THE UNIVERSITY OF THE WITWATERSRAND
SCHOOL OF ORAL HEALTH SCIENCES
DEPARTMENT OF ORTHODONTICS AND PAEDIATRIC DENTISTRY
DIVISION OF ORTHODONTICS

EVALUATION OF TREATMENT OUTCOMES IN A GRADUATE ORTHODONTIC CLINIC AT WITS USING THE ABO CAST AND RADIOGRAPHIC EXAMINATION

A research project submitted to the Postgraduate Committee

in partial fulfilment of the requirements for the degree of

Master of Dentistry

in the branch of
Orthodontics

BY
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Declaration of authenticity

I, Mthobeli Vundla, declare that this research project **"Evaluation of treatment outcomes in a graduate orthodontic clinic at WITS University using the ABO Cast and Radiographic Examination"** is my own, unaided work. It is being submitted for the Degree of MDent (Orthodontics) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

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(Signature of student)

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ABSTRACT

Background: Every orthodontist has a signature on the treatment that he/she provides to his/her patients. Treatment outcomes have been evaluated in a variety of ways, some of which have been considered to be ideal for teaching programs. This has not been done at Wits, which is the purpose of this study.

Objectives: To evaluate the treatment outcomes of patients treated in the graduate orthodontics programme at Wits with respect to the registrars and consultants who managed the cases.

Material and Methods: The post-treatment study casts and radiographs of patients treated by the graduating class of 2015 at Wits were evaluated using the ABO Cast and Radiographic Examination score (CRE). The scores were categorized into four groups: less than or equal (LE) to 20; greater than (GT) 20 but LE 25; GT 25 but LE 30; and CRE GT 30. Frequency data analysis were employed to assess the data. Trend tests were applied to establish the presence of a pattern, if any, with respect to time of graduation of the Consultants, the place of their training and treatment outcomes.

Results: A total of 105 records met the requisite criteria with 54 records coming from two registrars and the remaining 51 from a third. Only five records had a score GT25 and were excluded as outliers. Seventy six of the records scored LE20 and 24 recorded CRE scores of GT20 but LE25. The GLM procedure showed significant differences in the scores of the three registrars ($p=0.002$). The Scheffe test found that two registrars received exactly the same score while the third had a significantly lower score. The LSMeans were 14.26, 17.23 and 17.92. No significant differences could be established among the consultants.

Conclusion: All the registrars provided excellent treatment since 76% of the cases scored LT20. The treatment supervision provided by the consultants was consistent as there were no significant differences between their scores.

ABBREVIATIONS

ABO: American Board of Orthodontics

AP: Anterior Posterior

CCA: Comprehensive Clinical Assessment

CID: Consultant Identification

CRE: Cast and Radiographic Examination

GLM: Generalized Linear Model

GT: Greater than or equal

IO: Indiana University

LE: less than or equal

LSMean: Least Squares Mean

OGS: Objective Grading System

Q_{CSMH}: Mantel Haenszel Correlation Statistic

PAR: Peer Assessment Rating

PI: Primary investigator

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Orthodontic finishing is defined as an “art” comprising individual perceptions and minor, but relevant, details in treatment outcome. The primary goals of orthodontic treatment are to obtain a harmonious, balanced oral system with a functional occlusion that has pleasing dental aesthetics, healthy oral and dental structures (healthy periodontium), is associated with improved facial appearance (facial aesthetics), and which contributes to stability of the treatment results.[1] Finishing is the most difficult stage of orthodontic treatment and can sometimes be deceptive. In the endeavour to identify the crucial criteria which may be essential to the achievement of the accepted goals, a number of proposals have been made. In the 1900s, Angle emphasized the importance of maxillary first molars as the centre of occlusion. He believed that if the full complement of teeth were present and in ideal occlusion, good facial aesthetics and harmony would be achieved. [2]

Tweed identified a cephalometric diagnostic triangle, the “Tweed triangle”, in which he proposed that the mandibular incisors should be upright in relation to the mandibular plane.[3] In the 1970s, Andrews formulated the Six Keys to Occlusion and declared that teeth should be positioned in the centre of the supporting alveolar bone.[4] In 2000, Andrews expanded on his concepts and proposed a concept of Orofacial Harmony, suggesting that the Six Elements of Orofacial Harmony should be the universal optimal treatment goals in orthodontic finishing irrespective of the age, sex, and race of the patient.[5] These six elements are:

1. Ideal arch shape and length: the goal is achieved when the arches are harmonious in shape and length. The arches are well co-ordinated and unique for that particular individual with normal tooth sizes (without a Bolton discrepancy), the roots of all the

teeth are positioned centrally over the basal bone, with correct inclinations of the crowns to allow optimal function with the opposing dentition. The transverse dimension of the maxilla should be harmonious with the width of the mandible, allowing the establishment of proper occlusion in maximum intercuspation, without balancing interferences (i.e. minimal Curve of Wilson).

2. Ideal anterior-posterior (AP) jaw positions: The goal of this element is to achieve correct anterior position of the maxilla and the mandible (Class I). The AP position of the maxilla is achieved when the Facial Axis points of the maxillary central incisors are on the Goal Anterior Limit Line with the crowns of each central incisor properly inclined for optimal function and occlusion. The AP position of the mandible is achieved when the mandibular central incisors are positioned to satisfy “Element I” and are coupled with the maxillary central incisors, also in “Element I” position, while the mandible is in centric relation.
3. Ideal jaw widths: In patients without craniofacial anomalies, the mandibular jaw width is usually optimal and naturally correct. The orthodontic treatment goal is always to maintain the mandibular transverse dimension while the maxilla is treated according to the lower arch width. The goal of the maxilla in this Element is to achieve proper cusp fossa relationship with the lingual cusps of the maxillary posterior teeth occluding against the buccal cusps of the mandibular posterior teeth (functional cusps). The maxillary arch is a few millimetres wider than the mandibular to allow proper inclination of posterior teeth with adequate posterior overjet while maintaining correct buccolingual inclination as assessed by the Curve of Wilson. If the maxillary posterior teeth are correctly inclined but do not have proper fossa cusp relationship or have correct cusp fossa relationship with excessive buccolingual inclinations, orthopaedic expansion is then needed to correct the transverse relationships of the two arches.

