ABO OBJECTIVE GRADING SYSTEM

BASED ON CLINICAL

PHOTOGRAPHY

Bryan R. Wirtz, D.D.S.

An Abstract Presented to the Graduate Faculty of
Saint Louis University in Partial Fulfillment
of the Requirements for the Degree of
Master of Science in Dentistry (Research)

2012

Abstract

Purpose: To determine if the American Board of Orthodontics' Objective Grading System can be accurately applied through clinical photography. **Materials and Method:** The sample consisted of ten ABO Board graders and ten orthodontic residents from Saint Louis University. The sample graded ten finished orthodontic cases using the Objective Grading System based only on clinical photography and their scores were subsequently compared to the same cases scored traditionally using the final plaster orthodontic models. A Cronbach's alpha reliability test was performed to determine individual subject categorical reliability and a oneway ANOVA was completed to compare the results of the Board graders and residents as two groups. **Results:** Only five of the twenty subjects were found reliable for more than one of the eight categories evaluated in the Objective Grading System. Within groups, the ANOVA revealed that only Board graders evaluating buccolingual inclination was found to be significantly different than gold standard scores from plaster models. The Board graders significantly underestimated the gold standard in this category. **Conclusion:** The American Board of Orthodontics thrives on examiner synchronization and reliability. Since individual reliability in this study tested poorly, it cannot be recommended to replace plaster models with clinical photography when applying the Objective Grading System.

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COMMITTEE IN CHARGE OF CANDIDACY:

Professor Eustaquio Araujo,
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Professor Peter Buschang

Assistant Professor Patrick Foley

Dedication

I would like to dedicate this thesis to my family. My family has been a constant source of support and encouragement for me throughout my professional education and in life. I truly appreciate all their love.

Acknowledgements

I would like to recognize the following individuals and groups for their guidance and assistance throughout my residency and during my thesis composition:

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CHAPTER I: INTRODUCTION

In 1929, Ketchum and several other colleagues established the American Board of Orthodontics (ABO) with the purpose of "elevating the level of orthodontic care for the public by encouraging excellence in clinical practice and specialty education." [1] Initially Board certification was given only to highly respected orthodontists. However, once the American Dental Association recognized the American Board of Orthodontics as the official certifying Board for the specialty, the Board's popularity grew rapidly.

Since 1950 several different methods for certification were implemented, modified and eventually eliminated throughout the evolution of Board certification. Currently, phase III of the examination utilizes a method known as the Discrepancy Index to determine case complexity and the Objective Grading System to evaluate treatment outcome.[1]

The Objective Grading System was initiated in 1999 as a way to ensure a reliable, reproducible and accurate assessment of treatment outcomes. At this time, completion of the Objective Grading System requires orthodontic records in the form of a panoramic radiograph, clinical photography and a set of high quality orthodontic models.[1] Over the past twelve years, the records requirements have changed very little and minimal research has been done to determine if the Objective Grading System can be performed without the use of orthodontic models.

The purpose of this study is to attempt to apply the Objective Grading System using only clinical photography. Sheridan illustrated in 2001 that over 90% of orthodontists take both pre-treatment and post-treatment clinical photography. In this article, an orthodontist was quoted saying "I would take final models on a case that was interesting."[2] It is likely that many orthodontic offices are not taking finished models as well. Consequently, many finished cases

could not be used for phase III of Board certification. If this study reveals an accurate Objective Grading System score using only clinical photography, over 90% of orthodontists could attempt Board certification using only photography and the American Board of Orthodontics could possibly consider modifying its records requirements for phase III of the examination.

CHAPTER II: REVIEW OF THE LITERATURE

The American Board of Orthodontics

History

The American Board of Orthodontics was created in 1929 in Estes Park, Colorado, by Ketchum and several other colleagues from the American Society of Orthodontia. The American Board of Orthodontics was the first specialty board in the field of dentistry and at that time, only ophthalmology and otolaryngology specialty boards were in existence.[1]

The American Board of Orthodontics was created for the purpose of establishing a system to be used for certifying orthodontic specialists. Their goal is to "elevate the level of orthodontic care for the public by encouraging excellence in clinical practice and specialty education."[1] The American Board has created four objectives:

1) To evaluate the skills and clinical competency of those graduating from accredited orthodontic programs.
2) To re-evaluate the skill of those who become certified via a process known as recertification.
3) To support graduate, post-graduate and continuing education in orthodontics.
4) To encourage certification throughout the world.

Achieving certification by the American Board of Orthodontics does not lead to obtaining a degree nor does it confer any legal, privilege or license to practice orthodontics. Achieving a certificate by the Board is considered a certification of attainment for a practicing orthodontist. Once one achieves certification he or she is referred to as a Diplomate.[1]

Certification

Initially, certification of Diplomates was done by credentials only. In the 1950's, after the Board was named the only certifying body in orthodontics by the American Dental Association, certification became more prestigious and more orthodontists sought certification. The American Board of Orthodontics then decided to collect applications, determine eligibility and grant certification.[1]

In the late 1950's and 1960's, a thesis and presenting clinical case reports was required for certification by the American Board. In 1964, the need for a written examination was brought to the forefront and from 1964-1978 writing a thesis or passing a written exam, along with presenting case reports, was used for certification. In 1978, writing a thesis was no longer required and the certification process became a written exam and clinical case reports.[1]

Currently the American Board of Orthodontics is certifying much the same way it did in 1978. Certification is achieved by passing three phases. The three phases are application, written examination and clinical examination.

Application – Phase I may be completed by a dentist who has graduated from an advanced orthodontic education program that has been approved by the Commission on Dental Accreditation of the American Dental Association. An applicant may also begin phase I of the certification process if he or she is a full time student/resident in an accredited orthodontic program. A certificate/degree or a letter from the department's Program Director is also required by the American Board of Orthodontics to complete phase I.

Written Examination – Phase II of Board certification is a one day written exam that consists of 240 multiple choice questions. Questions for the exam are created by the ABO Board of directors, orthodontic educators and some are contributed by orthodontic residents. Once

questions are submitted to the Board, the examination committee selects and modifies the questions to create a question bank to be used for the examination. The test is criterion-referenced. This means that the minimally competent examinee is used to set the criterion and all other scores are generated in relation to this benchmark.[1]

The American Dental Associations Council on Dental Accreditation has selected topics to be tested on the exam. Those topics are basic sciences, applied biomedical sciences, orthodontic theory, orthodontic practice, related dental disciplines and the orthodontic literature. To ensure safety and integrity, the examination is computerized and taken at various testing centers in the United States and Canada.[1]

Clinical Examination – Phase III of Board certification is a presentation of treated orthodontic cases to test the clinician's skills and treatment knowledge. Various pathways are available to a candidate to complete Phase III of the examination. However, in general, the Phase III consists of two parts; case reports presented by the examinee and board cases presented to the examinee. Case reports presented by the examinee are brought to the examination and undergo a comprehensive evaluation and a comprehensive oral evaluation. Board cases presented to the examinee involve critiquing the diagnosis and treatment planning skills of the examinee using an unknown case chosen by the Board. All certifications remain valid for ten years.[1]

Initial Certification Examination (ICE) – The initial certification exam is available for recent graduates of an orthodontic residency program. The ICE must be started within twenty-four months after graduation and completed within ten years after the completion of the ICE. The ICE examination allows graduates to use cases treated during residency to obtain board certification. A minimum of three cases, out of the required six, may be brought to the

examination and banked. The cases will undergo a comprehensive evaluation and a comprehensive oral examination about the cases will be given to the examinee. Within ten years of completing this process a candidate must submit the remaining cases via mail. Case selection must be made in accordance to the ABO's standards. The candidate must also succeed in the case report oral examination.[1]

Beginning Certification Examination - The beginning certification examination is an option available to all orthodontists that did not take the initial certification examination within twenty-four months after graduation. Six cases treated by examinee must be brought to the exam and meet the specifications set forth by the Board. The cases will undergo a comprehensive evaluation and a comprehensive oral examination will be given to the examinee. The candidate must also succeed in the case report oral examination.[1]

Gateway Certification Examination – This examination is available for current Diplomates who were certified under the initial gateway offer. This examination must be taken before the expiration date on the Diplomate's current ABO certificate. Six cases treated by examinee must be brought to the exam and meet the specifications set forth by the Board. The cases will undergo a comprehensive evaluation and a comprehensive oral examination will be given to the examinee. The candidate must also succeed in the case report oral examination.[1]

Recertification Examinations – Specific requirements for recertification are determined by the Board. Recertification lasts for ten years.[1]

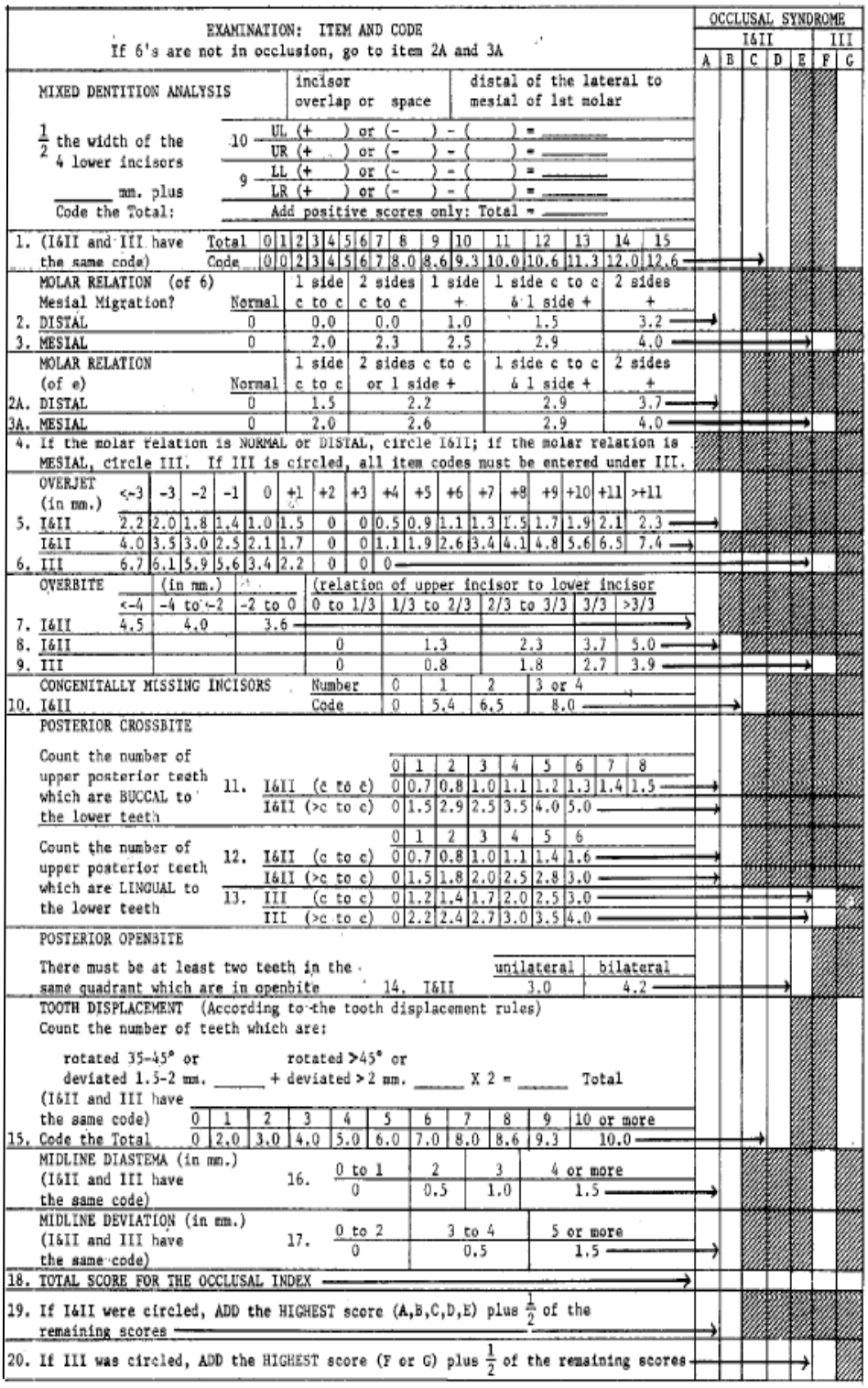
Voluntary Recertification Examination – This examination is available for current Diplomates who have a non-time-limited certificate.[1]

