TREATMENT DIFFICULTY ASSESSMENT OF POSTGRADUATE ORTHODONTIC CASES AT A UNIVERSITY CLINIC

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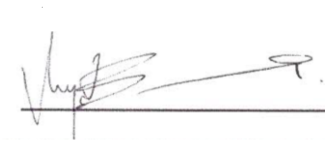
Declaration

I, Vuyo Bomvana, declare that this research project **"Treatment difficulty assessment of postgraduate orthodontic cases at a university clinic"** is my own unaided work. It is being submitted for the Degree of Master of Dentistry in the branch of Orthodontics at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



31st day of August 2020

Dedication

Dedicated to my loving wife, Leabetswe and daughters, Keoikantse and Lalitha, for all their support, patience and sacrifice throughout my journey of development.

‘A day in school will profit you, for its work endures like the mountains.’

- Duauf, circa 2150 – 1990 BC

Abstract

Background: Judgement of the degree of treatment complexity and difficulty posed by an orthodontic case may be assessed using proposed, validated and objective indices.

Objectives: To assess the treatment complexity and difficulty of cases treated at a South African University by orthodontic registrars.

Materials and Methods: A retrospective, descriptive, cross-sectional study of 49 pre-treatment patient records were electronically assessed using the ABO Discrepancy Index (DI). The DI scores were categorized into four degrees of DI complexity. The data were statistically analysed and all tests were at 5% level of significance.

Results: No significant associations were found of DI with race, gender and malocclusion, nor between the cases allocated to registrars. Anterior openbite, ANB, SN-MP and IMPA were found to primarily influence the DI score.

Conclusion: All the registrars had most of their cases in the very difficult category. ANB, SN-MP, IMPA and anterior openbite had the most influence on DI.

Acknowledgements

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Abbreviations and Nomenclature

%	Percentage
A	A-point
ABO	American Board of Orthodontics
ACS	Additional complexity score
ANB	(A-point)-Nasion-(B-point) angle
AOB	Anterior openbite
B	B-point
BXB	Buccal crossbite
CBCT	Cone beam computed tomography
CI	Confidence interval
CS	Crowding score
DI	Discrepancy Index
FMA	Frankfort Mandibular plane angle
FMIA	Frankfort Mandibular Incisal angle
Go	Gonion
GT10LE20	greater than 10 but less than or equal to 20
GT20LE30	greater than 20 but less than or equal to 30
GT30	greater than 30
HPCSA	Health Professions Council of South Africa
HREC	Human Research Ethics Committee
ICON	Index of Complexity, Outcome and Need
IMPA	Lower incisor to mandibular plane angle
IOTN	Index of Orthodontic Treatment Need
IQR	Interquartile Range
LCD	Liquid crystal display
LE10	less than or equal to 10
LFH	Lower facial height
LO	Lateral openbite
LXB	Lingual crossbite
Me	Menton

N	Nasion
OB	Overbite
OI	Occlusal Index
OJ	Overjet
OR	Occlusal relationship
p	p value
PAR	Peer Assessment Rating
pts	Points
S	Sella
SMU	Sefako Makgatho Health Sciences University
SN	Sella-Nasion plane
SNA	Sella-Nasion-(A-point) angle
SNB	Sella-Nasion-(B-point) angle
SN-MP	SN mandibular plane angle
USA	United States of America
VB	Vuyo Bomvana

Chapter 1
Introduction and Literature Review

The orthodontic profession is committed to the principle of quality assurance of the highest standards in the endeavour to ensure optimal treatment for each and every patient. Orthodontists aim for the same goals of treatment irrespective of the initial malocclusion and severity. They strive to achieve a functional occlusion combined with the best possible aesthetics (both dental and soft tissue), providing optimal temporo-mandibular function, improvement of the patient's psycho-social disposition, stability of treatment results and the maintenance and preservation of healthy hard and soft oral tissues.[1] Differences in the original malocclusions may not only influence the success of treatment and associated peer review processes, but may be relevant in terms of predictions of the duration of treatment, have an impact on the frequency of referral of cases to specialists and on the determination of patient fees.[2–7]