4. Ideal jaw heights: This is the vertical relationships of the jaws. The goal of this Element is to have the heights of both the maxilla and the mandible in distinct and correct dimensions for that individual. The jaw heights are ideal when the lower posterior facial height is the same or within 10mm of both the upper and lower anterior facial heights. The occlusal plane should be between +2° and +10° as measured from the transverse plane of the patient's head from the lateral view. In repose, the vertical position of the tips of the maxillary central incisors should be level with the lower border of the upper lip.
5. Ideal chin prominence: The goal of this element is to achieve ideal prominence of pogonion in relation to the facial axis of the lower incisor. Pogonion should lie on a line perpendicular to the occlusal plane and which passes through the Facial Axis of the mandibular incisors.
6. Ideal occlusion: The Element defines the "Six Keys to Normal Occlusion" by Lawrence Andrews. The goal is to achieve static and functional occlusion. For occlusion to be ideal, attention must be given the crowns, the roots, the supporting periodontal structures, the temporomandibular joint, and the jaws. Minor jaw discrepancies can be camouflaged by orthodontic treatment alone, while ideal occlusion cannot be achieved in the presence of severe inter-jaw discrepancies without surgical intervention.

   The Six Keys:

   Keys to Normal Occlusion are the characteristics of the teeth found to be shared in natural occlusion. Key I is correct inter-arch relationships, Key II is correct crown angulations, Key III is correct crown inclinations, Key IV is the absence of rotations, Key V shows tight interproximal contacts, and Key VI is the depth of the Curve of Spee, that is, flat to slightly concave. These six characteristics should be expected in successfully treated patients, unless there are limitations that lead to

compromised treatment. The six characteristics serve as the measure of the static relationship of successful orthodontic treatment.

Andrew hypothesized that The Six Elements should form the optimal orthodontic treatment goals for the six areas for which orthodontists have expertise and diagnostic responsibility. The Six Elements are a complete set of orthodontic goals, provide guidelines for managing patients, and define a three-dimensional positionally-correct classification system that can assist in the attainment of good orthodontic results.

Finishing of orthodontic treatment is often evaluated in four major categories: intraoral, radiographic and functional objectives, which all can be evaluated using the ABO and CRE system, and, fourthly, extraoral objectives. Intraoral evaluation includes assessment of each individual tooth according to the first (horizontal), second (vertical), and third (torque) order positions according to the Andrews Six Keys to occlusion. In the first order, rotation, spaces, and interproximal contacts are assessed for dental aesthetics and proper occlusion. The second order is evaluated for even marginal ridges and there is an assumption that if marginal ridges are level, the roots will be parallel and the alveolar bone in the patient without periodontal disease will be level. Root parallelism is also important for stability of the treated results and prevention of periodontal problems. The third order is important for occlusal contact of the opposing teeth and smile aesthetics. A slight Curve of Wilson is required for proper function. Should this curve be accentuated, balancing contacts result on the non-working side. Balancing interferences have been shown to have detrimental effects in the long term for both the occlusion and the TMJ area.[6] In the inter-arch analysis, the first molars and the cuspids are evaluated for inter-occlusal relationship as per Angle's classification of occlusion. The midlines should be coincident and any discrepancy of more than 2mm will result in poor aesthetics or in inadequate occlusal relationships in the buccal segments. Incisor and gingival display are important

for aesthetic purposes. Females show about 2mm of incisors at rest while males show 1mm. Females also display about 1mm of gingiva when smiling, while males generally do not show any gingiva. Appropriate consideration must be given during treatment planning for the objectives in vertical incisor and gingival display. The buccal corridors should be eliminated, while any cant in the upper incisor segment must be corrected. Root angulation and parallelism must be evaluated for the following reasons: stability, potential periodontic problems due to root proximity, proper inclinations to allow occlusal loads to be transmitted along the long axes of the teeth. All the roots must be parallel at finishing.[7] These and other suggestions have made important contributions towards identifying problems with the final finishing of orthodontic treatment, data which is essential for developing strategies to efficiently improve clinical outcomes. Establishing accurate, precise, and valid methods for measuring treatment success is important for both practitioners and health care consumers. Assessing the quality of the treatment outcome is very difficult due to the fact that improved facial aesthetics is often considered as an ideal goal for orthodontic treatment, but this goal is subjective and lies “in the eye of the beholder”. However reliable monitoring of clinical outcomes is a challenging problem and various indices have been implemented to assess the outcome of orthodontic treatment. The indices usually compare the pre-treatment and the post-treatment records to evaluate the quality of the orthodontic treatment. Some of these methods are not yet been proven for their validity, precision, and reliability.[8]

PAR INDEX

One such system, the Peer Assessment Rating (PAR), was developed in 1987 in the endeavour to ensure uniform interpretation and application criteria in the measurement of malocclusion.[9] It has been used in both the United States and the United Kingdom to evaluate and compare treatment outcomes of orthodontic treatment. The index has been

validated in the United Kingdom (PAR UK) and also applied in the United States (PAR US). The PAR US uses a different weighting system as it discarded the mandibular anterior alignment component. The index uses both the pre-treatment and the post-treatment treatment study casts to determine the relative improvement of the malocclusion or efficacy of the treatment according to five criteria (US system) or seven criteria (British weighting).[10] Previous studies of the PAR index have shown that treatment outcomes are similar when using the PAR index in extraction and non-extraction cases, and in patients managed with Phase I and Phase II orthodontic treatment or with Phase II only. The PAR index provides a single summary score of all occlusal anomalies that may be found in a dentate patient. The score estimates how far the dentition deviates from normal alignment or occlusion. A PAR score of zero represents normal occlusion and alignment while a higher PAR score indicates a severe deviation from the normal occlusion. The pre-treatment score can be compared with the post-treatment score and the difference between the two scores indicates the degree of improvement and, therefore the success of orthodontic treatment, which is then categorized as worse, no different, improved or greatly improved. A minimum of 30% improvement from the pre-treatment score is required for the case to be categorized as improved, while a change of the PAR score of at least 22 points is needed before the case can be classified as greatly improved. While the PAR Index has good reliability and validity, the system lacks precision in discriminating between the minor tooth position discrepancies that form part of the American Board of Orthodontics (ABO) grading system. The PAR measures only straight teeth, and requires both the pre-treatment and post-treatment study casts to generate the score. It does not evaluate the fine details of the dental alignment and occlusal discrepancies. In 2015, Chalabi et al. compared treatment outcomes of the cases treated in the postgraduate orthodontic programme at the University of Buffalo using the UK and the US weighted PAR and the Cast and Radiographic Examination (CRE).[11] The mean PAR UK was 84.62% and the PAR US, 81.05%, which indicated a great standard of orthodontic

treatment. However, when the Objective Grading System (OGS: an ABO evaluation developed in the USA) was applied, 62 % of those cases would have failed the ABO examination. The researchers concluded that the PAR index cannot replace the ABO CRE system in assessing quality of treatment, while the CRE cannot replace the PAR system in establishing the amount of improvement in a treated case. This is due to the fact that the PAR index does not precisely measure the occlusal characteristics.