Orthodontic Treatment Indices

Evaluating treatment need and treatment outcome can be a very difficult and time consuming job. Over the years, many indices have been created to assess treatment need, treatment complexity and treatment outcome. Not only must an index be created to perform such a task but it must be reliable, reproducible and accurate for each and every malocclusion. Summer's Occlusal Index, Dental Aesthetic Index, Peer Assessment Rating, Index of Orthodontic Treatment Need and the Index of Complexity, Outcome and Need will be described in the following sections.

Summers' Occlusal Index

In 1966 Summers developed the Occlusal Index for evaluating the severity of a malocclusion. The Occlusal Index begins by determining the dental age of the patient. Then occlusal categories such as molar relation, overbite, overjet, posterior crossbite, posterior open bite, tooth displacement (actual and potential), midline relations and missing permanent teeth are assessed for each case. Each category is scored appropriately and applied to the correct weighted equation based on the predetermined dental age. Figure 2.1 shows an example of an examination form used to determine the Occlusal Index.[3]



EXAMINATION: ITEM AND CODE
If 6's are not in occlusion, go to item 2A and 3A

OCCLUSAL SYNDROME: I&II (A B C D E) III (F G)

MIXED DENTITION ANALYSIS — incisor overlap or space — distal of the lateral to mesial of 1st molar

1/2 the width of the 4 lower incisors ____ mm. plus
Code the Total:

10 — UL (+) or (-) - ( ) = ____
UR (+) or (-) - ( ) = ____
9 — LL (+) or (-) - ( ) = ____
LR (+) or (-) - ( ) = ____
Add positive scores only: Total = ____

1. (I&II and III have the same code)	Total	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Code	0	0	2	3	4	5	6	7	8.0	8.6	9.3	10.0	10.6	11.3	12.0	12.6

MOLAR RELATION (of 6) Mesial Migration?	Normal	1 side c to c	2 sides c to c	1 side +	1 side c to c & 1 side +	2 sides +
2. DISTAL	0	0.0	0.0	1.0	1.5	3.2
3. MESIAL	0	2.0	2.3	2.5	2.9	4.0

MOLAR RELATION (of e)	Normal	1 side c to c	2 sides c to c or 1 side +	1 side c to c & 1 side +	2 sides +
2A. DISTAL	0	1.5	2.2	2.9	3.7
3A. MESIAL	0	2.0	2.6	2.9	4.0

4. If the molar relation is NORMAL or DISTAL, circle I&II; if the molar relation is MESIAL, circle III. If III is circled, all item codes must be entered under III.

OVERJET (in mm.)	<-3	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	>+11
5. I&II	2.2	2.0	1.8	1.4	1.0	1.5	0	0	0.5	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3
I&I	4.0	3.5	3.0	2.5	2.1	1.7	0	0	1.1	1.9	2.6	3.4	4.1	4.8	5.6	6.5	7.4
6. III	6.7	6.1	5.9	5.6	3.4	2.2	0	0	0								

OVERBITE (in mm.)	<-4	-4 to -2	-2 to 0	(relation of upper incisor to lower incisor: 0 to 1/3	1/3 to 2/3	2/3 to 3/3	3/3	>3/3
7. I&II	4.5	4.0	3.6					
8. I&II				0	1.3	2.3	3.7	5.0
9. III				0	0.8	1.8	2.7	3.9

CONGENITALLY MISSING INCISORS	Number	0	1	2	3 or 4
10. I&II	Code	0	5.4	6.5	8.0

POSTERIOR CROSSBITE

Count the number of upper posterior teeth which are BUCCAL to the lower teeth

		0	1	2	3	4	5	6	7	8
11. I&II (c to c)		0	0.7	0.8	1.0	1.1	1.2	1.3	1.4	1.5
I&II (>c to c)		0	1.5	2.9	2.5	3.5	4.0	5.0		

Count the number of upper posterior teeth which are LINGUAL to the lower teeth

		0	1	2	3	4	5	6
12. I&II (c to c)		0	0.7	0.8	1.0	1.1	1.4	1.6
I&I (>c to c)		0	1.5	1.8	2.0	2.5	2.8	3.0
13. III (c to c)		0	1.2	1.4	1.7	2.0	2.5	3.0
III (>c to c)		0	2.2	2.4	2.7	3.0	3.5	4.0

POSTERIOR OPENBITE

There must be at least two teeth in the same quadrant which are in openbite

	unilateral	bilateral
14. I&II	3.0	4.2

TOOTH DISPLACEMENT (According to the tooth displacement rules)
Count the number of teeth which are:

rotated 35-45° or deviated 1.5-2 mm. ____ + rotated >45° or deviated >2 mm. ____ X 2 = ____ Total

(I&II and III have the same code)	0	1	2	3	4	5	6	7	8	9	10 or more
15. Code the Total	0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	8.6	9.3	10.0

MIDLINE DIASTEMA (in mm.) (I&II and III have the same code)	0 to 1	2	3	4 or more
16.	0	0.5	1.0	1.5

MIDLINE DEVIATION (in mm.) (I&II and III have the same code)	0 to 2	3 to 4	5 or more
17.	0	0.5	1.5

18. TOTAL SCORE FOR THE OCCLUSAL INDEX

19. If I&II were circled, ADD the HIGHEST score (A,B,C,D,E) plus 1/2 of the remaining scores

20. If III was circled, ADD the HIGHEST score (F or G) plus 1/2 of the remaining scores

Figure 2.1 – Summers' Occlusal Index worksheet. Available from "The Occlusal Index: A System for Identifying and Scoring Occlusal Disorders."[3]

Dental Aesthetic Index

A second index used to assess orthodontic need is called the Dental Aesthetic Index or DAI. Unlike Summers' Occlusal Index the DAI combines both the esthetic and the physical aspects of the occlusion to develop a treatment need score. The DAI was developed in 1986 by Jenny and Cons.[4]

The DAI was created using the public's perception of esthetics from photographs of 200 different occlusions. The photographs included both a full face photo and intraoral views. The result was the creation of a mathematical regression equation combining both esthetics and dental malocclusion. Table 2.1 shows the categories utilized and the rounded coefficient weights for each category. DAI scores of 30 and above indicate treatment is highly recommended.[4]

Table 2.1 – Components and rounded coefficients of the Dental Aesthetic Index. Table is available for use in "Comparing and contrasting two orthodontic indices, the Index of Orthodontic Treatment Need and the Dental Aesthetic Index."[4]

DAI Components	Regression Coefficients (Rounded Weights)
Number of visibly missing teeth[a]	6
Crowding (0, 1, or 2)[b]	1
Spacing (0, 1, or 2)[b]	1
Diastema, mm[c]	3
Largest anterior maxillary irregularity, mm[d]	1
Largest anterior mandibular irregularity, mm[d]	1
Anterior maxillary overjet, mm[e]	2
Anterior mandibular overjet, mm[e]	4
Vertical anterior open bite, mm[e]	4
Largest anteroposterior molar relation[e]	3
0 = class I occlusion	
1 = 1/2 cusp mesial/distal	
2 = whole cusp mesial/distal	
Constant	13

[a] Not counted if cusp tips were present.
[b] Assessed on incisor segments.
[c] Largest measurement.
[d] Site of greatest rotations or displacement from normal arch alignment.
[e] Measured with teeth in centric occlusion.

Peer Assessment Rating

In 1987 no index had been created to measure both initial malocclusion severity and treatment outcome. In England a group of ten orthodontists called the British Orthodontic Standards Working Party set out to create such an index. The result was the creation of the Peer Assessment Rating.

The Working Party evaluated over 200 pre-treatment and post-treatment dental casts and identified features to be assessed for use in the index. The eleven components of the PAR Index are upper right segment, upper anterior segment, upper left segment, lower right segment, lower anterior segment, lower left segment, right buccal occlusion, overjet, overbite, centerline and left buccal occlusion.[5]

Scores are calculated for each category and summed. A PAR ruler was also created to help clinicians determine a score quickly by analyzing a model. The ruler used to issue a PAR score can be seen in Figure 2.2. A PAR score of zero represents normal occlusion and alignment while a higher score indicates a higher severity of malocclusion. Pretreatment scores rarely exceed fifty. The pretreatment and posttreatment PAR scores can be compared and used to assess treatment success.[5]

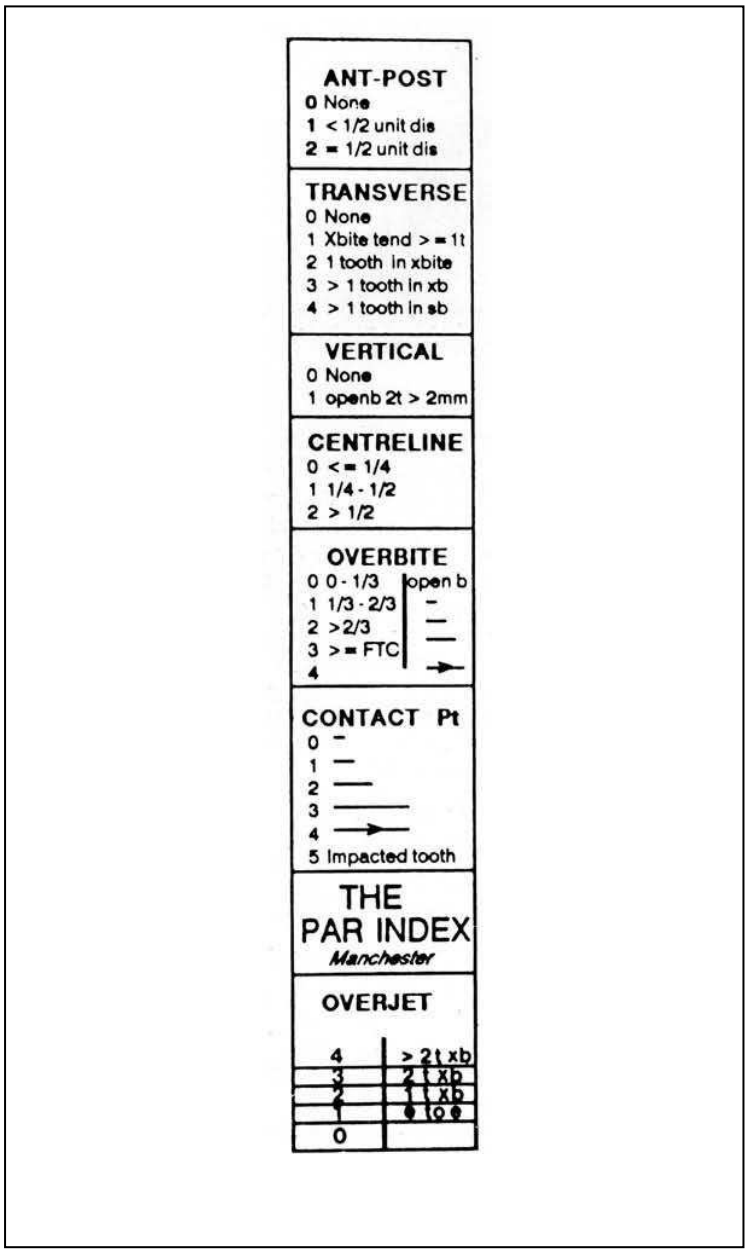


Figure 2.2 - PAR ruler[5]

