CA).[19]

Subject Selection Criteria

The inclusion and exclusion criteria are similar to those stated by Andrews, since this study uses the same sample of ideal occlusion study models.[18]

Inclusion criteria include 1) models of dentition who had never had orthodontic treatment and were in permanent dentition, (2) all teeth from 2nd molars forward, (3) Class 1 molar and canine relationship (4) would not benefit from orthodontic treatment.

Exclusion criteria included: 1) cleft lip/palate, 2) other craniofacial abnormality, 3) missing teeth (except third molars), 4) supernumerary teeth, 5) would benefit from orthodontic treatment.

Data Collection

Incisor contact was evaluated based on the standards set forth by the American Board of Orthodontics for overjet (see Table 5). To ensure examiner reliability the ABO measuring gauge was used (see Figure 3) to grade each upper incisor as follows:

- 0 = Incisor contact with mandibular dentition
    - *contact confirmed using 12 micron (0.0005 in.) shimstock (Almore Mfg. Company - Beaverton, OR)
- 1 = Incisor not contacting by less than 1mm
- 2 = Incisor not contacting greater than 1mm

Scores for each cast set were calculated as described in Table 5. For each incisor, when the overjet is 0 and 1mm, 1 point is scored. When the overjet is higher than 1mm, 2 points are scored. As a result, the highest anterior overjet score for a given set of casts is 8, and the lowest 0. Abbreviations for incisors were used as follows: upper right lateral incisors or UR2, upper right central incisor or UR1, upper left central incisor or UL1 and upper left lateral incisor or UL2. In some instances due to the low score output scores were dichotomized into groups (ex. Score of 0 and 1 were combined).

Gender and age were recorded whenever the information was available. Left and right comparisons were also described.

Statistical Analysis

Among the study sample, demographic characteristics and distribution of upper incisor contact measurements (individual and total anterior overjet) were examined using univariate statistics. Median and interquartile range were reported for non-normally distributed continuous variables. Frequencies and proportions were reported for categorical variables. Demographic characteristics were compared by overall incisor contact status. Continuous variables were compared using the Wilcoxon rank-sum test for non-normally distributed variables. Categorical variables (central vs lateral; left vs right sides) were compared using the chi squared test (or Fisher's exact test). The

associations between missingness of demographic data and incisor contact were tested using the chi squared and Fisher's exact tests. The median individual and total anterior overjet scores were compared to zero using the Wilcoxon signed-rank test. All analyses were conducted using SAS version 9.4 (SAS Institute, Inc., Cary, North Carolina).

CHAPTER 4

RESULTS

Descriptive statistics are presented in Table 9, gender was recorded for 99 casts. Only 97 had recorded ages, and for these casts, the median age was 22 ± 7 years old. Age and gender do not appear to play a major role in overjet distribution. The most frequent interarch contact for all incisors was between 0-1mm (95% for UR1, 92% for UR2, 96% for UL1 and 94% for UL2).

Table 9. Description of Study Sample

Variable	N = 140
Median Age (IQR)*	22 (7)
Gender, n (%)	
Male	49 (35.0)
Female	50 (35.7)
Unknown	41 (29.3)
Median Total Occlusion Score (IQR)	4 (1)
UR1 Occlusion Score, n (%)	
0	34 (24.3)
1	99 (70.7)
2	7 (5.0)
UR2 Occlusion Score, n (%)	
0	31 (22.1)
1	98 (70.0)
2	11 (7.9)
UL1 Occlusion Score, n (%)	
0	23 (16.4)
1	111 (79.3)
2	6 (4.3)
UL2 Occlusion Score, n (%)	
0	31 (22.1)
1	101 (72.1)
2	8 (5.7)

*Age missing on 43 patient models

The total score for a given set of cast can vary from 0 to 8. Figure 5 presents the distribution table for the total scoring. It shows that the data does not have a normal distribution, and out of 140 sets of casts, 93 scored either a total of 3 or 4 with only 4 casts receiving no point deductions (Table 10).