Comprehensive Clinical Assessment (CCA)

The Comprehensive Clinical Assessment (CCA) was developed at Indiana University School of Dentistry (IUSD) to supplement the Objective Grading System (OGS).[12] The CCA evaluation has three assessments for each category. Two points are deducted for each assessment that deviates from the ideal with a maximum of five points per each category. The sum of the CCA and the OGS scores is defined as the clinical outcome. The CCA method assesses:

I. Facial aesthetics: deterioration or improvement in frontal asymmetry, profile, and smile line. Pre-treatment and post-treatment extra-oral photos are compared for improvement or deterioration in facial aesthetics. Points are deducted if there is no improvement or the facial aesthetics have deteriorated.

II. Dental aesthetics: decalcifications, “black triangles” in the dentition, incisal edges, corridors, and embrasures in the dentition are assessed. Pre-treatment and posttreatment photographs are used in this assessment to identify any changes or deviations from the norm and points are deducted accordingly.

III. Vertical dimensions: control of vertical dimensions, lip competence, incisal exposure and management of growth during treatment.

IV. Arch form : symmetry, coordination, and dentition over basal bone

V. Periodontium preservation; bone loss, recession and development of gingival clefts.

VI. Root resorption: preservation of the root structures.

VII. Treatment efficiency: results achieved relative to treatment time. Points are deducted for moderate to severe compromises and one point is lost for every six months of treatment that exceeds the estimated treatment time

It is reported that the CCA has proven to be more sensitive than other indices in identifying compromises in long-term mixed dentition treatment.[12]

Objective Grading System and Cast and Radiographic Examination

The development of the OGS system dates back to 1994 when the ABO desired to make Phase III of certification more objective in the assessment of skills and knowledge of patient management through presentation of the records of patients treated by the orthodontist. Preliminary evaluation of 100 cases at the 1995 ABO Phase III examination revealed that 85% of errors occurred in alignment, marginal ridges, buccolingual inclinations, overjet, occlusal relationships, occlusal contacts, and root angulations.[13] To make the evaluations more effective, an instrument was designed which measured discrepancies in alignment, overjet, occlusal contacts, interproximal contacts, and occlusal relationships.

This system was termed the Objective Grading System and was first employed in 1999.[7] There have since been some minor modifications to the system which is now referred to as the Cast and Radiographic Examination (CRE) system. The unique feature of the CRE system is that treatment outcome is assessed on the final study casts and panoramic radiographs, and there is no reference to any pre-treatment score. The system has gained

recognition in the private and educational settings as a valid, precise, and reliable method to assess excellence in the field of Orthodontics.

Several studies[8,12,13] have compared treatment outcomes achieved in postgraduate programmes with those in private practices. Yang-Powers et al. (2002) used the ABO system to evaluate cases suitable for submission for Phase III of the ABO examination and found that of the cases that had previously passed the examination at the time, only 19.6% of the university cases and 46.95% of private practice cases would then pass the OGS CRE system.[13] Over the period 1998 to 2003, Campbell et al. evaluated treatment outcomes in a graduate orthodontic programme at Indiana University School of Dentistry using the OGS and found that 46,1% had an OGS score of less than 30, with the most common deficiency being lack of occlusal contacts.[8] Cook et al. (2005) found no significant differences in treatment outcomes between patients managed in a postgraduate orthodontic programme and those treated in private practice, regardless of the experience and expertise of the operator. The overall score in this survey for the postgraduate program was 25.14 and that for the private practice group, 25.97.[14]
In addition to diagnosis, treatment planning, and overall case management, the evaluation of treatment outcomes is essential in Orthodontics to help maintain a high level of clinical care and overall outcomes of treated cases.

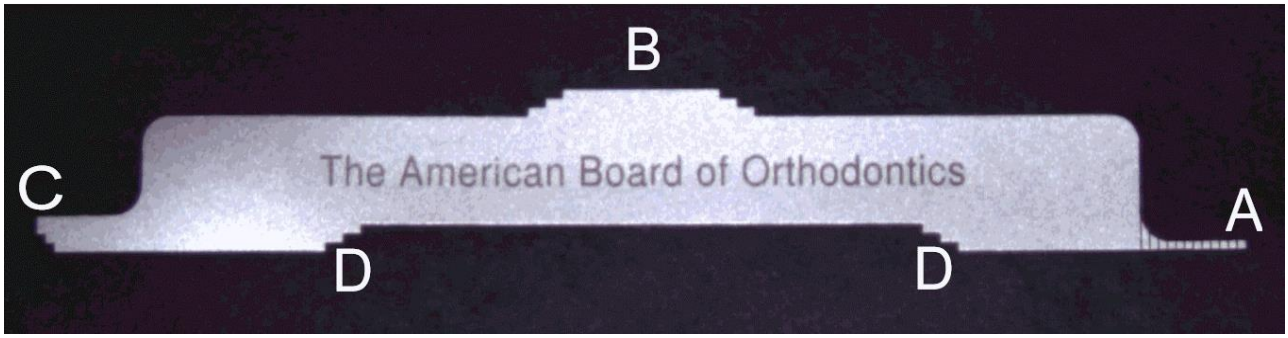


Figure 1. ABO measuring gauge **A**: This part has increments of 1mm and is used to measure discrepancies in alignment, overjet, occlusal contacts, interproximal contact, and occlusal relationships. The width is 0.5mm. **B**: This part of the gauge has steps of 1mm in height and is used to evaluate discrepancies in the mandibular posterior buccolingual inclinations (Mandibular 3rd Order). **C**: This part of the gauge has steps of 1mm in height and is used to evaluate discrepancies in marginal ridges (2nd Order). **D**: This part of the gauge has steps of 1mm in height and is used to evaluate maxillary posterior buccolingual inclinations (Maxillary 3rd Order).

CHAPTER II

STATEMENT OF PURPOSE

Continuous assessment of the quality of treated orthodontic cases in postgraduate clinics and in private practice is of paramount importance because it provides insight about the standard of orthodontic care and can also help to identify problems in the finishing of these cases. Strategies may then be developed to efficiently improve clinical outcomes. The most effective way to assess the quality of orthodontic treatment is a quantitative assessment of the outcomes of the cases.

Several studies have been conducted to assess treatment outcomes in graduate orthodontic clinics, while some studies have compared cases treated in postgraduate clinics with those managed in private practice.[8,12,13] However, this has not been done at Wits, nor has it been conducted at any of the orthodontic programmes in South Africa. The assessment of orthodontic treatment outcomes has been and still is traditionally accomplished in some countries by relying on the subjective opinions of experienced clinicians. In recent years, several attempts have been made to try to find an index that can be precise, valid, and objective in evaluating treatment outcomes. Currently, there are no established criteria for this purpose in South Africa. Indeed, generally, there is no objective system of grading that has been widely accepted, although the CRE is one of the most detailed indices in use. Several[12–14] studies have been conducted to evaluate the success of orthodontic treatment in private and educational setting and the CRE has now become widely accepted as the best system of assessing treatment outcomes.