Index of Orthodontic Treatment Need

In 1989 Brook and Shaw developed the Index of Orthodontic Treatment Need (IOTN) to assess the need for orthodontic treatment. Similar to the PAR Index, the IOTN has

both an esthetic component and a dental health component. The IOTN is used in the United Kingdom.[4,6]

The esthetic component of the IOTN is scored by looking at photographs. Photograph one represents the most esthetic and photograph ten the most unaesthetic. The patient and doctor match the occlusion as best as possible to that of the patient. Figure 2.3 below shows the ten photographs used for the esthetic component of the IOTN.[4]

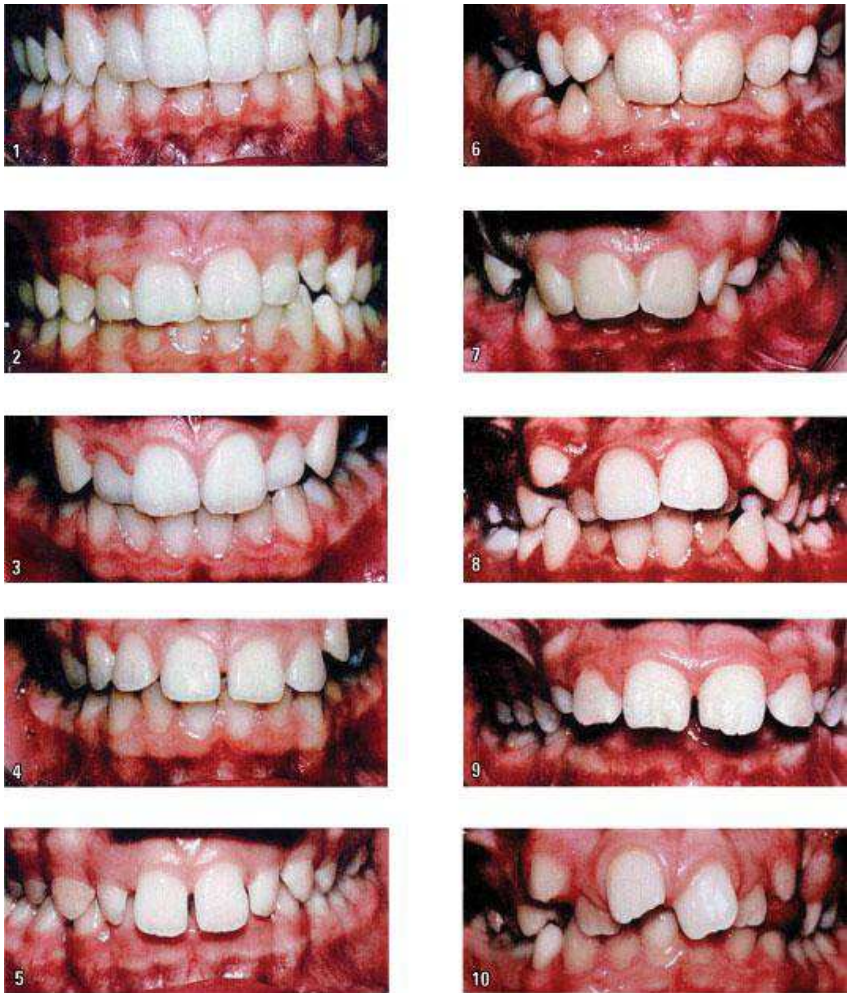


Figure 2.3 – IOTN esthetic component. Figure is available for use in "Comparing and contrasting two orthodontic indices, the Index of Orthodontic Treatment Need and the Dental Aesthetic Index."[4]

The dental component of the IOTN is a scale of five grades. Grade one includes minor dental problems while grade five consists of complex dental problems indicating a high need for orthodontic treatment. The doctor will place the malocclusion into the appropriate grade. Applying the IOTN to determine treatment need is done by initially using the dental component and then if necessary applying the esthetic score. Figure 2.4 illustrates the five grades of the dental component of the IOTN.[4]

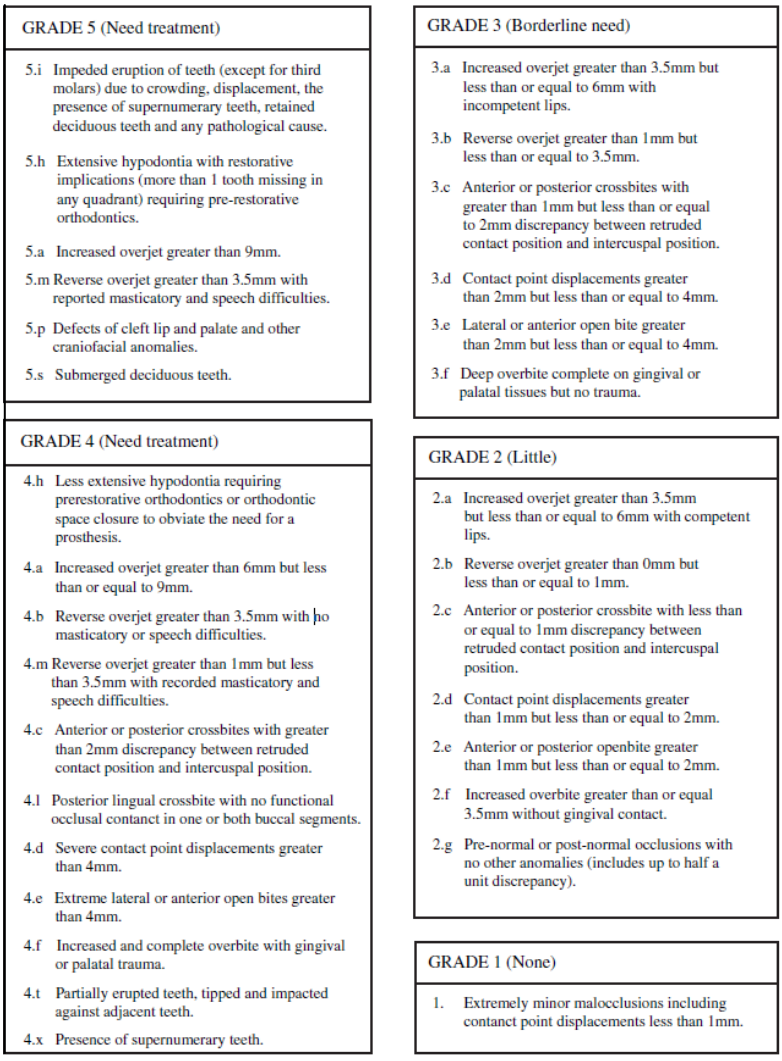


Figure 2.4 – IOTN dental component. Figure is available for use in "Comparing and contrasting two orthodontic indices, the Index of Orthodontic Treatment Need and the Dental Aesthetic Index."[4]

Index of Complexity, Outcome and Need

An index developed from components of the IOTN and PAR is called the Index of Complexity, Outcome and Need (ICON). The ICON was developed in England by Richmond and Daniels in 1998 and similar to the PAR, this index can be used to evaluate pre-treatment difficulty and post-treatment success.[7]

The ICON uses five occlusal characteristics each placed into a weighted mathematical formula to develop a summed score. The categories used are: Brook and Shaw's aesthetic component of the IOTN, crossbite, upper arch crowding/spacing, buccal segment antero-posterior relationships and anterior vertical relationship. Table 2.2 illustrates the five categories used for the ICON and how to score each trait. Table 2.3 shows the multiplier used for each category to develop a summed score.[7]

Table 2.2 – ICON categories. Table is available for use in "The Development of the Index of Complexity, Outcome and Need (ICON)."[7]

	Score	0	1	2	3	4	5
Aesthetic	1–10 As judged using IOTN AC						
Upper arch crowding	Score only the highest trait either spacing or crowding	Less than 2 mm	2·1 to 5 mm	5·1 to 9 mm	9·1 to 13 mm	13·1 to 17 mm	> 17 mm or impacted teeth
Upper spacing		Up to 2 mm	2·1–5 mm	5·1–9 mm	>9 mm		
Crossbite	Transverse relationship of cusp to cusp or worse	No crossbite	Crossbite present				
Incisor open bite	Score only the highest trait either open bite or overbite	Complete bite	Less than 1 mm	1·1–2 mm	2·1–4 mm	>4 mm	
Incisor overbite	Lower incisor coverage	Up to ⅓ tooth	⅓–⅔ coverage	⅔ up to full covered	Fully covered		
Buccal segment anteroposterior	Left and right added together	Cusp to embrasure relationship only, Class I, II or III	Any cusp relation up to but not including cusp to cusp	Cusp to cusp relationship			

Table 2.3 – ICON traits and weighting. Table is available for use in "The Development of the Index of Complexity, Outcome and Need (ICON)."[7]

Occlusal trait	ICON weighting
IOTN Aesthetic Component	7
Left + right buccal antero-posterior	3
Upper arch Crowding	5
Overbite	4
Crossbite	5
Treatment need cut-off	43
Treatment outcome cut-off	31

Cases that score above 77 are considered very difficult while cases that score below 30 are considered easy. Pre-treatment scores can be compared to post-treatment scores to determine clinical success.[7]

American Board of Orthodontics' Indices

Development of the Discrepancy Index and Objective Grading System

In 1998, The American Board of Orthodontics felt previous indices determined case difficulty rather than case complexity. Case difficulty is subjective and the Board felt that determining case complexity was more quantifiable. Case complexity is defined as "a combination of factors, symptoms, or signs of a disease or disorder which forms a syndrome."[8] Although many felt the PAR Index was quantifiable, the Board felt the PAR does not detect minor variations in tooth position in the outcome.[9] Subsequently, in 1998 a group of fourteen current and past ABO directors convened to develop an index to be used to quantify case complexity. The result of this meeting was the creation of the Discrepancy Index.[8]

To determine the Discrepancy Index, orthodontic records in the form of models, cephalometric and panoramic radiographs must be used. The records are scored using the discrepancy index and then can be applied to satisfy the case requirements for phase III of the certification process. Elements used to determine the Discrepancy Index are overjet, overbite, anterior open bite, lateral open bite, crowding, occlusion, lingual posterior crossbite, buccal posterior crossbite, ANB angle, IMPA and SN-GoGn angle. Additionally, other factors such as missing or supernumerary teeth, midline discrepancy, impaction, transposition and anomalies of tooth size and shape can all be scored.[8] A Discrepancy Index form can be seen in Figure 2.5.