Occlusion may be defined as "the manner in which the teeth intercuspate."[8] This concept encompasses all variations from good occlusion to malocclusion.[8] Investigators previously described varying degrees of occlusion as seen in each case, as opposed to malocclusion, leading to considerable confusion.[9–15] Angle was the first to describe a "normal" occlusion and orthodontic treatment may be considered for any patient whose occlusion deviates from that criterion.[9] This system sets the maxillary first molar as the key to occlusion.[9] The malocclusion classification centres on the extent of deviation of the position of the mesiobuccal cusp of the maxillary first molar away from Angle's concept of the "ideal" interdigital contact relationship of the cusp with the mesiobuccal groove of the mandibular first molar.[9]

Despite Angle's and other proposed classifications, classification of malocclusion has been difficult to use in epidemiology because of a lack of precision and at times poorly defined features.[8] A clear consensus on the classification and assessment of malocclusions would be useful clinically for diagnosis and for the planning of treatment for patients. Several studies have followed the initial attempts to define normal occlusion. Hence a number of indices and postulates have been developed to assist the clinician in diagnosing malocclusion (and orthodontic diagnosis in general) and to assess the need for treatment.[8–24]

Some indices have been useful as tools for assessing treatment need,[8, 18, 22, 23] others for quantifying treatment difficulty, complexity and malocclusion severity[8,16–21,23,24] and for evaluating treatment outcomes and the degree of treatment success.[15, 16, 20, 23, 24] The indices may be applied in assigning quality control measures for the orthodontic specialist,[16, 18, 24] in public health[8, 25] and in considering the epidemiology of malocclusion,[8, 26] in assisting general dentists in their case selection of patients for orthodontic treatment,[3, 5, 7] in monitoring graduate orthodontic training programmes and for the estimation of appropriate remuneration for the delivery of treatment.[2, 5–7, 27–32]

Nevertheless, measuring case complexity or difficulty by orthodontists and dental practitioners has tended to be a subjective exercise with no proven objective method for quantification.[33] Most desirable would be an objective, reliable, valid and accepted index or indices. The numerous indices that have been developed by different investigators have been helpful, although all have their limitations. It is relevant, then, to discuss some selected examples of indices with reference to their application in the assessment of the difficulty and complexity of malocclusions.

Six keys to normal occlusion

In an effort to define ideal occlusion, six keys to normal occlusion were defined by Andrews in 1972, this being the first deliberate attempt to gather data which could be used systematically as a reference to good occlusion.[15] The keys were significant occlusal characteristics observed from the records of patients who had not received orthodontic treatment, but whose occlusion was deemed ideal. The characteristics were compared with those exhibited by 1150 archived treated cases.[15] The six keys include: the molar relationship (the first upper molar and lower second molar – "Stolarization" of the first upper molar); crown angulation (mesio-distal tip); crown inclination (bucco-lingual and labio-lingual); no rotations (first order discrepancy among individual teeth in each dental arch); no spacing (tight proximal contacts between the teeth in each arch) and flat occlusal planes (flat or minimal curve of Spee).[13, 15] Any deviation from these ideal characteristics would be indicative of an incomplete result in a treated case.[15] The innovation of the pre-adjusted Edgewise fixed appliance owes its genesis to these six keys.

These findings were instrumental in providing the clinician with treatment goals at which to strive and was an initial step by Andrews, who later formulated the six elements of orthodontic philosophy.[34] These elements include: the dental arch; anteroposterior jaw positions; width of the maxilla; the heights of the jaws; chin prominence and occlusion.[34] The suggestions made by Andrews are recognised as important concepts which have contributed to a refinement of orthodontic objectives. The keys do not however offer an objective assessment of the degree of difficulty of the case.