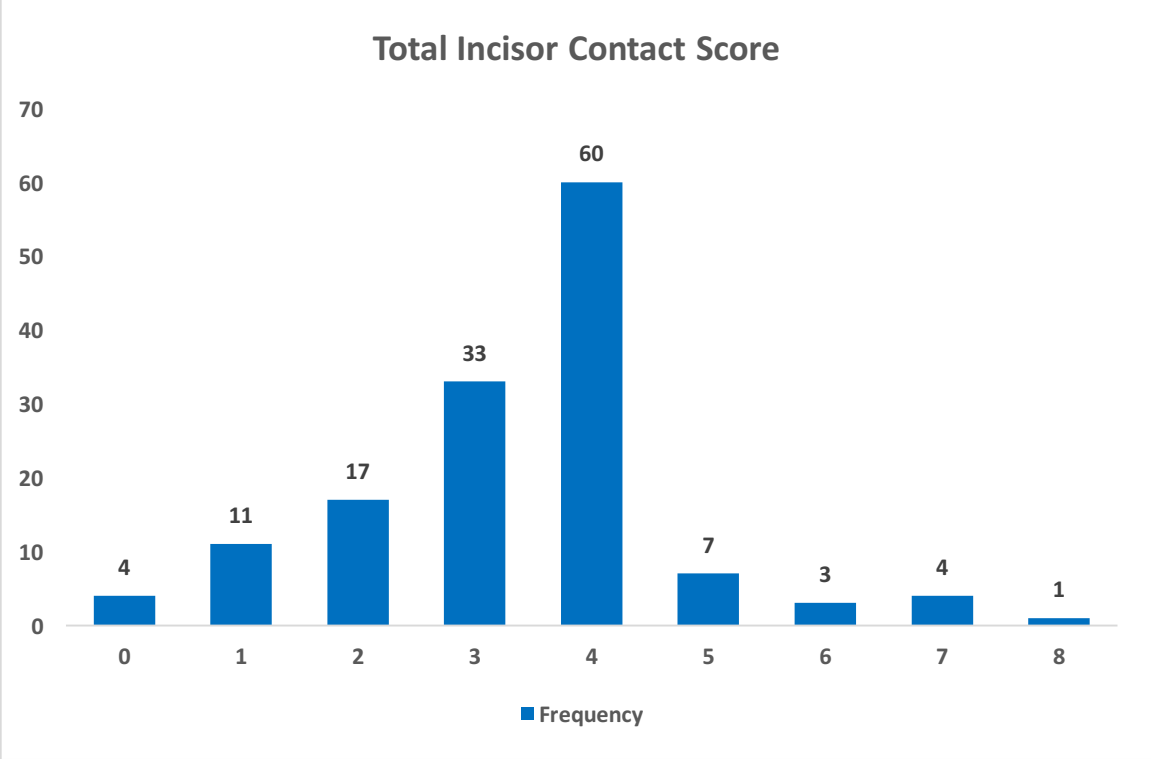

FIGURE 6. Distribution table for Incisor contact Score

Table 10 Total distribution scores for incisor contact*

Total	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	4	2.86	4	2.86
1	11	7.86	15	10.71
2	17	12.14	32	22.86
3	33	23.57	65	46.43
4	60	42.86	125	89.29
5	7	5.00	132	94.29
6	3	2.14	135	96.43
7	4	2.86	139	99.29
8	1	0.71	140	100.00

*Mean: 3.4, Median: 4.0, Mode: 4.0

In order to understand the scoring results, individual incisors were dichotomized into categories 0/1 or 2. At least 92% of the incisors scored a 0 or 1. The distribution of dichotomized scores is presented in Table 11.

Table 11. Distribution of dichotomized scores for each incisor

UR1	Frequency	Percent
0 or 1	133	95.00
2	7	5.00
UR2		
0 or 1	129	92.14
2	11	7.86
UL1		
0 or 1	134	95.71
2	6	4.29
UL2		
0 or 1	132	94.29
2	8	5.71

Symmetry was also examined, to see if the scoring consistently differed between the left and the right sides. Results were remarkably symmetrical with over half the study sample of both lateral and central incisors both scoring 1. Results are presented in Table 12 and 13. Left and right sides were also compared to determine any consistent trend. Left sides generally matched right sides in all fields assessed.