EXAM YEAR ABO DISCREPANCY INDEX Version 2011-2012

ABO ID # CASE# PATIENT

TOTAL D.I. SCORE

Examiners will verify measurements in each parameter.

OVERJET

0 – 0.9 mm. (edge-to-edge)	= 1 pt.
1 – 3 mm.	= 0 pts.
3.1 – 5 mm.	= 2 pts.
5.1 – 7 mm.	= 3 pts.
7.1 – 9 mm.	= 4 pts.
> 9 mm.	= 5 pts.
Negative Overjet (x-bite): 1 pt. per mm. per tooth	= ___pts.

Total

OVERBITE

0 – 3 mm.	= 0 pts.
3.1 – 5 mm.	= 2 pts.
5.1 – 7 mm.	= 3 pts.
Impinging (100%)	= 5 pts

Total

ANTERIOR OPEN BITE

0 mm. (edge-to-edge), 1 pt. per tooth =___pts.
then 1 pt. per additional full mm. per tooth =___pts.

Total

LATERAL OPEN BITE

2 pts. per mm. per tooth

Total

CROWDING (only one arch)

0 – 1 mm.	= 0 pts.
1.1 – 3 mm.	= 1 pts.
3.1 – 5 mm.	= 2 pts.
5.1 – 7 mm.	= 4 pts.
> 7 mm.	= 7 pts.

Total

OCCLUSION

Class I to end on	= 0 pts.	
End-to-End Class II or III	= 2 pts. per side	____pts.
Full Class II or III	= 4 pts. per side	____pts.
Beyond Class II or III	= 1 pt. per mm additional	____pts.

Total

LINGUAL POSTERIOR X-BITE

1 pt. per tooth Total

BUCCAL POSTERIOR X-BITE

2 pts. per tooth Total

CEPHALOMETRICS (See Instructions)

ANB ≥6° or ≤ -2°	@4pts. = ___
Each degree > 6°	___x 1 pt. = ___
Each degree < -2°	___x 1 pt. = ___
SN-MP	
≥ 38°	@2pts. = ___
Each degree > 38°	___x 2 pts.= ___
<26°	@1pt. = ___
Each degree < 26°	___x 1 pt. = ___
$\bar{1}$ to MP > 99°	@1pt. = ___
Each degree > 99°	___x 1 pt. = ___

Total

OTHER (See Instructions)

Supernumerary teeth	___x 1 pt. = ___
Ankylosis of perm. teeth	___x 2 pts. = ___
Anomalous morphology	___x 2 pts. = ___
Impaction (except 3rd molars)	___x 2 pts. = ___
Midline discrepancy (≥3 mm)	@ 2 pts. = ___
Missing teeth (except 3rd molars)	___x 1 pt. = ___
Missing teeth, congenital	___x 2 pts. = ___
Spacing (4 or more, per arch)	___x 2 pts. = ___
Spacing(mx cent diastema ≥ 2 mm)	@ 2 pts. = ___
Tooth transposition	___x 2 pts. = ___
Skeletal asymmetry(nonsurgical tx)	@ 3 pts. = ___
Addl. treatment complexities	___x 2 pts. = ___

Identify:

Total Other

Figure 2.5 – The Discrepancy Index. Form is available for use at www.americanboardortho.com[1]

The Discrepancy Index underwent significant field testing from 2000 through 2002. The following year, the Discrepancy Index was fully implemented and is used for determining case complexity for phase III of ABO certification.[8]

Coinciding with the creation of the Discrepancy Index, the development of the Objective Grading System was taking place to evaluate treatment outcome. The Objective Grading System's history begins in 1994 when the Board desired to make phase III of certification more objective. Previous treatment indexes did not satisfy the ABO's desire for reliability and precision and in 1995 field testing began to develop a new index to evaluate treatment results. Initial tests revealed 85% of treatment errors occurred in alignment, marginal ridges, buccolingual inclination, overjet, occlusal relationships, occlusal contacts and root angulation.

Objective Grading System testing in 1996 revealed poor inter-examiner reliability. To increase reliability a measuring instrument was created the following year. Additionally, the examiners added an additional category of interproximal contacts for scoring. In 1998 a final field test was conducted with a newly designed measuring tool (Figure 2. 6) and a yearly calibration of Board graders was instituted to increase inter-examiner reliability. The result of this field test was extremely successful and in 1999 the Objective Grading System was initiated and to be used for all examinees for phase III of Board certification.[9]

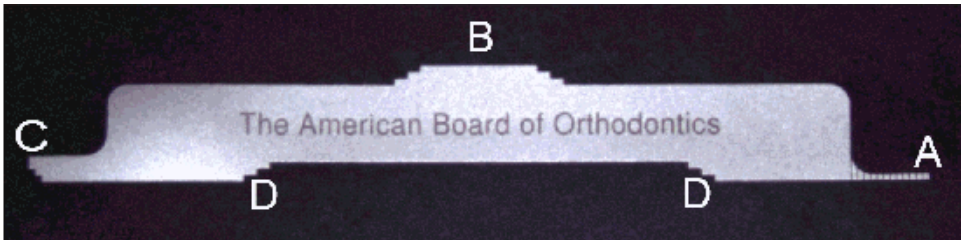


Figure 2.6 – ABO measuring tool[1]

The Objective Grading System

The current Objective Grading System includes eight criteria: alignment, marginal ridges, buccolingual inclination, occlusal relationships, occlusal contacts, overjet, interproximal contacts and root angulation. All categories can be evaluated from orthodontic models and a panoramic radiograph.

Alignment is an important category because it is a critical goal of orthodontic therapy and has a heavy influence on smile esthetics in the anterior region. Alignment is scored by evaluating the incisal edges and lingual surfaces of the maxillary anterior teeth and the incisal edges and labio-incisal surfaces in the mandibular anterior region. In the posterior dentition, the central grooves of the maxillary teeth are evaluated and the buccal cusps of the mandibular teeth are assessed for alignment. It has been shown that 80% of deductions are taken in the second molar and lateral incisor regions.[9]

Marginal ridges are evaluated to demonstrate proper vertical positioning of the teeth. If done correctly, the cemento-enamel junctions and bone height will be level and proper occlusal contacts can be obtained. Field tests indicate the majority of marginal ridge discrepancies occur between the maxillary and mandibular first and second molars.[9]

To establish proper occlusion and eliminate balancing interferences during excursions, buccolingual inclination is assessed. Buccolingual inclination refers to the heights of the buccal and lingual cusps of the posterior teeth. Ideally, these heights should be equal. Buccolingual inclination of the maxillary and mandibular second molars has proven the most difficult to obtain.[9]

To evaluate the anterior posterior relationship of the occlusion the Occlusal Relationship category uses Angle's Classification of Occlusion to determine success. In this

category, the buccal cusps of the maxillary canines and posterior teeth must align within one millimeter of the embrasures in the mandibular dentition.[9]

Occlusal Contacts are scored to determine if maximum intercuspation has been established. In this category, the buccal cusps of the mandibular dentition and the lingual cusps of the maxillary dentition must be in contact with their opposing arch. If a cusp is malformed it is not scored. The highest error is seen in the second molar region.[9]

Overjet evaluates the transverse relationship of the posterior dentition and the anterior posterior relationship of the anterior teeth. In the anterior region, mandibular teeth should contact the lingual surface of the maxillary teeth. In the posterior, mandibular buccal cusps and maxillary lingual cusps are evaluated. Errors typically occur in the second molar and lower incisor regions.[9]

To evaluate residual spaces in the dental arch post-treatment Interproximal Contacts are assessed. Spaces in the arch can lead to food impaction and can be unaesthetic if in the anterior region. Typically, this category loses very few points.[9]

Although newer methods are available such as cone-beam to evaluate root parallelism, Root Angulation is assessed in phase III using a panoramic radiograph. Parallel roots ensure maximum bone present between adjacent teeth which could be important in patients who suffer from periodontal disease. Dilacerated roots are not scored.[9] An Objective Grading System form can be seen in Figure 2.7.

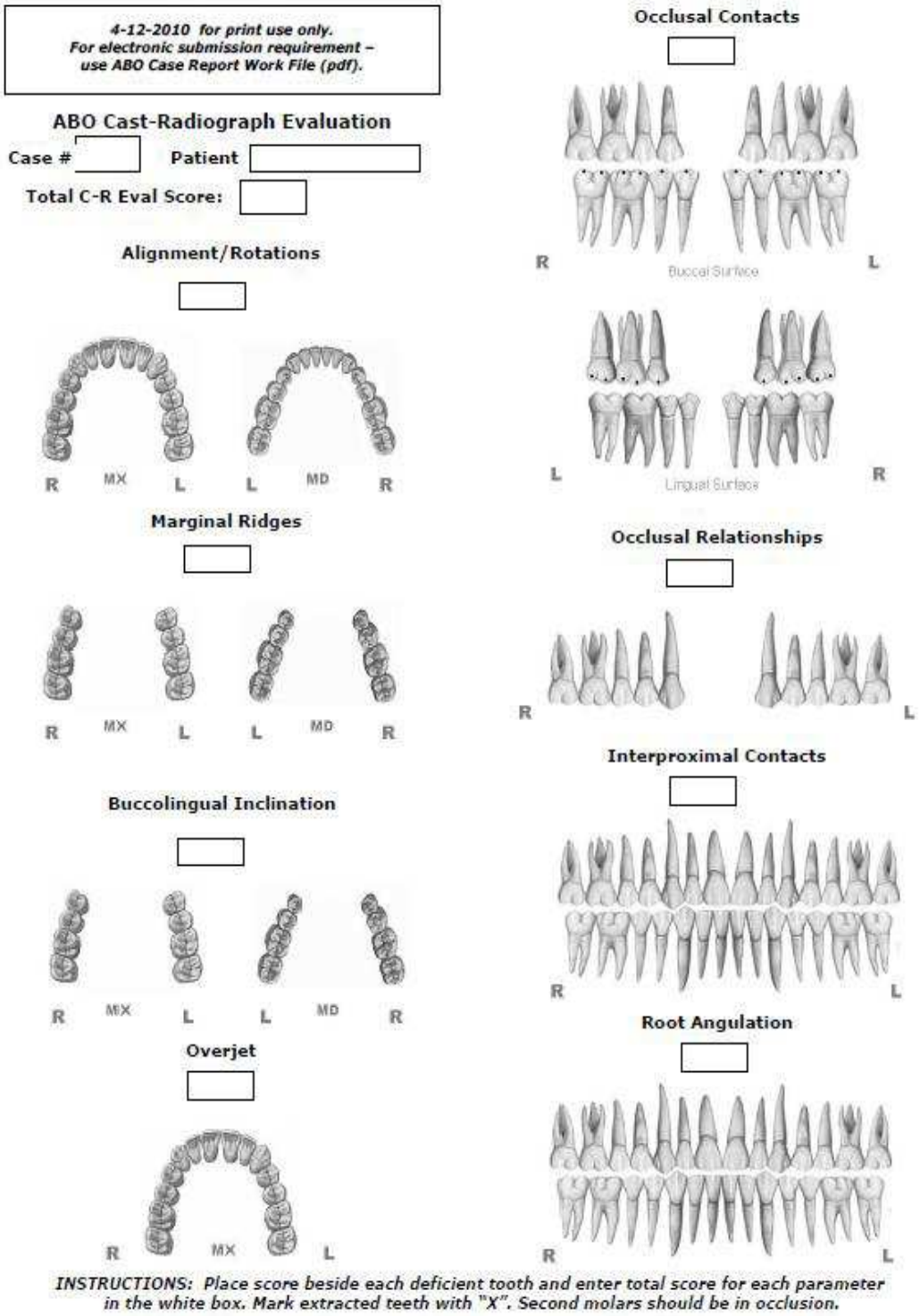


Figure 2.7 – Objective Grading System form. Available for use at www.americanboardortho.com[1]