The Occlusal Index

The occlusal index (OI) was developed as a tool to measure occlusion and malocclusion for epidemiological purposes.[8] The OI was adopted in South Africa in 1985 following the recommendations of the Working Group for the Co-ordination of Oral Health Studies as a quantitative assessment tool for malocclusion; because it was viewed as an objective, reliable method of measurement.[35]

Nine occlusal and dental characteristics are scored in the OI, namely: dental age, molar relationships, overbite, overjet, tooth displacement, posterior crossbite, posterior openbite, midline relationships and missing permanent teeth.[8] It has different scoring schemes for primary, transitional and permanent dentitions and, when comparisons are needed, allows for subjective classifications from its objective measurements.[8] Whilst the index has high validity and reliability, it is mainly useful for measuring treatment need and records a low performance in measuring treatment difficulty.[8]

The Peer Assessment Rating Index

The Peer Assessment Rating (PAR) index was formulated over a sequence of six meetings of the British Orthodontic Standards Working Party in 1987, and was further developed in 1992.[16] The PAR index delivers one summative score for all occlusal deviations and may be used for all types of malocclusions.[16] It comprises 11 elements measuring occlusal traits which present in: the right and left buccal segments; upper and lower anterior segments; right and left buccal occlusion; overbite; overjet and midlines.[16]

These occlusal traits are measured on pre- and post-treatment dental models to provide two scores. The difference between the scores indicates the degree of improvement and is therefore a measure of the treatment success achieved by orthodontic intervention.[16] The PAR index was specifically designed to give a more objective assessment of treatment success as well as of treatment difficulty.[36] It has been proven to be reliable, having been used extensively as a method of appraisal in Europe, but has enjoyed only limited application in United States of America (USA).[37, 40, 45]

Treatment severity and difficulty may be assessed using the PAR index, targeting traits such as midline discrepancy, buccal occlusion, upper anterior crowding, overjet and overbite.[32] These traits do carry weight in determining treatment difficulty. However, lower anterior and buccal crowding were not considered as it was concluded by the panel of 11 orthodontists involved in the International PAR Index validation study (DeGuzman et al.) that it was the aetiology of these features that was of more concern, and hence the index when used in the USA was modified by removing those parameters.[31] To determine factors affecting treatment difficulty other than occlusion itself, the PAR index and the Index of Orthodontic Treatment Need (IOTN) were used by Cassinelli and co-workers.[37] Ten easy and ten difficult treated cases selected by ten orthodontists were evaluated and it was concluded that difficult cases presented more severe pre-treatment malocclusion and greater treatment need.[37] Furthermore, it was found that post-treatment there were residual deficiencies in the finishing of these more difficult cases, longer treatment duration and a need for further treatment.[37] Compliance and oral hygiene challenges were also found to be factors in difficult cases, which were also more likely to require extractions, additional appointments and changes in treatment plan during orthodontic management.[37]

Two studies assessing orthodontic outcomes and using the PAR index found it a reliable adjunctive tool for treatment outcome appraisal, but also concluded that it was not sufficiently precise to distinguish between a good and an excellent treatment result.[27, 31] The index has also been criticized for being too lenient on treatment outcomes of cases with poor finishes.[31, 33] In simple cases – those with low initial PAR index scores – and cases with minor and limited treatment objectives, the index has however been deemed strict.[33]

The Index of Complexity, Outcome and Need

The Index of Complexity, Outcome and Need (ICON) has components for the assessment of aesthetics, cross-bite, crowding of the dental arches, impactions, buccal segment occlusion and overjet.[18] The index has been specifically developed and designed to allow assessments of need, treatment complexity and treatment outcome, using one set of occlusal traits, adopted from the PAR index and from the IOTN.[18, 33]