Table 12. Central incisor distribution of scores

Frequency Percent Row % Column %	Table of UR1 by UL1			
	UL1			
UR1	0	1	2	Total
0	12 8.6 35.3 52.2	21 15.0 61.8 18.9	1 0.7 2.9 16.7	34 24.3
1	10 7.1 10.1 43.5	86 61.4 86.9 77.5	3 2.1 3.0 50.0	99 70.7
2	1 0.7 14.3 4.4	4 2.9 57.1 3.6	2 1.4 28.6 33.3	7 5.0
Total	23 16.4	111 79.3	6 4.3	140 100.0

Table 13. Lateral incisor distribution of scores

Frequency Percent Row % Column %	Table of UR2 by UL2			
	UL2			
UR2	0	1	2	Total
0	11 7.9 35.5 35.5	20 14.3 64.5 19.8	0 0.0 0.0 0.0	31 22.1
1	20 14.3 20.4 64.5	74 52.9 75.5 73.3	4 2.9 4.1 50.0	98 70.0
2	0 0.0 0.0 0.0	7 5.0 63.6 6.9	4 2.9 36.4 50.0	11 7.9
Total	31 22.1	101 72.1	8 5.7	140 100.0

The central incisors were also compared to the lateral incisors to determine where the overjet was more frequent (Table 14 and 15). Similar trends were seen in all categories. It was noted that 93.6% of central incisors and 89.3% of lateral incisors scored a 1 or 0 for all dental casts measured.

Table 14. Grouped central incisors by score

	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0 for both teeth	12	8.6	12	8.6
0 for one tooth and 1 for the other	31	22.1	43	30.7
0 for one tooth and 2 for the other	2	1.4	45	32.1
1 for both teeth	86	61.4	31	93.6
1 for one tooth and 2 for the other	7	5.0	138	98.6
2 for both teeth	2	1.4	140	100.0

Table 15. Grouped lateral incisors by score

	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0 for both teeth	11	7.9	11	7.9
0 for one tooth and 1 for the other	40	28.6	51	36.4
0 for one tooth and 2 for the other	-	-	-	-
1 for both teeth	74	52.9	125	89.3
1 for one tooth and 2 for the other	11	7.9	136	97.1
2 for both teeth	4	2.9	140	100.0

Table 16. Dichotomized and grouped central and lateral incisors

Table of dichotomized and grouped central and lateral incisors				
	Laterals			
Centrals	0/1 for both teeth	0/1 for one tooth and 2 for other	2 for both teeth	Total
0/1 for both teeth	123	6	0	129
	87.9	4.3	0.0	92.1
	95.4	4.7	0.0	
	98.4	54.6	0.0	
0/1 for one tooth and 2 for other	2	4	3	9
	1.4	2.9	2.1	6.4
	22.2	44.4	33.3	
	1.6	36.4	75.0	
2 for both teeth	0	1	1	2
	0.0	0.7	0.7	1.4
	0.0	50.0	50.0	
	0.0	9.1	25.0	
Total	125	11	4	140
	89.3	7.9	2.9	100.0

Frequency
Percent
Row %
Column %

Due to the low number of contacting incisors, central and lateral scores were dichotomized and grouped. Table 16 reflects these findings. It was interesting to note that because of the extremely low percentage of all contacting incisors (2.9%), a score of 0 or 1 was combined. This led to the finding that 87.9 % of all incisors had a 0 or 1 for all teeth. These results also showed that it was extremely rare for all incisors to have an overjet over 1mm with only 0.7% of the data set possessing this characteristic.

Lastly, hypothesis testing was performed to evaluate whether each median value of each individual and total incisor contact score was significantly different from zero. In all incisors contact scores as a group and individually (UR1, UR2, UL1, UL2) there was a statistically significant difference then that expected of by the ABO with all P values < 0.0001, thereby forcing us to reject the null hypothesis.

CHAPTER 5

DISCUSSION

Incisor contact in optimal occlusion should be an important topic of discussion among all orthodontists. The revised system for grading orthodontic treatment results was first used in 1999 to objectively evaluate completed orthodontic treatment.[2] Because incisor contact in optimally occluding patients without orthodontic treatment, as it is defined in this paper, had not been previously investigated, guidelines based on patient samples were unavailable. The American Board of Orthodontics grades treatment results heavily in this area with a possible 8 point deduction. [1] Our results do not support the current ABO grading system for overjet as it relates to incisors.