Objective Grading System Scoring

Alignment – No deductions are made if the teeth are aligned within 0.5 mm of ideal. If the tooth is 0.5-1.0 mm out of alignment a point in deducted for each tooth. If the alignment error is greater than 1.0 mm two points will be subtracted. No more than two points will be subtracted from any tooth and the maximum deduction for alignment is 64 points.[9]

Marginal Ridges – If adjacent marginal ridges are within 0.5 mm of each other, no deductions are taken. If the heights of adjacent marginal ridges vary from 0.5-1.0 mm one point shall be deducted for the contact. If the variation is greater than 1.0 mm two points are deducted. No more than two points are deducted from any one contact.[9]

Buccolingual Inclination – In the mandibular arch, the measurement gauge lies on the buccal cusps of the right and left mandibular posterior teeth. If the lingual cusp is within 1.0 mm of the buccal cusp no points are deducted. If the discrepancy is between 1.0-2.0 mm one point is deducted. If greater than 2.0 mm of discrepancy exists two points shall be deducted. No more than two points shall be deducted from a single tooth. The same technique is used for the maxillary dentition except the gauge lies on the lingual cusps and analyses is performed on the buccal.[9]

Occlusal Contacts – In the mandibular arch, the buccal cusps should be in contact with the opposing arch. In the maxillary arch, the lingual cusps should be in contact. If a cusp is diminutive it is not scored. If the cusp is contacting its adjacent arch zero points are deducted. If the cusp is within 1.0 mm one point is deducted. If the distance is greater than 1.0 mm two points are deducted. No more than two points can be deducted for a single tooth.[9]

Occlusal Relationship – For cases finished in Angle Class I relationship, the maxillary buccal cusp tips of the canines, premolars and molars should align within 1.0 mm of the adjacent

embrasure. If the relationship is in error between 1.0-2.0 mm only one point shall be deducted per tooth. If the deviation is greater than 2.0 mm, two points shall be deducted. No more than two points can be deducted for a single tooth. If the extraction pattern dictates finishing a case in Angle Class II or III this is acceptable by the Board. The appropriate relationship will be scored as if it were Class I.[9]

Overjet – In the anterior region, the mandibular incisors should contact the lingual surface of the maxillary teeth. If this occurs, no points are deducted. If the distance is less than 1.0 mm, one point is deducted. If the distance is greater than 1.0 mm, two points are deducted. In the posterior region, the mandibular buccal cusps should occlude in the center of the opposing tooth. If the distance is less than 1.0 mm, one point is deducted. If the distance is greater than 1.0 mm two points are deducted. No more than two points can be deducted from any tooth.[9]

Interproximal Contacts – This category is scored by assessing any residual space between adjacent teeth. If no space exists, no points are deducted. If space remains and it is less than 1.0 mm, one point is deducted. If the space is greater than 1.0 mm two points are deducted per contact. No more than two points are subtracted from any contact.[9]

Root Angulation – Although not ideal, the use of a panoramic radiograph is used to reasonably assess root angulation and parallelism. If the deviation is less than 1.0 mm, no points are deducted. If the relationship between adjacent roots is deviated from 1.0-2.0 mm one point is subtracted. If the deviation is greater than 2.0 mm, two points are deducted. No more than two points will be subtracted per tooth.[9]

In general, cases that lose more than 30 points will fail and cases that are deducted less than 20 points will pass. Treatment planning, quality of records and accomplishment of

treatment objectives are also carefully assessed to determine passing phase III.[9] The ABO scoring reference sheet can be seen in Figure 2.8.

Reference - ABO Cast/Radiograph Evaluation

Updated 4-21-2010

See Grading System for Casts-Radiographs for entire discussion

ALIGNMENT/ROTATIONS

0.5 - 1 mm = 1 for each tooth
> 1 mm = 2 for each tooth

OCCLUSAL CONTACTS***

0 mm = satisfactory
≤ 1 mm = 1 (for each posterior
> 1 mm = 2 tooth out of contact)

*** Do **not** score diminutive distolingual cusps of the maxillary 1st and 2nd molars, nor lingual cusps of the mandibular first premolars. **Maximum of 2 points per tooth**.

MARGINAL RIDGES*

0.5 - 1 mm = 1 (for each interproximal contact
> 1 mm = 2 between posterior teeth)

* Do **not** include the canine-premolar contact
Do **not** include the distal of lower 1st premolar

OCCLUSAL RELATIONSHIP

< 1 mm = satisfactory
1 - 2 mm = 1 (for each maxillary **tooth** from the
> 2 mm = 2 the canines to the 2nd molars)

BUCCOLINGUAL INCLINATION**

0 - 1 mm = satisfactory
1.1 - 2 mm = 1 (for each posterior tooth)
> 2 mm = 2

** Do **not** score the mandibular 1st premolars nor the distal cusps of the second molars.

INTERPROXIMAL CONTACTS

0.6 - 1 mm = 1 (for each interproximal
> 1 mm = 2 **contact)**

OVERJET

0 mm = satisfactory
≤ 1 mm = 1 (for each maxillary
> 1 mm = 2 **tooth**)

ROOT ANGULATION

Parallel = 0
Not parallel = 1
Root contacting
adjacent root = 2 (for each **occurrence**)

Do **not** score the maxillary and mandibular canines.

NOTE: Gauge Width is 0.5 mm; Gauge Height is 1 mm
Third molars are not scored unless they substitute for the second molars.

Figure 2.8 – ABO scoring reference sheet. Available for use at www.americanboardortho.com[1]

Related Studies

Prior to each ABO clinical examination synchronization of grading occurs. With eight separate scoring categories on the Objective Grading System and Board graders with various differences in education, practice experience and treatment philosophies differences in scoring was anticipated. In February of 2009 fifty-two examiners convened in Dallas for synchronization. Two sets of finished records were evaluated by each grader. Their scores were compared to the "gold standard" or in other words, scores given to the cases by ABO directors. The results obtained were encouraging and demonstrated that five out of six examiners scored within one half deviation of the gold standard. This test reveals that synchronization is occurring among ABO graders and that a level playing field exists for examinees.[10]

As orthodontic offices advance in technology, traditional plaster models are being replaced by digital computerized models of the teeth. The Board has recognized this transition and currently allows pre-treatment digital models to be used for phase III of the examination. Digital pre-treatment models can be presented in printed form to the ABO's current specifications or in digital form provided that the examinee utilizes an accepted software program to determine the Discrepancy Index.[1]

In 2007, Okunami and Kusnoto attempted to perform the Objective Grading System using digital post-treatment models. In this study, 30 post-treatment plaster models were graded by a calibrated resident and the same models were scored using a digital system. The results showed the inability for the digital models have an accurate score for occlusal contacts, occlusal relationships and total score. In addition, the software used could not measure buccolingual inclination and this category was omitted. Problems such as overlapping of the teeth in

occlusion and the inability to measure buccolingual inclination, were reported to the software manufacturer in attempt to develop a more accurate system.[11]

In 2008, with updated computer software, Hildebrand and Palomo repeated a very similar study. In their study, 36 cases were scored using the Objective Grading System by a reliable, calibrated investigator on plaster models and by updated digital software. Results showed that the digital software produced scores that were on average nine points higher than the plaster models. Inadequacies were seen in alignment, occlusal contacts and overjet. On a positive note, the updated software was able to accurately assess buccolingual inclination. However, Hildebrand and Palomo did see similar problems as Okunami and Kusnoto when teeth were digitally in occlusion. Hildebrand and Palomo concluded that the current software cannot be used to accurately assess cases using the Objective Grading System.[12]

As previous attempts to evolve the certification process using post-treatment digital models have, as of now, fallen short, other ideas should be tested and considered to continue the evolution of the certification process. As technology has improved, so has the quality and accuracy of digital clinical photography. Currently, the ABO requires three facial photographs and five intraoral photographs to be submitted for case evaluation. With this in mind, the investigator set out to determine if the Objective Grading System can be accurately applied using only clinical photographs. Quoting past ABO director Vaden, "Although the adoption of new technologies and methods of testing presents new opportunities that a proactive and innovative Board must consider, the Board will retain focus on its mission established in 1929."[13] It is the goal of this research to apply advancing technology, without sacrificing quality and accuracy and attempt to determine if accurate post-treatment scores can be obtained using the Objective Grading System based solely on clinical photography.

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CHAPTER III: JOURNAL ARTICLE

Abstract

Purpose: To determine if the American Board of Orthodontics' Objective Grading System can be accurately applied through clinical photography. **Materials and Method:** The sample consisted of ten ABO Board graders and ten orthodontic residents from Saint Louis University. The sample graded ten finished orthodontic cases using the Objective Grading System based only on clinical photography and their scores were subsequently compared to the same cases scored traditionally using the final plaster orthodontic models. A Cronbach's alpha reliability test was performed to determine individual subject categorical reliability and a oneway ANOVA was completed to compare the results of the Board graders and residents as two groups. **Results:** Only five of the twenty subjects were found reliable for more than one of the eight categories evaluated in the Objective Grading System. Within groups, the ANOVA revealed that only Board graders evaluating buccolingual inclination was found to be significantly different than gold standard scores from plaster models. The Board graders significantly underestimated the gold standard in this category. **Conclusion:** The American Board of Orthodontics thrives on examiner synchronization and reliability. Since individual reliability in this study tested poorly, it cannot be recommended to replace plaster models with clinical photography when applying the Objective Grading System.

Introduction

In 1929, Ketchum and several other colleagues established the American Board of Orthodontics (ABO) with the purpose of "elevating the level of orthodontic care for the public by encouraging excellence in clinical practice and specialty education."[1] Initially Board certification was given only to highly respected orthodontists. However, once the American Dental Association recognized the American Board of Orthodontics as the official certifying Board for the specialty, the Board's popularity grew rapidly.[1]

Since 1950 several different methods for certification were implemented, modified and eventually eliminated throughout the evolution of Board certification. Currently, phase III of the examination utilizes a method known as the Discrepancy Index to determine case complexity and the Objective Grading System to evaluate treatment outcome.