Treatment complexity is determined using five categories ranging from simple to very difficult, based on occlusal factors. A simple case has a score of less than 29, mild ranges from 29 to 50, moderate 51 to 63, difficult 64 to 77 with very difficult being above 77.[18, 28] The index recognises that similar malocclusions which differ in complexity can require treatments of differing duration which may influence the outcome of orthodontic management. It is valuable to have a method of differentiation which could assist the clinician in determining how difficult it would be to treat any particular malocclusion, and the ICON was found to have an acceptable reliability in measuring treatment complexity.[18] It was not, however, conclusive on whether complexity affects treatment outcome and success.[36]

Canine Treatment Difficulty Index

The aim of this index was to measure the difficulty of the treatment involved in the correction of unerupted maxillary canines.[20] Its development followed a process similar to that used in the development of the PAR index. Thirty cases in which one unerupted, displaced maxillary canine had been successfully treated were evaluated and scored by a panel of 14 orthodontists.[20] The treatment difficulty index comprised a perceived difficulty score as judged by the panel and a graded difficulty score according to nine factors considered likely to influence treatment success and outcome.[20] These nine factors were: patient age (at the start of treatment); angulation of the unerupted canine relative to the upper midline; vertical position of the unerupted canine to the occlusal plane of the adjacent permanent incisor; bucco-palatal positions of the unerupted canine; horizontal positions of the unerupted canine; upper permanent incisor alignment; space between the premolar and lateral incisor; coincidence of upper and lower midlines and rotations.[20] Horizontal position of the unerupted canine was found to be most important factor in determining treatment difficulty, followed by vertical and bucco-palatal positions.[20]

This index has been found to be useful in the assessment of the treatment difficulty of this particular problem, but currently there has been no literature on its acceptability and application in clinical practice.

Index of Orthodontic Treatment Complexity

The motivation behind the conception of this index was to address the limitations of the ICON which had a higher weighting of aesthetics as opposed to complexity, and to augment the PAR index occlusal factors in measuring complexity.[21] A sample of 120 dental models equally distributing the major malocclusion classes were assessed, the models being part of treatment records from Birmingham Dental and Walsall Manor Hospitals.[21]

These pre-treatment dental study models were examined by a panel of 16 examiners (12 orthodontists and four registrars).[21] First, perceived complexity was graded on a six-point scale, beginning with one being simple right through to five being extremely complex and six regarded as treatment impossible without surgery.[21] Secondly the examiners were required to consider a list of 11 pre-determined occlusal factors derived from the PAR index (with the addition of absent teeth, teeth of poor prognosis and spacing as supplementary factors), and from that list to choose three factors, placing them in order of importance.[21] The index scores showed modest but highly significant correlations with assessments of treatment complexity.[21]

The 21 Point Cephalometric Severity Index

A study was conducted in 2014 under the auspices of the University of the Witwatersrand, Johannesburg with the prime objective of evaluating the treatment outcomes of cases treated with the Tip-Edge® bracket and Edgewise bracket systems in the treatment of Class II malocclusions.[38, 39] There were 24 cephalometric parameters measured, divided into angular and linear measurements, which are tabulated in Table 1.[38, 39] Part two of the study entailed developing The 21 Point Cephalometric Severity Index from the findings.[24] These 21 parameters were divided into five areas deemed crucial in order to achieve treatment success.[24]

The cephalometric measurements include skeletal (angular and linear), dental (angular and linear) and soft tissue linear parameters all of which were scored according to the extent of deviation from the norms of the Steiner, Harvold and Ricketts analyses.[24,40–42] The quantitative assessment of these parameters may be useful firstly in determining the treatment difficulty and secondly, in comparing pre-treatment and post-treatment scores in order to determine treatment success.[24]

This index has not, however, been subjected to any further assessment.