The objectives of the study, therefore, were:

1. **Primary objective**:

   To utilize the ABO Cast and Radiographic Examination (CRE) system to evaluate the treatment outcomes of patients managed at the postgraduate orthodontic clinic of the University of the Witwatersrand, Johannesburg.

2. **Specific objectives**:

To compare the outcomes of treatment in relation to:

a. ***The Registrars***: Is it possible that the registrars will produce different treatment outcomes as assessed using the CRE even though their cases are severally under the supervision of the same consultants?

b. ***Consultant with respect to years in practice***: Is it possible that the treatment outcomes achieved by the registrars are dependent upon the consultant and is this affected by the number of years in which the consultant has been in practice? It is expected that orthodontists benefit from experience after they graduate from training, hence years in practice may have a correlation with the outcomes.

c. ***Consultant with respect to place of graduation***: Does the place of graduation of the consultant affect the treatment outcome? There is no standardization of treatment approaches. It is possible that any one programme has emphasis on aspects that do not necessarily produce the occlusion that is the objective of the CRE standards?

CHAPTER III

MATERIAL AND METHODS

Study design

The material for this ancillary study was obtained from the posttreatment records of patients treated by the Graduating Class of 2015 (GC2015) in the postgraduate clinic at the University of the Witwatersrand, Parktown, Johannesburg. At the beginning of the study, all of the records of the patients treated by the GC2015 were reviewed for inclusion. These records included study models, panoramic and cephalometric radiographs.

Inclusion criteria:

The records had to satisfy the following criteria in order to be included in the study:

1. The treatment of the patients had to have been started by the GC2015.
2. All treatments would have been commenced and completed between 2011 and 2015.
3. The materials for the study included panoramic radiographs and study casts, all of which had to be of good quality.

Exclusion criteria

1. Patients not treated to completion by the GC2015.
2. Incomplete end-of-treatment records.
3. Patients with significant craniofacial anomalies.
    a. Cleft lip or cleft lip and palate.
    b. Syndromes
4. Phase I of treatment for patients who had received two phases of treatment.

Material to be accessioned:

The material accessioned from the patient records whose treatment had been completed

included final models and panoramic radiographs, together with details of the supervising clinician. The records were graded using the ABO, CRE system and all the data were recorded on the official ABO forms. These were electronic and the scores were automatically calculated. These forms are shown in Figure 2.

Assessment criteria

The following information was assessed and recorded from the models and radiographs. All measurements on the plaster models were done using the ABO gauge (Figure 1). This is a summary of the detailed approach to the assessment, which is available on the ABO website.[15] For each criterion, points are negatively assigned based on the degree by which a relationship deviates from ideal.

1. Alignment (first order).
    a. Anterior region (canine-canine): In an ideal relationship, the labial surfaces of the mandibular incisors must be aligned with tight contacts and no rotations, as defined by Little.[16] In the maxillary arch, alignment focuses on the palatal surfaces of the incisors.
    b. Posterior regions: the buccal cusps of the molars and premolars are assessed for alignment in the mandibular arch while in the maxillary arch, consideration is given to the central grooves of the molars and premolars which must lie in a straight line.
2. Marginal ridges (second order). Ideal: all the marginal ridges of the adjacent posterior teeth should be level, in a patient with no restorations or periodontal bone loss.

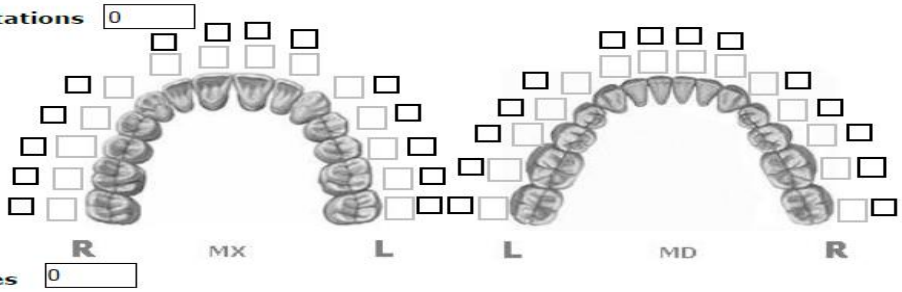
EXAM YEAR
ABO ID #

ABO Cast-Radiograph Evaluation
CASE# PATIENT NAME

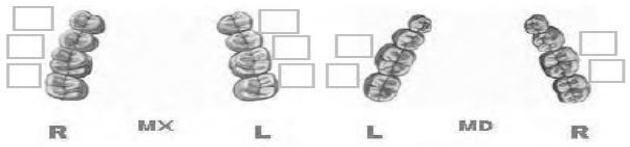
INSTRUCTIONS: Second molars should be in occlusion. Mark extracted teeth with a check in the bolded box. Place score beside each deficient tooth.

Total C-R Eval Score: 0

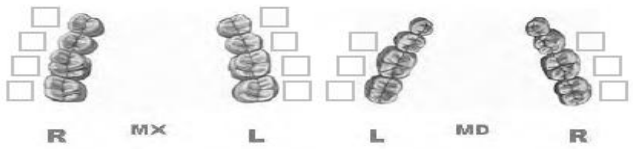
Alignment/Rotations 0



Marginal Ridges 0



Buccolingual Inclination 0



Overjet 0

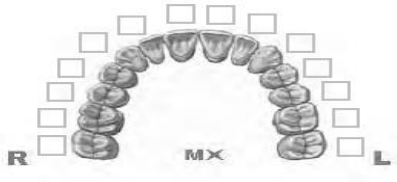


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Figure 2 A. Cast and radiograph examination form. **Alignment**: this assesses the first order (horizontal) alignment of the teeth. **Marginal ridges**: this section is used to assess the 2nd order alignment of the teeth. **Buccolingual inclination**: This part assesses the 3rd order positions of the molars and/or premolars. (In this research, premolars were not assessed.) **Overjet**: overjet is assessed in the buccal as well as anterior segments.