The Objective Grading System was initiated in 1999 as a way to ensure a reliable, reproducible and accurate assessment of treatment outcomes. At this time, the Objective Grading System requires orthodontic records in the form of a panoramic radiograph, clinical photography and a set of high quality finished orthodontic models.[1] The categories evaluated in the Objective Grading System are alignment, marginal ridges, buccolingual inclination, overjet, occlusal contacts, occlusal relationship, interproximal contacts and root angulation. Over the past twelve years, the records requirements have changed very little and minimal research has been done to determine if the Objective Grading System can be performed without the use of orthodontic models.

As orthodontic offices advance in technology, traditional plaster models are being replaced by digital computerized models of the teeth. The Board has recognized this transition and currently allows pre-treatment digital models to be used for phase III of the examination. Okunami and Kusnoto in 2007 and later Hildebrand and Palomo in 2008 attempted to apply the

Objective Grading System to post-treatment digital models using computerized software. Unfortunately, problems such as overlapping of the teeth in occlusion and inability to measure buccolingual inclination were reported and attempts to develop a more accurate system are ongoing.[2,3]

As previous attempts to evolve the certification process using post-treatment digital models have, as of now, fallen short, other ideas should be tested and considered to continue the evolution of the certification process. As technology has improved, so has the quality and accuracy of digital clinical photography.

The purpose of this study is to attempt to apply the Objective Grading System using only clinical photography. Many orthodontists today are opting to use photography instead of plaster models to save chair time and to provide a quick, accurate and reliable overview of a patient's occlusion. Sheridan illustrated in 2001 that over 90% of orthodontists take both pre-treatment and post-treatment clinical photography. In this article, an orthodontist was quoted saying "I would take final models on a case that was interesting."[4] It is likely that many orthodontic offices are not taking finished models as well. Consequently, many finished cases could not be used for phase III of Board certification. If this study reveals an accurate Objective Grading System score using only clinical photography, over 90% of orthodontists could attempt Board certification using only photography and the American Board of Orthodontics could possibly consider modifying its records requirements for phase III of the examination.

Materials and Methods

Research Design

Ten finished orthodontic cases were randomly selected from the Orthodontic Department at Saint Louis University's Center for Advanced Dental Education. The inclusion criteria for the finished cases selected were: A high quality set of finished orthodontic models, a final composite nine layout of clinical photography (Figure 3.1) and all cases selected were both started and finished by the same orthodontic resident.

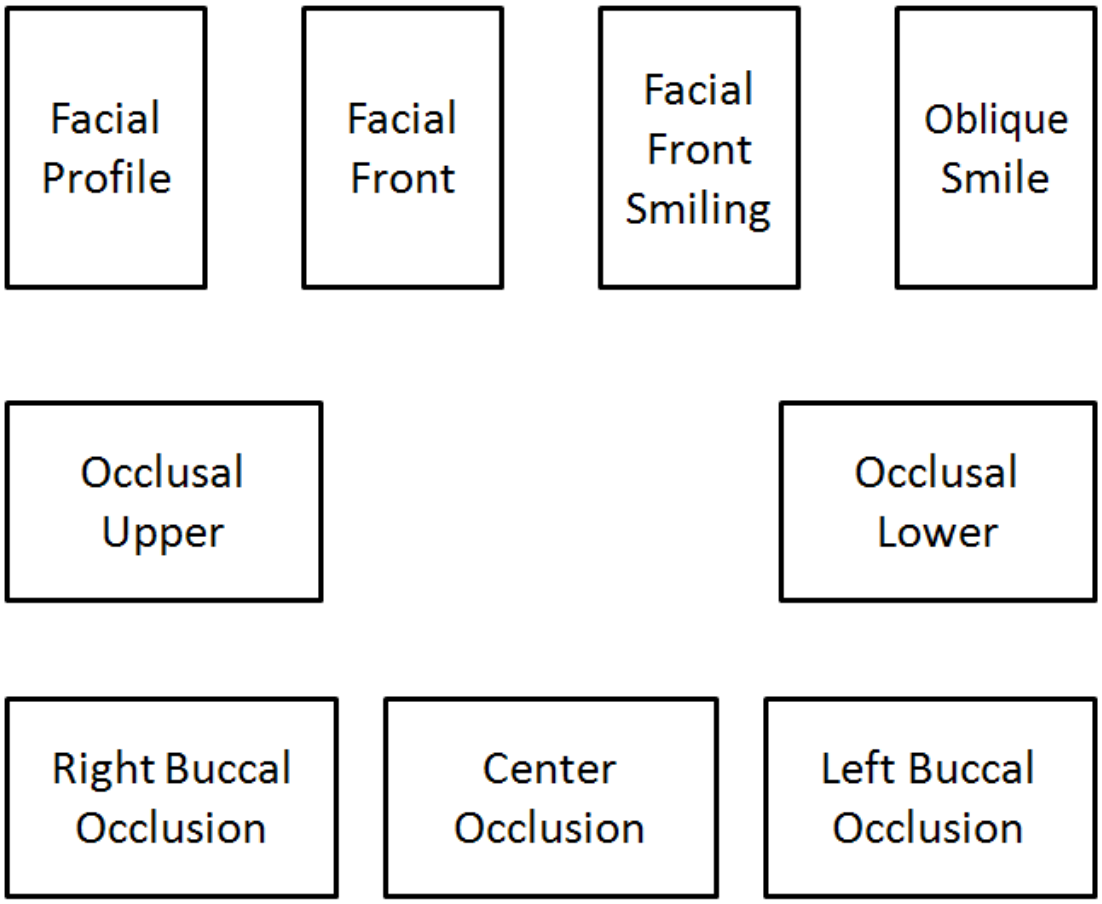

Figure 3.1 – Composite nine layout

Twenty-five Board graders from the American Board of Orthodontics were randomly selected from faculty reference and mailed a composite nine photographic layout of the ten selected finished orthodontic cases. Along with the photographs, the Board graders were also mailed a short questionnaire, instructions, an Objective Grading System reference sheet and ten ABO Objective Grading System forms to complete for each case.

The questionnaire was used to determine orthodontic experience, treatment technique and number of experience years as a Board grader for the ABO. The questionnaire can be seen in Appendix A. All material was asked to be returned anonymously in a pre-paid envelope and mailed back to the primary investigator at Saint Louis University.

Instructions for the Board graders were to apply the Objective Grading System to the best of their ability using only the composite nine photographs. In addition, the Board graders were asked to list two categories for each case that they found most difficult to judge using only the photographs.

Ten orthodontic residents at Saint Louis University were asked to voluntarily participate in this study. The orthodontic residents at Saint Louis University received a two hour lecture on the ABO Discrepancy Index and the Objective Grading System. In addition, the residents received a hands-on model grading demonstration from an experienced ABO Board grader. Therefore, all residents became familiar with how to perform the ABO Objective Grading System but lacked extensive experience. The residents completed the survey in the same manner as the Board graders but were not asked to fill out the questionnaire. Scores for each of the ten cases were collected from each resident as well as the two most difficult categories to assess for each case.

After the cases were sent to the Board graders the private investigator was calibrated to obtain a gold standard Objective Grading System score for each of the ten cases used in the study. Calibration was performed using models from ten finished cases previously scored by a past ABO president and current Board grader. The private investigator blindly scored these cases three separate times, each two weeks apart, until the averages for each category was at or above ninety percent. No radiographic analysis was performed in this study. Once calibrated, the primary investigator and the research team individually scored the models of the ten cases used in the study using the final plaster models. The scores from the research team were compared and the primary investigator and faculty advisor established the gold standard score for each of the ten cases.

Test Preparation

Before the Board graders were mailed the photographs and the ten residents were asked to participate, the private investigator and faculty advisor reviewed the instructions, questionnaire and the quality of the clinical photographs to be used. Both agreed that the instructions for the participants were clear and concise and the materials were ready to be distributed.

In addition, a resident who did not participate in the study was asked to perform a test trial. The resident was given all the materials to be sent to the Board graders and asked to grade two cases using only the clinical photographs. The resident was able to complete all tasks detailed in the instructions and did not have any additional questions regarding his responsibilities.

A Typical Test

Each of the participants was asked to score ten cases using the Objective Grading System based only on clinical photographs. The participants were asked to analyze the photographs for each case and score each category (except root angulation) on the provided Objective Grading System form. The categories analyzed were total score, alignment, marginal ridges, buccolingual inclination, overjet, occlusal contacts, occlusal relationship and interproximal contacts. The test was complete when each category was scored for each of the ten cases, the two hardest categories to score were recorded and, if a Board grader, the questionnaire was completed.

Data Organization, Reduction and Analysis

Fourteen envelopes were returned from the twenty-five Board graders initially sent surveys. Of the fourteen, only ten were completed entirely and used in the study. The data from the ten board graders and the ten residents was entered into Microsoft Excel and analyzed via SPSS.

Overall accuracy for each category was compared to the gold standard using a oneway Analysis of Variance (ANOVA) for both the Board graders and the residents. Statistically significant categorical differences were tested to a $P < 0.05$. In addition, individual reliability for each Board grader and resident were analyzed using Cronbach's alpha to a significance of $\alpha > 0.70$. A T-test was also performed combining the residents and Board graders score and comparing to the gold standard. The categories listed as the most difficult to assess by the Board graders and residents were totaled and compared to the results.

Results

The questionnaire revealed that nine out of ten Board graders that participated in the study had over thirty years of orthodontic experience. The average number of years they have been graders for the ABO was 8.1 years. The most experienced grader was grader number six who has been a Board grader for twenty-one years. Half of the Board graders practice with a Tweed philosophy while half practice straight wire. Board grader information can be seen in Table 3.1.

Table 3.1 - Breakdown of Board grader experience and technique

	Years in Practice	Years Board Grader	Technique
Board Grader 1	30+	8	Tweed
Board Grader 2	30+	4	Tweed
Board Grader 3	30+	7	Straight Wire
Board Grader 4	30+	8	Straight Wire
Board Grader 5	16-30	2	Straight Wire
Board Grader 6	30+	21	Tweed
Board Grader 7	30+	12	Tweed
Board Grader 8	30+	4	Tweed
Board Grader 9	30+	5	Straight Wire
Board Grader 10	30+	10	Straight Wire

Survey results also illustrated that the Board graders and the residents listed occlusal contacts, buccolingual inclination and marginal ridges to be the hardest categories to assess using only clinical photography. Figure 3.3 shows the breakdown the categories that the subjects listed as most difficult for them to grade from the photographs.