Table 1: Cephalometric parameters in the 21 Point Cephalometric Severity Index

Angular Cephalometric Parameters	Linear Cephalometric Parameters
SNA	SN plane
SNB	Porion to Nasion (N)
ANB	Porion to A-point
SN to mandibular plane angle (SN-MP)	Maxillary length
Y-axis	Mandibular length
Occlusal Plane	Lower face height (LFH)
Palatal Plane	Wits analysis
SN to upper incisor	Upper incisor to NA plane
Upper incisor to NA plane	Lower incisor to NB plane
Lower incisor to NB plane	Upper lip to E-plane
Interincisal angle	Lower lip to E-plane
Lower incisor to mandibular plane angle (IMPA)	Lower incisor to A-Pogonion Line

Along with classification of the malocclusion and an assessment of its severity and case complexity, treatment difficulty can also be quantified by using the Probability Index and the American Board of Orthodontics (ABO) Discrepancy index (DI).[17, 19]

The Probability Index

The Tweed Foundation recommends a method of assessing treatment difficulty. It was developed using studies of pre- and post-treatment records of successfully and unsuccessfully treated Class II malocclusion cases on which were based conclusions about the factors that are likely to contribute to treatment difficulty.[17] The method was developed for three specific reasons: to supplement the diagnostic process, secondly to act as a guide for treatment planning and thirdly for prediction of treatment success or failure.[17, 43] The assessment involves five cephalometric measurements in the cranial facial analysis, which are FMA, SNB angle, FMIA, ANB angle and occlusal plane inclination, and several dental study model measurements are used to determine the total space analysis. These data are combined with an assessment of the panoramic radiograph to determine the Difficulty Index.[17] This may be used to quantify the difficulty of a case prior to treatment and to identify those Class II malocclusions which can be treated with orthodontic fixed appliances alone or which will require both orthodontic management and orthognathic surgery.[17]

The Discrepancy Index

The Discrepancy Index (DI) was developed by ABO with the intention to ensure that candidates in the ABO Phase III Board examinations were exposed to and presented cases which exhibited a multiple range of "target disorders" and difficulties.[19] Initially developed in 1998 and still currently used, the calculation of the DI score relies on the assessment of pre-treatment records, comprising the dental study models, lateral cephalogram, panoramic radiograph and any additional special investigations (extra–oral photographs, peri-apical intra–oral radiographs and cone beam computed tomography - CBCT).[19]

The DI, which is similar in some aspects to the Probability Index, measures target disorders involving overjet, overbite, anterior openbite, lateral openbite, crowding, occlusion, lingual posterior crossbite, buccal posterior crossbite; cephalometric measurements of the ANB, IMPA and SN-MP angles; as well as additional conditions likely to affect or add to treatment complexity - which may be supernumerary teeth, permanent tooth ankylosis, abnormal tooth morphology, impacted teeth (except third molars), midlines, missing teeth, congenitally missing teeth, spacing, diastemata, transpositions, skeletal asymmetry and any other complexities.[2, 19]

The conditions measured in the DI were chosen as they could be compared with accepted norms and were routinely treated by orthodontists.[19] Observations showed that some DI components such as overjet, overbite, crowding, occlusal relationships, the cephalometric measurements and tooth transpositions exerted a major influence on the overall DI score.[30, 44]

After the initial development of the DI, the ABO conducted a number of field pilot studies from 1999 to 2002 in order to collect data which may have modified the requirements of the Board Examinations.[19] Based on data from these pilot studies, the ABO decided to change the requirements for the submission of examination cases.[19] A DI score ranging less than ten has been considered a simple case. Therefore graduate orthodontic students and candidate orthodontists were encouraged to present for the ABO examination two cases having a DI of 25 or above; a DI of 16 and above for six cases and a DI of seven and above for two cases.[19] This would ensure that they had exposure to and experience in, the management of the range of cases that they were likely to encounter post-graduation and in practice.[19, 45] Used in this way the DI in fact offers an effective and objective criterion which will contribute to ensuring that orthodontic registrars are exposed to an appropriate spread of clinical experience during training.