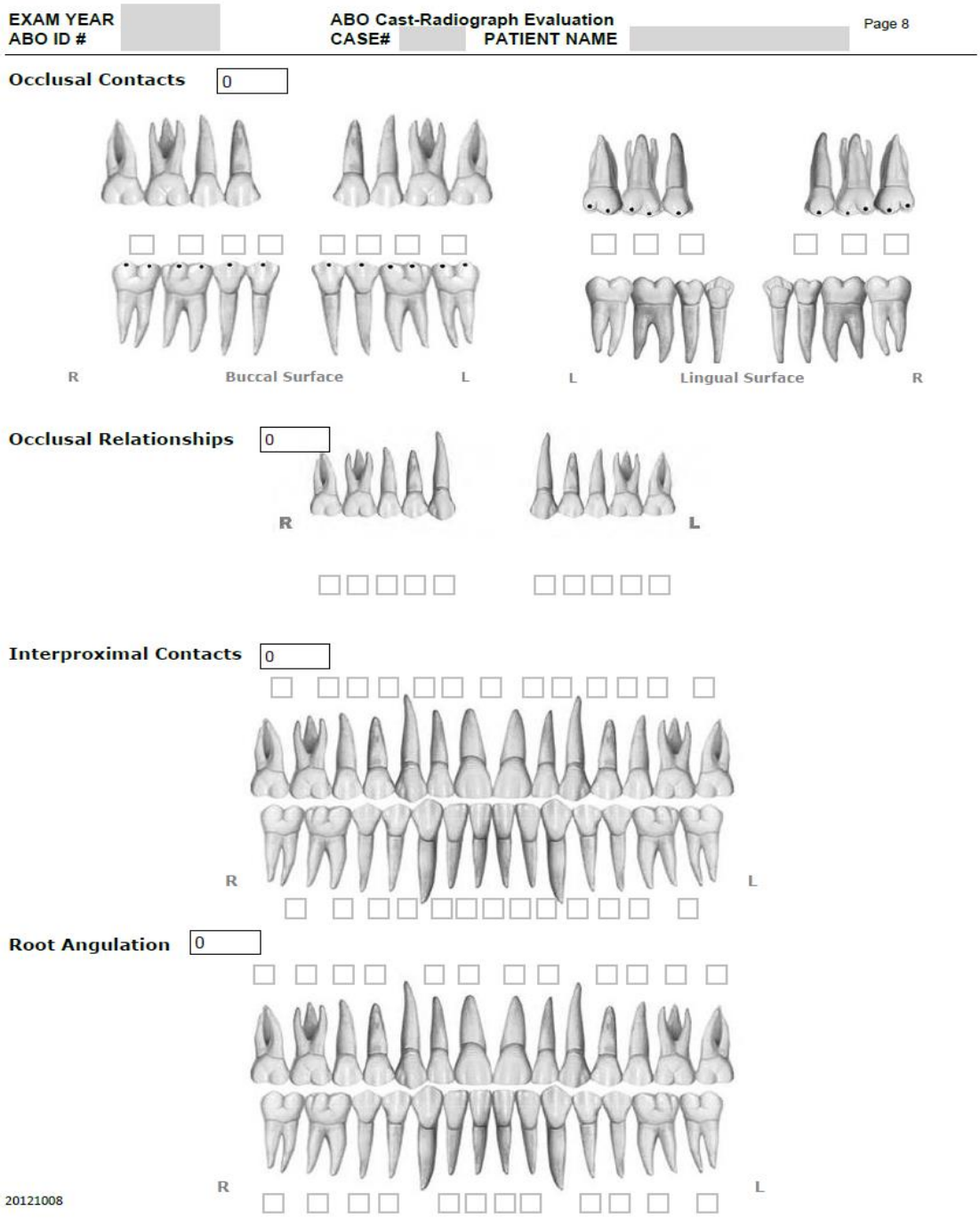

Figure 2B. Cast and radiograph examination form (continued). Occlusal contacts: Occlusal contacts are assessed on the buccal cusps of the mandibular posterior teeth and the lingual cusps of the maxillary molars and premolars. **Occlusal relationships**: This is Angle's classification of Class I, II and III. **Interproximal contacts**: these are the contacts between adjacent teeth with the expectation of no spacing. **Root angulation**: root angulation is assessed on the panoramic radiograph.

3. Buccolingual inclinations. Ideal: there should be no significant difference between the heights of the buccal and the lingual cusps (i.e. no excessive Curve of Wilson). Mandibular first premolars and distal cusps of the second molars are not graded.
4. Occlusal relationships. Ideal: the buccal cusps of the maxillary molars, premolars, canines must align within 1mm of the interproximal embrasures of the mandibular posterior teeth. The mesiobuccal cusp of the maxillary first permanent molar should occlude within 1mm of the mesiobuccal groove of the mandibular first permanent molar (Angle Class One) classification.[1]
5. Occlusal relationships. Ideal: the adequacy of posterior occlusion to ensure maximum intercuspation of the opposing teeth (functional cusp). Any diminutive cusp is not graded.
6. Overjet. This is the assessment of the anteroposterior relationship of the anterior teeth and the relative transverse relationship of the posterior teeth. Ideal: Anterior region, the mandibular incisors should be in contact with palatal surfaces of the maxillary anterior teeth. Posteriorly, mandibular buccal cusps and maxillary lingual cusps are used to assess whether the ideal positions within the fossae of the opposing teeth is satisfied.
7. Interproximal spaces. Ideal: there should be no spaces between adjacent teeth.
8. Root angulation. This is assessed using the panoramic radiograph. Ideal: All the roots should be parallel. Canines are not graded when using the panoramic radiograph.

One point is scored for each deviation up to a maximum of two points per tooth depending on the degree of the deviation. The ABO measuring gauge is used for precision, reliability, and validity. The gauge has areas A, B, C, and D for measuring the eight components of the Cast and Radiographic Examination, has scales with increments of one mm and a probe of a width of 0.5mm (Figure 1). The ideal relationship would attract a

score of zero and hence a perfectly treated patient would have a score of zero. Scores of 20 points constitute acceptable treatment, while a score of more than 30 points is considered unsatisfactory.

The data were then stratified accordingly as detailed in the data analysis.

DATA ANALYSIS

The accessioned data were entered into a Microsoft Excel © spread sheet and then uploaded into SAS © software, version 9.2 (SAS Institute, Carrey, NC) where the rest of the statistical manipulations were conducted. The data were then stratified, within SAS, into the following categories:

1. Group A: Cast and Radiographic Examination score of less than or equal (LE) to 20 (LE20). Such outcomes were considered excellent treatment results.
2. Group B: CRE score greater than (GT) 20 but LE to 25 (GT20LE25). This indicated good treatment outcome.
3. Group C: CRE score GT 25 but LE 30 (GT25LE30). This result would indicate a satisfactory result.
4. Group D: CRE score GT 30. Such an outcome meant unsatisfactory results.

Frequency data analyses were then employed to compare the data among the graduate students and as well to assess for differences, if any, among the supervising consultants. Trend tests were employed to establish the presence of a pattern, if any, with respect to time of graduation of the consultants, the place of training and the treatment outcome.