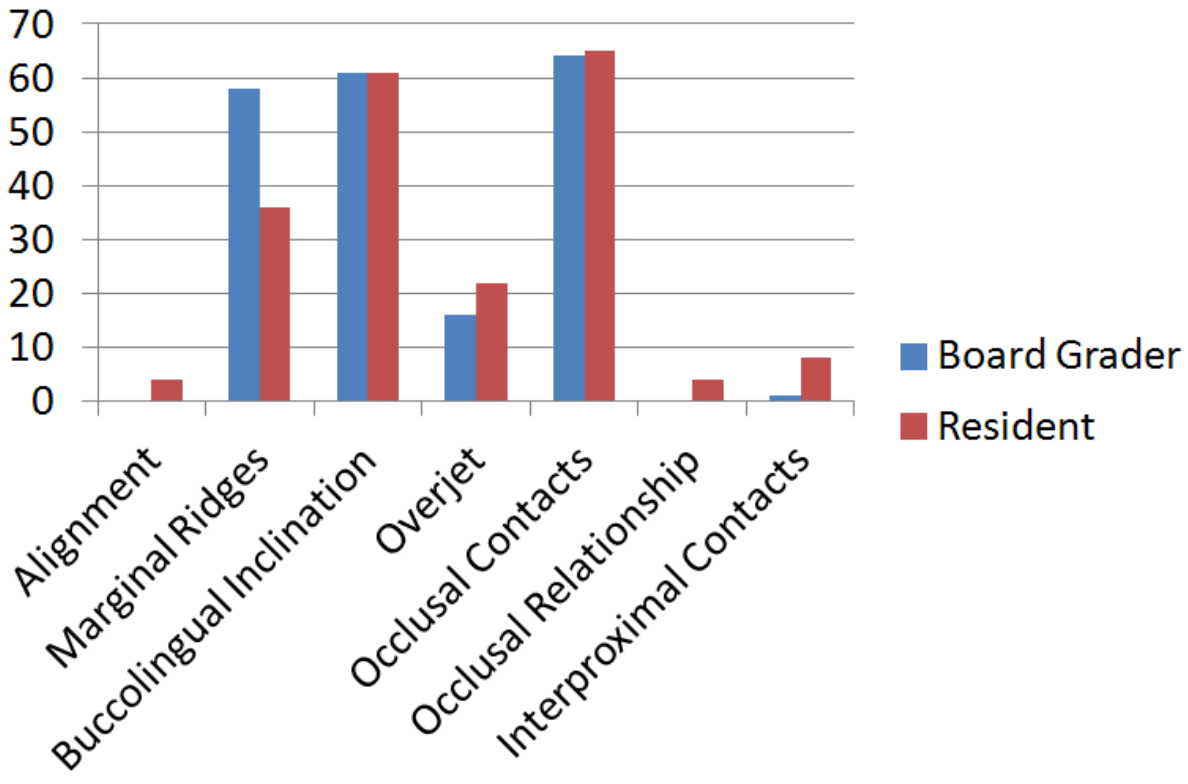

Figure 3.3 - Most difficult categories listed to assess from photographs.

To determine the subject's individual reliability to the gold standard a reliability test known as Cronbach's alpha was performed. The Cronbach's alpha tested if each subject was able to reliably score each category for each of the ten cases when compared to the gold standard. Significance for the Cronbach's alpha was set at alpha greater than or equal to 0.70. Negative values indicated an inverse relationship for the subjects' reliability. The results revealed that no subjects were able to reliably assess total score, occlusal contacts or occlusal relationship for all ten cases. One Board grader reliably assessed buccolingual inclination and one Board grader and one resident were able to reliably assess alignment and overjet for each case. One Board grader and three residents were able to reliably assess marginal ridges while the most reliable category to assess was interproximal contacts with three Board graders and three

residents testing reliable. Table 3.2 illustrates subject reliability for each of the eight categories for all ten finished cases.

Table 3.2 – Cronbach alpha subject reliability scores. Statistically significant at an $\alpha \geq 0.70$

	Total Score	Alignment	Marginal Ridges	Buccolingual Inclination	Overjet	Occlusal Contacts	Occlusal Relationship	Interproximal Contacts
B.G. 1	.067	.418	.479	-4.267	-.222	-.928	-.248	0
B.G. 2	-.007	-.054	.114	-.714	.368	.236	.116	.372
B.G. 3	.534	.711*	.320	-.395	.259	.076	-.368	.730*
B.G. 4	.167	.421	.163	0	.424	.330	-.489	-.360
B.G. 5	.160	.321	.721*	-.113	.377	.109	-.396	.723*
B.G. 6	.432	-.033	.336	.368	-1.898	.600	.425	0
B.G. 7	.665	.341	-.580	.849*	.023	.125	.559	-.450
B.G. 8	.170	.587	.639	-.840	.717*	.339	-.968	.839*
B.G. 9	.456	.614	.266	.230	0	.607	.378	-.694
B.G. 10	.154	.455	.626	-.082	-.222	-.054	.489	0
Res. 1	.294	.271	.853*	.478	.696	-.162	-.120	.810*
Res. 2	-.456	.241	.517	-.651	.480	-.303	-.567	.580
Res. 3	-.888	.279	-.366	-1.994	.480	.453	.333	-.588
Res. 4	.436	.326	.874*	.133	.231	.278	-.233	.512
Res. 5	.363	.781*	-.151	-.123	-.124	.210	-.685	.823*
Res. 6	-.244	-.326	.910*	-.716	-.526	-.329	-.344	-.238
Res. 7	.558	.633	.383	.259	.907*	.220	-.315	0
Res. 8	.462	.373	-.280	.565	.424	.433	-.157	0
Res. 9	.368	.666	.654	-.414	.682	-.497	-.281	.855*
Res. 10	-.074	.223	-.023	.051	.452	.431	-.171	0

Board graders three, five and eight and residents one and five were the only subjects who tested reliable in more than category. The total number of residents and Board graders that tested reliable for each category can be seen in Figure 3.4.

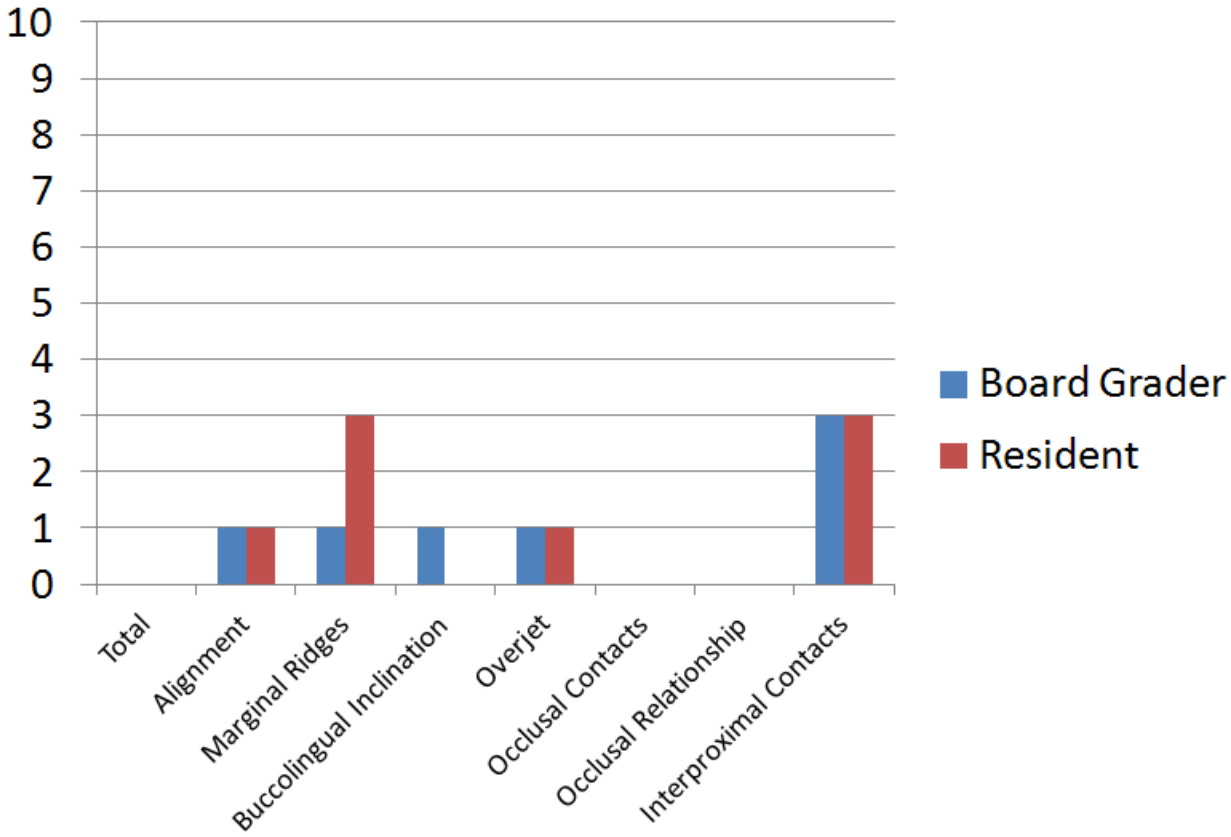

Figure 3.4 – Board graders and residents reliable for each category

Occlusal contacts and buccolingual inclination were listed by the subjects as the two most difficult categories to assess from the photographs. Both tested poorly reliable with no subjects testing reliable for occlusal contacts and only one subject testing reliable for buccolingual inclination. Marginal ridges were listed as the third hardest category to assess from the photographs but it tested second most reliable with five out of twenty subjects testing reliable for the category.

Statistical tests were also performed to compare accuracy of Board graders as a group and the residents as a group compared to the gold standard. To test the groupings, average scores for

each of the ten cases for the Board graders, residents and gold standard were calculated for each of the eight categories. In general, Board grader averages were lower than the gold standard. Alignment and marginal ridges were the only two categories that the Board graders overestimated. The residents underestimated all categories except interproximal contacts.

An ANOVA was conducted to compare the average scores of the Board graders and residents to each other and to the gold standard. The ANOVA revealed that significant score differences were seen between the groups in the categories of buccolingual inclination, overjet and interproximal contacts. Table 3.3 shows the results of the ANOVA and Appendix B shows the means and standard deviations for each group.

Table 3.3 - ANOVA results. B.G. = Board graders, Res = Residents and Gold = Gold Standard. Statistically significant at $P < 0.05$. N of 100 represents ten Board graders and ten residents each grading ten different independent cases.

Category	Group	N	Mean	S.D.	F	Significance
Total Score	B.G.	100	13.150	6.694	2.249	0.108
	Res	100	14.780	7.599		
	Gold	10	17.100	5.446		
	Total	210	14.114	7.137		
Alignment	B.G.	100	3.850	2.698	2.496	0.085
	Res	100	3.130	2.013		
	Gold	10	3.100	1.197		
	Total	210	3.471	2.358		
Marginal Ridges	B.G.	100	3.500	2.802	2.720	0.068
	Res	100	2.650	2.430		
	Gold	10	3.100	1.197		
	Total	210	3.076	2.598		
Buccolingual Inclination	B.G.	100	1.440	1.666	3.818	0.024*
	Res	100	1.900	2.414		
	Gold	10	3.200	2.098		
	Total	210	1.743	2.103		
Overjet	B.G.	100	0.680	1.340	4.410	0.013*
	Res	100	1.280	1.770		
	Gold	10	1.600	1.506		
	Total	210	1.010	1.592		
Occlusal Contacts	B.G.	100	1.680	1.792	2.979	0.053
	Res	100	2.350	2.341		
	Gold	10	2.600	1.897		
	Total	210	2.043	2.096		
Occlusal Relationship	B.G.	100	1.680	2.538	2.030	0.134
	Res	100	2.310	2.317		
	Gold	10	2.600	1.506		
	Total	210	2.024	2.409		
Interproximal Contacts	B.G.	100	0.320	0.777	11.486	0.000*
	Res	100	1.160	1.594		
	Gold	10	0.900	0.994		
	Total	210	0.748	1.304		

To identify where the significant differences were located between the three groups for buccolngual inclination, overjet and interproximal contacts a Tukey HSD post hoc test was performed. The post hoc test revealed that significance differences were seen between the Board graders and the gold standard for buccolingual inclination. Board graders significantly underestimated the gold standard in this category. Significant differences were seen between the Board graders and the residents for both overjet and interproximal contacts. These results can be seen in Table 3.4.