Okeson reported that heavy anterior contacts are often extremely harmful to the dentition, displacing the teeth or causing heavy and damaging vibrations known as fremitus that can negatively impact alveolar bone proper surrounding the teeth.[25] This study is the first to show incisor contact distribution in ideal occlusion. The results clearly indicate that the overwhelming majority, or 97%, of patients do not have all incisor teeth contacting. Bjork's implant studies have shown that when the mandible grows forward relative to the maxilla in the late teens, the lower incisors may be displaced lingually.[24] Yet another point that should not go unrecognized is Proffit's remarks on late mandibular jaw growth. Proffit stated that when late mandibular growth occurs, the following cascade of effects may be seen: The mandible is displaced distally leading to temporomandibular joint disorders; the upper incisors are proclined and displaced

forward resulting in spacing; the lower incisors are displaced distally resulting in lower incisor crowding.[9] It is also common knowledge that all healthy teeth possess a periodontal ligament capable of allowing proprioception and slight tooth movement during mastication.[26] Plaster dental casts are incapable of transferring this important characteristic of the final orthodontically treated patient. This feature alone would leave one to believe that if stone model teeth are contacting then they most certainly are contacting harder during mastication. This in turn can lead to detrimental side effects spoken of above. This study suggests that this is yet another reason why only 8.6% of central incisors pairs and 7.9% of lateral incisors pairs were found to be contacting in the current study.

From a clinical point of view, and in order to fulfill the ABO requirements, many clinicians find themselves reducing the mesio-distal diameter of the maxillary incisors to retract them and achieve incisor coupling. The interproximal reduction technique was popularized in 1980 by Sheridan, even though it had been introduced much earlier by Ballard.[27] The aim of the technique is to remove otherwise healthy enamel in order to create space to align the teeth, or in the present case, to provide space for incisor retraction. One of the main indications for interproximal stripping is to compensate for the presence of tooth-size discrepancy (Bolton discrepancy).[21] In this scenario, when the discrepancy is diagnosed, the tooth-mass excess can be reduced by recontouring the mesial and distal aspects of the desired teeth. The results from this study provide assurance that upper incisor interproximal reduction for the sole aim of achieving anterior coupling is unnecessary, as tight anterior contacts with the opposing arch do not occur in ideal untreated dentitions.

It should also be noted that the PAR index has showed an excellent intra-examiner and inter-examiner reliability and is still used today as a measure to grade results. A lower PAR score is an indication of treatment success. Using the PAR system an overjet of 0-3mm achieve a score of 0.[17, 28] The scores from our study indicate the vast majority of optimal occlusions fall well within this range. This leads us to reflect upon why the ABO would deduct points for anything but incisor contact, and whether a change in the current grading rubric should be considered.

Guidelines for occlusal contact need to come from quality samples of living humans and not from human skulls post-mortem. Wheelers anatomy text references anterior tooth contact based on limited skull samples of optimal occlusion.[29] Moreover, other elements such as proprioception, muscle tone, tongue posture can be evaluated. The data from the present study suggests that the optimal overjet relationship of upper incisor to lower incisors be ≤1mm.

To the authors knowledge, no study has been shown to evaluate the incisor contact or overjet in the optimally occluding patient. It is the goal of this research to provide sound, quality data that can be used as the orthodontist approaches the end of orthodontic treatment for their patients and provide them with a standard of anterior tooth contact. The findings of this study rejects the null hypothesis that there is no significant difference between incisor contact of the untreated optimal occlusion and that expected of by the American Board of Orthodontics.

Future studies could attempt to gather additional background information for this subtype of patient. Examples include: cephalometric measurements, history of

temporomandibular joint derangement and serial dental casts during each decade of life to analyze changes in occlusion and tooth contact.

CHAPTER 6

CONCLUSIONS

- Upper incisors do not contact in optimal occlusion. Only 2.9% of the study sample contained all 4 incisors contacting.
- The average incisor contact score, based on ABO grading is 4. This implies that the optimal overjet relationship of upper incisor to lower incisors be ≤1mm.
- Central and lateral incisors overjet ranges are similar.
- There is no significant difference between overjet ranges when comparing left versus right upper incisors.

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APPENDIX

INSTITUTIONAL REVIEW BOARD APPROVAL

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Institutional Review Board for Human Use

DATE: April 12, 2017

MEMORANDUM

TO: Ryan Baker
Principal Investigator

FROM: Cari Oliver, CIP
Assistant Director
Institutional Review Board for Human Use (IRB)

RE: Request for Determination – Not Human Subjects Research
IRB Protocol **N170309006 – Incisor Occlusion in Nonorthodontic Patients with Normal Occlusion**

A member of the Office of the IRB has reviewed your Application for Not Human Subjects Research Designation for above referenced proposal.

The reviewer has determined that this proposal is **not** subject to FDA regulations and is **not** Human Subjects Research. Note that any changes to the project should be resubmitted to the Office of the IRB for determination.

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