Error of Method

The primary investigator (PI) collected all the data for this study. A current ABO diplomate who is familiar with the system calibrated the PI via a replication approach until there was a 95% level of agreement. Ten sets of records were randomly selected, measured, and re-measured two weeks after the initial set of measurements. The first and repeat measurements were compared using Dahlberg's formula.

ETHICS

1. Permission to access the records was sought from and granted by the CEO of Wits Oral Health Centre. Ethical clearance to conduct the study was granted unconditionally by the Wits Human Research Ethics Committee **(HREC, 12 May 2017, clearance certificate number: M170117, ref 14/49)**. This ancillary project forms part of a larger project which aims to assess the treatment outcomes of patients treated by orthodontic Registrars in South Africa.

2. **Confidentiality**

   None of the information relating to the patient or treating clinicians appears in the analysed data. For purposes of confidentiality, the registrars and their supervisors were randomly allocated codes. Only the primary collector of the data had access to the coding. None of the codes will appear in any published data, and neither can they be linked back to the treating doctors or the patients.

CHAPTER IV

Results

Distribution of patients by Registrars and CRE scores

A total of 180 records were reviewed. Seventy five records did not meet the inclusion criteria and were excluded thus leaving a final sample of 105 records. There were three registrars. Fifty one of the records were from a single registrar while the remaining 54 were equally distributed among two registrars. This information is summarized in Table I. Of the patients treated by Reg1, only one patient had a score greater than 30 (Group D) and one in Group C. Reg2 did not have any outcomes in Groups C and D while Reg3 had three patient outcomes in Group C and none in Group D. Because of the minority of cases in groups C and D, these two groups were excluded since they were contributing to more than 5% of the cells with scores of less than 5, which compromised the statistical calculations. Thus there remained 100 patient outcomes to compare after exclusion of the five in groups C and D for statistical reasons. See Table II.

The Mantel-Haenszel (Q_{CSMH}) correlation statistic showed significant association between CRE scores and the registrars ($p = 0.0073$). This was supported by the Fisher's exact test with $p = 0.0124$.

Table III shows the least squares means (LSMean) of the CRE scores of the registrars. The Generalized Linear Model (GLM) adjusted for multiple comparisons between the scores using the Scheffe test showed significant differences between Reg1 and Reg2 and between Reg2 and Reg3 but no difference between Reg1 and Reg3 (Tables IV and V).

Table I. Frequency distribution of the CRE scores by registrar. Frequency (percentage).

Registrar	CRE GROUP				Total
	A	B	C	D	
Reg1	22 (20.95)	3 (2.86)	1 (0.95)	1 (0.95)	27 (25.71)
Reg2	24 (22.86)	3 (2.86)	0 (0.00)	0 (0.00)	27 (25.71)
Reg3	30 (28.57)	18 (17.14)	3 (2.86)	0 (0.00)	51 (48.57)
Total	76 (72.38)	24 (22.86)	4 (3.81)	1 (0.95)	105 (100.0)

Table II. Frequency distribution of the CRE scores by registrar after exclusion of Groups C and D. Frequency (percentage).

Registrar	CRE GROUP		
	A	B	TOTAL
Reg1	22 (22.00)	3 (3.00)	25 (25.00)
Reg2	24 (24.00)	3 (3.00)	27 (27.00)
Reg3	30 (30.00)	18 (18.00)	48 (48.00)
Total	76 (76.00)	24 (24.00)	100 (100.00)

Table III. Least squares means (LSMean) adjusted for multiple comparisons using the Scheffe test. LCL = Lower Confidence Level, UCL = Upper Confidence Level.

		95% confidence limits		
Registrar	**LSMean**	**LCL**	**UCL**	**LSMean Number**
Reg1	17.2271451	15.484573	18.969718	1
Reg2	14.2628171	12.585318	15.940316	2
Reg3	17.9203147	16.632227	19.208402	3

Table IV. Cross comparisons of the CRE scores of the three registrars. Refer to Table III for the LSMean number.

LSMean Number	1	2	3
1		0.0475	0.8085
2	0.0475		0.0024
3	0.8085	0.0024	

Table V. The difference between the means of the CRE scores of the three registrars, adjusted for multiple comparisons using the Scheffe test. Refer to Table III for the LSMean number. LCL = Lower Confidence Level, UCL = Upper Confidence Level.

		95% Confidence Limit	
Comparisons	**Difference between means**	LCL	UCL
Reg1 vs Reg2	2.964328	0.026153	5.902503
Reg1 vs Reg3	-0.693170	3.337048	1.950709
Reg2 vs Reg3	-3.657498	6.192962	1.122033

Is there a difference in the CRE scores amongst the Consultants?

The consultant outcomes were analyzed using the final sample of 100. There were ten Consultants supervising the three registrars, each having different numbers of patients (Table VI). Seven consultants had qualified from the same postgraduate orthodontic programme, while the other three had qualified from different programmes. The average number of years in practice was 25 years, 7 months.

Q_{CSMH} showed no significant difference amongst the CRE scores of the consultants ($p=0.3043$). The GLM procedure adjusted for multiple comparisons using the Scheffe test further substantiated the equal treatment outcomes amongst the consultants. This information is shown in Tables VII and VIII.

Can one detect a trend in the treatment outcomes of the Consultants?

The Cochran-Armitage Trend was applied to assess for the existence, if any, of a pattern in the treatment outcomes based on the expertise of the consultants. The Cochran-Armitage Trend was non-significant with $p=0.8200$. This was supported by the non-zero correlation static of 0.0512 with $p=0.8209$.

Table VI. Patient distribution by CID and CRE Score {(Frequency (Percent)} after exclusion of groups “C” and “D”.

Consultant	GROUP		
	A	B	TOTAL
Cons 1	18 (18.00)	4 (4.00)	22 (22.00)
Cons 2	4 (4.00)	2 (2.00)	6 (6.00)
Cons 3	6 (6.00)	2 (2.00)	8 (8.00)
Cons 4	6 (6.00)	3 (3.00)	9 (9.00)
Cons 5	7 (7.00)	1 (1.00)	8 (8.00)
Cons 6	6 (6.00)	7 (7.00)	13 (13.00)
Cons 7	10 (10.00)	2 (2.00)	12 (12.00)
Cons 8	10 (10.00)	1 (1.00)	11 (11.00)
Cons 9	3 (3.00)	0 (0.00)	3 (3.00)
Cons10	6 (6.00)	2 (2.00)	8 (8.00)
Total	76 (76.00)	24 (24.00)	100 (100.00)

Table VII. Least squares means of the consultants adjusted for multiple comparisons using the Scheffe test. (LCL= Lower Confidence Limit. UCL= Upper Confidence Limit).