Table 3.4 - Tukey HSD post hoc test. Group 1 = Board graders, group 2 = Residents, group 3 = Gold standard. Significant value $P < 0.05$

Category	Group	Comparison Group	Significance
Buccolingual Inclination	1	2	0.262
		3	0.030*
	2	1	0.262
		3	0.114
	3	1	0.030*
		2	0.144
Overjet	1	2	0.020*
		3	0.182
	2	1	0.020*
		3	0.812
	3	1	0.182
		2	0.812
Interproximal Contacts	1	2	0.000*
		3	0.340
	2	1	0.000*
		3	0.804
	3	1	0.340
		2	0.804

To determine the accuracy of the Board graders and the residents together, their combined scores for each category were averaged and compared to the gold standard. A T-test was performed to compare the two groups. The results showed that a statistically significant difference from the gold standard was seen in the category of buccolingual inclination with the

Board graders and residents significantly underestimating the gold standard. The results of the T-test can be seen in Table 3.5.

Table 3.5 - Combined Board grader and resident averages to the gold standard. T-critical is ±2.048.

Category	Mean $_{B.G. + Res}$	Mean $_{Gold}$	T
Total Score	13.965	17.100	-1.720
Alignment	3.490	3.100	0.691
Marginal Ridges	3.075	3.100	0.055
Buccolingual Inclination	1.670	3.200	-3.080*
Overjet	0.98	1.600	-1.410
Occlusal Contacts	2.015	2.600	-0.971
Occlusal Relationship	1.995	2.600	-0.936
Interproximal Contacts	0.740	0.900	-0.538

Discussion

To become a Board certified orthodontist the candidate must complete the three phases of the ABO's certification process. First, the candidate must have graduated or is currently completing an orthodontic education from an accredited orthodontic program. Secondly, the candidate must successfully complete the written examination given by the American Board of Orthodontists. Finally, phase III of certification is a clinical examination where treated cases are shown by the candidate and used to test the clinician's skills and treatment knowledge. If the candidate completes all three phases of the examination, certification is complete and the candidate is known as a Diplomate.[1]

To evaluate the outcome of the orthodontically treated cases in phase III of the examination, the Board utilizes the Objective Grading System. The Objective Grading System was created in 1994 and later implemented in 1999 to make phase III of the examination more objective and because previous treatment indexes did not satisfy the ABO's desire for reliability and precision.[1,5] The categories evaluated by the Objective Grading System are alignment, marginal ridges, buccolingual inclination, overjet, occlusal contacts, occlusal relationship, interproximal contacts and root angulation. Deductions from each category summed for a total score.

To apply the Objective Grading System the American Board requires a panoramic radiograph, final clinical photography and a final set of finished orthodontic models for each case. Without the records, a candidate cannot complete the examination. Sheridan illustrated in 2001 that over 90% of orthodontists take both pre-treatment and post-treatment clinical photography but many orthodontists only take final models "…on a case that was interesting."[4] As a result, many orthodontists are not eligible to become Board certified without having final

models. It was the goal of this study to determine if an accurate Objective Grading System score can be obtained using only clinical photography. If photography is found accurate, it may be beneficial for the Board to remove the model requirement in phase III allowing more orthodontists to become Board eligible.

To complete this research, ten finished orthodontic cases were scored from photography alone by ten current Board graders and ten orthodontic residents using the Objective Grading System. Root angulation was omitted from this study. The results obtained from the Board graders and residents were compared to the cases scored traditionally using the orthodontic models. In addition, all subjects were asked to list which two categories were the most difficult to assess using the photographs. The Board graders were also asked to complete a short questionnaire.

The results of the questionnaire revealed that the Board graders that participated in this study had extensive experience in both private practice and years as a Board grader. The average number of years the Board graders have been grading for the ABO was 8.1 years. Therefore, it would be fair to conclude that experts with the Objective Grading System and its application were utilized in the study.

Board graders and residents reported that by looking only at the photographs that occlusal contacts was the most difficult category to assess. Individual reliability results support this finding because no participants were found reliable for this category. Many subjects wrote on the grading sheets that they could not see the lingual contact areas of the teeth in occlusion from the photographs. Knowingly, a photograph of teeth from the lingual aspect is impossible and it was assumed that this category would be difficult to be assessed. Marginal ridges and buccolingual inclination were also listed as very difficult to assess from looking only at

photographs. The research team was also aware that these categories would be difficult to score but was hoping that larger, but certainly not all, discrepancies with marginal ridges and buccolingual inclination could be seen from the occlusal photographs. When looking at individual reliability results, buccolingual inclination tested poorly with only one subject testing reliable. However, larger marginal ridge discrepancies might have been detected by the subjects because this category tested second most reliable with four participants testing reliable.

On an individual basis, applying the Objective Grading System to clinical photography was not successful. A reliability test known as Cronbach's alpha was used to compare each subject's categorical scores to the gold standard. Only five of twenty subjects were able to test reliable for more than one of the eight categories. Additionally, six Board graders were unable to test reliable for any category. Even with Board grader expertise, many graders performed poorly using only clinical photography. Therefore, individually, it cannot be concluded that scoring cases using clinical photography is reliable.

To test group accuracy, scores from the Board graders, residents and the gold standard were averaged for all ten cases and compared using a oneway ANOVA. The ANOVA revealed that statistically significant differences were seen only in the categories of buccolingual inclination, overjet and interproximal contacts. A Tukey HSD post hoc test was performed and determined that the statistical differences were seen between the gold standard and the Board graders for buccolingual inclination and between the Board graders and residents for overjet and interproximal contacts. The Board graders significant underestimated the gold standard for buccolingual inclination.

Group accuracy painted a much different picture than individual accuracy. Group results showed that the only significant difference from the gold standard was the Board graders in the category of buccolingual inclination. When averaging the residents and Board graders it allowed those who performed better in this study to mask those that performed poorly. Additionally, those subjects who tended to over deduct averaged out those who took off very few points. Also, the categories of alignment, marginal ridges and occlusal contacts were very close to being significantly different than the gold standard. Since only ten residents and ten Board graders participated, increasing the sample size would probably increase differences and also affect the reliability of this study.

The Objective Grading System when performed only through clinical photography was found not to be reliable on an individual basis. When averaging scores for each group (except the Board graders and buccolingual inclination) the results for each category were found not to be statistically different from the gold standard. Since the sample size in this study was small and reliability is extremely important when completing the Objective Grading System, the results of the ANOVA are not as powerful as the Cronbach's reliability test. Therefore, it is the recommendation of the private investigator to keep the requirements of phase III intact and to not apply clinical photography to the Objective Grading System.

Two follow up studies could be done with this project. The first could duplicate this study with a similar research design and increase sample size. A larger sample size might yield additional significant differences in the ANOVA. However, this might be difficult as many Board graders did not demonstrate an interest to participate in this study. Many dismissed the idea of even attempting to score cases from the photographs because in their opinion it simply could not be done. A second follow up study could be to send Board graders final photographs

and a printed version of a final cone beam. The final cone beam could be manipulated to allow various views of the occlusion. This would give Board graders additional views of the occlusion needed to not only participate in the study but obtain accurate scores.

As of now, however, those orthodontists that wish to become certified by the American Board of Orthodontics must take a final set of orthodontic models.

Conclusions

The results obtained from this study yielded the following four conclusions:

1.) ABO Board graders and Saint Louis University residents listed occlusal contacts, buccolingual inclination and marginal ridges as the three categories they felt were the most difficult to assess using clinical photography.

2.) The ability for each subject to reliably score each category yielded extremely poor results for both Board graders and residents.

3.) Averaging each Board grader as a group and each resident as a group showed that there was only one category in which statistical difference from the gold standard was detected. This difference was seen among Board graders for the variable of buccolingual inclination.

4.) Since the American Board of Orthodontics thrives on examiner synchronization and reliability, it would not be beneficial to use only clinical photography and omit the requirement of final plaster models to complete the Objective Grading System.

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Appendix A

1.) How many years have you been practicing orthodontics?
   a. 1-15 years
   b. 16-30 years
   c. 30+ years

2.) What type of pre-treatment records do you routinely take at your office? (check all that apply)
   ___Models trimmed in CR/CO
   ___Panoramic Radiograph
   ___Cephalometric Radiograph
   ___Mounted Models
   ___Clinical Photography
   ___Other Please Specify _____

3.) What type of post-treatment records do you routinely take at your office? (check all that apply)
   ___Models trimmed in CR/CO
   ___Panoramic Radiograph
   ___Cephalometric Radiograph
   ___Mounted Models
   ___Clinical Photography
   ___Other Please Specify _____

4.) Are you certified by the American Board of Orthodontics?
   a. Yes
   b. No

5.) Are you an examiner for the ABO clinical exam?
   a. Yes
   b. No

6.) If yes to question 5, please indicate the number of years you have been an examiner.

   _____ years

7.) What type of orthodontics do you practice?
   a. Straight Wire
   b. 0/0 Tweed
   c. Damon
   d. Tip-Edge
   e. Other Please Specify _____

Figure A.1 - Board grader questionnaire

Appendix B

Table B.1 - Group means and standard deviations

Category	Group	Mean	Standard Deviation
Total	Board Graders	13.150	6.694
	Residents	14.780	7.599
Alignment	Board Graders	3.850	2.698
	Residents	3.130	2.013
Marginal Ridges	Board Graders	3.500	2.802
	Residents	2.650	2.430
Buccolingual Inclination	Board Graders	1.440	1.666
	Residents	1.900	2.414
Overjet	Board Graders	0.680	1.340
	Residents	1.280	1.770
Occlusal Contacts	Board Graders	1.680	1.792
	Residents	2.350	2.341
Occlusal Relationship	Board Graders	1.680	2.538
	Residents	2.310	2.317
Interproximal Contacts	Board Graders	0.320	0.777
	Residents	1.160	1.594

Vita Auctoris

Bryan Richard Wirtz was born on August 25, 1983, in Toledo, Ohio, to Mr. and Mrs. Robert Edward Wirtz Jr. In 2005 he received his undergraduate degree in biology from Ohio University in Athens, Ohio. Following undergraduate school, he attended The Ohio State University in Columbus, Ohio, where he received his Doctorate in Dental Surgery from the College of Dentistry. Dr. Wirtz expects to receive his Master of Science in Dentistry from Saint Louis University and receive his certificate as a specialist in the field of orthodontics from Saint Louis University's Center for Advanced Dental Education.