		95% Confidence Limits		
Consultant	**LSMean**	**LCL**	**UCL**	**LSMean Number**
Cons1	15.9340808	14.168453	17.699708	1
Cons2	17.1082221	13.681422	20.535023	2
Cons3	16.3535496	13.393617	19.313482	3
Cons4	17.0340923	14.264819	19.803365	4
Cons5	15.3874444	12.447008	18.327881	5
Cons6	19.6515591	17.287953	22.015165	6
Cons7	16.7207777	14.314337	19.127218	7
Cons8	13.2498989	10.701221	15.798577	8
Cons9	14.6666667	9.887366	19.445967	9
Cons10	18.5946316	15.663235	21.526028	10

Table VIII. Cross comparisons of the CRE scores of the three registrars. Refer to Table VII for the LSMean number.

i/j	1	2	3	4	5	6	7	8	9	10
1		1.0000	1.0000	1.0000	1.0000	0.7065	1.0000	0.9626	1.0000	0.9822
2	1.0000		1.0000	1.0000	0.9999	0.9966	1.0000	0.9464	0.9999	1.0000
3	1.0000	1.0000		1.0000	1.0000	0.9635	1.0000	0.9791	1.0000	0.9989
4	1.0000	1.0000	1.0000		0.9999	0.9891	1.0000	0.9037	0.9998	0.9999
5	1.0000	0.9999	1.0000	0.9999		0.8168	1.0000	0.9986	1.0000	0.9829
6	0.7065	0.9966	0.9635	0.9891	0.8168		0.9592	0.1420	0.9401	1.0000
7	1.0000	1.0000	1.0000	1.0000	1.0000	0.9592		0.9093	0.9999	0.9994
8	0.9626	0.9464	0.9791	0.9037	0.9986	0.1420	0.9093		1.0000	0.5857
9	1.0000	0.9999	1.0000	0.9998	1.0000	0.9401	0.9999	1.0000		0.9916
10	0.9822	1.0000	0.9989	0.9999	0.9829	1.0000	0.9994	0.5857	0.9916	

Is there an interaction between the Registrars and the Consultants as relates to the treatment outcomes?

To assess the interaction, two main effects were considered: Registrar and consultant. The GLM procedure in SAS showed no interaction between the consultants and the registrars in the CRE scores (p = 0.3918). Table IX reflects these results. The main effects of consultant and registrar have already been presented.

Table IX. Results of interaction between registrars and consultants and general outcomes of the consultants and the registrars.

Source	DF	Type III SS	Mean Square	F-value	Pr > F
Registrar/Consultant	18	331.3568584	18.4087144	1.08	0.3918
Consultant	9	160.3888243	17.8209805	1.04	0.4152
Registrar	2	219.5254207	109.7627103	6.43	0.0027

CHAPTER V

DISCUSSION

Assessing the quality of orthodontic treatment outcomes achieved by various registrars and consultants is highly valuable, not only for the institutions but also for the benefit of the patients receiving treatment. The quality of orthodontic treatment outcome in postgraduate programmes is in direct relation to the standard of training of the registrars and to the quality of the clinicians graduating from these programmes. One way to continually assess the standard of education in these settings is through objective assessment of the cases treated by the registrars under the supervision of the consultants.

Various methods of assessing treatment outcomes have been presented in the specialty of Orthodontics. The most prominent is the Objective Grading System (OGS) which has since been renamed and revised to the Cast and Radiographic Examination scoring system (CRE), used in this study. A higher score as measured by the ABO, CRE system represents not only imperfections or poor occlusion, but could be a pointer to factors having a profound impact on function, stability, aesthetics, and orofacial harmony. In this study, the CRE scores were low with 76% of the cases scoring less than 20 points (LT20) and 24% greater than 20 but less than 25 points (GT25LT20), which is a remarkable outcome in orthodontics.

One of the aims of the Health Professions Council of South Africa (HPCSA) is to ensure the highest excellence in education as well as in the independent private practices. The best way to establish and maintain high clinical excellence in clinical orthodontics is by the quantitative and qualitative assessment of the treatment outcomes. The CRE lends itself

as a useful tool for every clinician who is in the practice of orthodontics to apply in the evaluation and improvement of their clinical skills. The low scores obtained in this study are a measure of high quality outcomes.

One of the objectives of this study was to utilize the ABO, CRE system to evaluate the quality of the treatment outcomes of patients managed in the postgraduate orthodontic clinic at Wits. The study showed that the overall quality of treatment for the cases treated at Wits was satisfactory with all patients attaining good to excellent results as indicated by the CRE scores of LT20 (76%) and GT20LE25 (24%). Several[13,17,18] studies have shown that CRE scores tend to improve with settling, hence the ABO allows for the records to be taken at no later than twelve months after appliance removal to allow for the occlusion to settle with retention. The results in our study are based on the final patient records which were obtained immediately after appliance removal. Greco et al. (2010) have demonstrated that all parameters of the occlusion tend to improve with time during the retention phase of treatment and this is called “settling” of the occlusion. An exception to this observation are first order discrepancies (alignment) which tend to deteriorate over time after removal of active appliances.[17] Nett and Huang assessed 100 subjects at least 10 years post-retention, selected randomly from amongst more than 800 records stored in the archives of the University of Washington.[18] They found that the scores had improved significantly, by approximately four points, from an average of 21.5 post-treatment to 17.5 post-retention. They reported that similar patterns of improvements were found for all criteria, except alignment which deteriorated as the rest of the other characteristics improved. The study by Yang-Powers et al. also attributed better scores in occlusal contacts and overjet for the ABO group as being due to possible settling of teeth after appliance removal, while the university group had higher scores in occlusal contacts and overjet.[13] It is possible then that the CRE scores could have been even lower in our study had the records been taken a few months after appliance removal, thus allowing for

settling of the occlusion, since traits that improve with retention might have significantly contributed to the reduction of the overall CRE scores in the study. It is also possible that the consultants also prognosticated that certain parameters of occlusion were favourable and were going to improve during settling, and as a result termination of treatment was advised although the discrepancies may not have been fully corrected at the time of appliance removal.

A secondary objective was to assess treatment outcomes with respect to the consultant's experience as judged by the number of years in practice and place of graduation. The quality of the treatment outcomes in orthodontics distinguishes the true master of the profession from amongst his/her colleagues.[1] According to Abei et al.,[19] the treatment outcomes of specialists are better than those of non-specialists. Abei et al.[19] attributed the superior treatment outcomes for the specialists to the extra hours of training that they would have undergone during training. It has been suggested that one gains orthodontic expertise while still in the postgraduate programme as a registrar and that that skill is later fine-tuned in practice through knowledge, experience and the exposure to various cases in the field.[14] As one becomes an expert in the field, the quality of the treatment outcomes should also improve. Whilst it may be true that the number of years in practice may play a significant role in determining the quality of the outcomes of the cases, the results in the current study showed no difference among the cases managed in the orthodontic clinic at Wits since the treatment outcomes were the same across all the consultants irrespective of the number of years in practice.

There was no interaction between the registrars and the consultants in so far as the treatment outcomes were concerned as shown by the p-value of $p = 0.3918$ for the interaction term. The registrars at Wits treat their patients directly under the supervision of

the clinical supervisors. The equality in the treatment outcomes demonstrated good supervision as the outcomes of the consultants and the registrars combined were similar.

A significant difference ($p = 0.0073$) was found amongst the CRE scores of the registrars with LSMeans of 17.92, 17.23, and 14.26. This should be interpreted with caution because of the poor distribution of the records, a factor which could not be overcome since the sample was one of convenience. The two registrars with equal number of patients (26) had similar LSMean scores of 17.93 and 17.23 ($p = 0.81$). The third registrar had a lower LSMean score of 14.26 and this could be due to the larger number of cases (48) selected from this registrar.

The traits and expectations of clinicians are somehow greatly influenced by their educational background (place of graduation), resulting in different finishing protocols and treatment outcomes. Since decisions in orthodontic finishing are greatly influenced by individual perception, it could have been expected that certain trends related to the consultant's background might be have been established in the treatment outcomes of our cases. No such trends or patterns were found in respect to the place of graduation even though the consultants had studied at different schools. The registrars were supervised by a total of 10 consultants. Seven of the consultants had trained in the same programme while three had graduated from different schools with one being foreign trained. Saghafi et al. have reported that there is a marked inter-regional variation in treatment outcomes due to different teaching systems, and the demands and expectations of patients.[20] The outcomes of this study could not support the findings of Saghafi et al.

Yet to be understood is how and why so many of the Wits cases achieved similar scores while treated by different consultants from various backgrounds? When there is no prescribed finishing protocol most of the clinicians tend to aim for the "Andrews Six Keys

to Normal Occlusion" during finishing, which could potentially be the objective of the consultants at Wits. The similar results could be attributed to the bracket systems used. The bracket systems were however not evaluated in this research.

A possible strength in the CRE system is that evaluation is based on how closely the finished case accords with specific criteria irrespective of the initial malocclusion. In this way a clear standard of excellence is established and a defined clinical target is defined. Although the CRE scores in this study showed good results, it is still advisable that the Wits postgraduate orthodontic programme establishes and implements standardized finishing criteria so as to maintain and improve the level of clinical excellence in the postgraduate clinic. This is consistent with the findings of Knierm et al. who reported that treatment outcomes at Indiana University improved over the three year period due to the changes that were introduced in clinical protocols which were instituted to correct deficiencies that had been identified in the previous years.[22] Following the introduction of the changes, the CRE scores at Indiana University improved by 9.4 points (34.59 in 1998-2000 to 25.19 in 2001-2003). Carvajal-Florez et al. also reported improvement of the CRE scores after the implementation of a standardized approach to finishing in the postgraduate clinics of orthodontics of Universidad de Antioquia.[23] Thus implementation of standardized requirements for the finishing of cases at the Wits postgraduate clinic will ensure that the treatment outcomes of cases parallel the quality of clinical management received by patients and the level of training offered by the programme.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The ABO CRE has been proven as a most precise, valid, and reliable tool to evaluate efficiency and quality of treatment outcomes in educational settings. The system can also be used to maintain the standard of orthodontic care in postgraduate orthodontic programmes or to compare treatment outcomes between settings. In this study, a total of 100 cases treated by the graduating class of 2015 were evaluated using the CRE. The study findings can be **summarized** as follows:

- All the registrars provided excellent treatment since 76% of the cases recorded CRE scores LT20 and only 24% were GT20 but LE25.
- While some difference was observed amongst the registrars, this could have emanated from the sample of convenience which favoured one registrar over the other two.
- No significant differences could be established among the consultants.
- There was no statistically significant interaction between the registrars and the consultants in the treatment outcomes.
- Although the results of the study were excellent, implementation of standardized finishing objectives at the Wits postgraduate orthodontic clinic is recommended to assist in maintenance and improvement of the quality of services offered.

Conclusion

All the registrars provided high quality treatment since the CRE scores were generally less than 25, with 76% scoring at less than 20. The treatment supervision provided by the consultants was the same as there were no significant differences in their scores.

Limitations and Recommendations

1. Although the CRE scores in this study showed good results, it is highly recommended that Wits postgraduate orthodontic programme establishes standardized finishing objectives to maintain and improve patient treatment outcomes as well as registrar training.
2. The samples in this study were low. Efforts should be made to properly archive the records of the patients to allow evaluation of treatment outcomes.
3. Currently there is no standardized way of evaluating treatment outcomes in the various teaching programmes. The ABO CRE should be implemented by all the postgraduate orthodontic programmes and the College of Medicine of South Africa in certifying graduates who have obtained their training in SA or other countries.
4. This study is part of a bigger project to evaluate all programmes in South Africa. This study provides evidence which endorses the whole project.

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APPENDIX

ABO SCORING SHEET

	Criteria		Grading	Points lost
Model Analysis	Md	1st Order (alignment, rotations)	*	
		2nd Order (marginal ridges)	*	
		3rd Order (buccolingual inclination)	**	
	Mx	1st Order (alignment, rotations)	*	
		2nd Order (marginal ridges)	*	
		3rd Order (buccolingual inclination)	**	
	Occlusal Contacts	Buccal cusps Md	***	
		Lingual cusps Mx	***	
	Occlusal Relationships		****	
	Overjet		*/	
	Interproximal contacts		*//	
Pano	Root angulation		*///	
			TOTAL	

Criteria for Deducting Points

*	0 - 0.5 mm	0 pts.	*/	0 - 0.5 mm	0 pts.
	0.5 – 1 mm	1 pt.		0.5 – 1 mm	1 pt.
	>1 mm	2 pts.		>1 mm	2 pts.
**	0 – 1 mm	0 pts.	*//	0 - 0. 5 mm	0 pts.
	>1 – 2 mm	1 pt		0.5 – 1 mm	1 pt.
	>2 mm	2 pts.		>1 mm	2 pts.
***	0.1 – 1 mm	1 pt.	*///	0 – 1 mm	0 pts.
	>1 mm	2 pts.		>1 mm	1 pt.
****	1 - 2 mm	1 pt.		touching	2 pts.
	>2 mm	2 pts.			