The DI gives an objective measure of case difficulty, reducing the likelihood of varying and subjective evaluations by the examiners.[19, 45, 46] The DI together with the PAR Index has been found to be reliable in measuring malocclusion severity with the DI being more biased towards Class II malocclusion reliability; in contrast, the PAR Index fared better in reliability of assessment of Class III.[27, 47, 48]

It may be expected that the higher the DI score, the more compromised the treatment outcome would be. This relationship was found in severe malocclusions but there was a weak association in moderate to mild malocclusions.[30,32] Indeed, recently the Thai Board of Orthodontists, using the ABO DI and Objective Grading System, found overall that DI scores ranging from simple to difficult cases had no correlation with the treatment outcome,[49] which is in contrast with previous studies by Parrish and co-workers along with Vu and co-workers.[30, 32] It has been shown that the DI can be associated with treatment duration, with higher DI scores with some component parameters of the index adding about a further 11 days of treatment per point of increase in DI score.[7, 30] The reliability of the DI compared with the PAR index is favourable, but its weighting in scoring crowding needs to be re-evaluated to account for racial and ethnic differences.[2, 27, 44, 47, 48]

Demographic variables such as age, race and gender have been tested for relationships with the DI, because it has been found with other indices such as the PAR index and ICON particularly, that gender does affect the scores.[33,50,51] The DI has thus far been found to be unaffected by age and race, but gender does influence the DI, with males tending to have a higher DI score.[27,44] The DI with its proven reliability and its ease of application, has been used in many studies to assess treatment difficulty and complexity.[2, 7, 27, 29, 30, 44, 47–49, 52]

Further investigations relying on the DI system are well warranted.

Statement of purpose

While orthodontists generally admire the results of their work, they anecdotally refer to a demanding case as "difficult". This has often lacked a standard by which that difficulty can be assessed. The United Kingdom, the European Union and the USA have established indices of treatment difficulty and complexity, but these have not been widely used in South Africa. The DI is the method adopted in ABO Board examinations in the USA for the assessment of treatment difficulty and complexity. This investigation aims to utilise the DI in an assessment of cases selected for orthodontic treatment by registrars in a South African University.

The aim of the study

The aim of this research is to use the DI to assess the difficulty and complexity of the malocclusions presented by patients who were accepted for orthodontic treatment by the orthodontic registrars at Sefako Makgatho Health Sciences University (SMU) between 1 January 2011 and 31 December 2015.

The objectives of the study

To explore the range of case difficulty of patients selected for treatment by orthodontic registrars at the SMU using the DI.

1. To determine whether there is uniformity in the case allocation amongst the registrars at SMU according to complexity and difficulty as assessed by the DI.
2. To assess whether gender, age and race influence the DI scores.
3. To explore which occlusal parameters influence the DI scores.

Chapter 2
Materials and Methods

Study design

This was a retrospective, descriptive, cross-sectional study which assessed data obtained from the pre-treatment records of patients who had been treated between 1 January 2011 and 31 December 2015 in the postgraduate orthodontic programme at SMU. This specific period was chosen because it extended over the four year period of study for the degree Master in Dentistry (Orthodontics) for one cohort of registrars.

Inclusion criteria

All available patient records which included:

1. Pre-treatment dental study models with bite registration (wax bite).
2. Pre-treatment lateral cephalogram, panoramic radiographs and any other pertinent radiographs.

The lateral cephalogram (as shown in Figure 1) and the radiographs had to be of a quality adequate to ensure clearly identifiable landmarks and the dental study models were required to be of high accuracy and correctly trimmed according to accepted norms and standards.[53]

Exclusion criteria

1. Records of patients with severe craniofacial abnormalities such as cleft lip and palate.
2. Absence of a wax bite, making the occlusal relationships of the dental study models uncertain.
3. Dental study models with broken teeth.
4. Lateral cephalograms lacking the image of a ruler, which is necessary for the calculation of magnification factors.

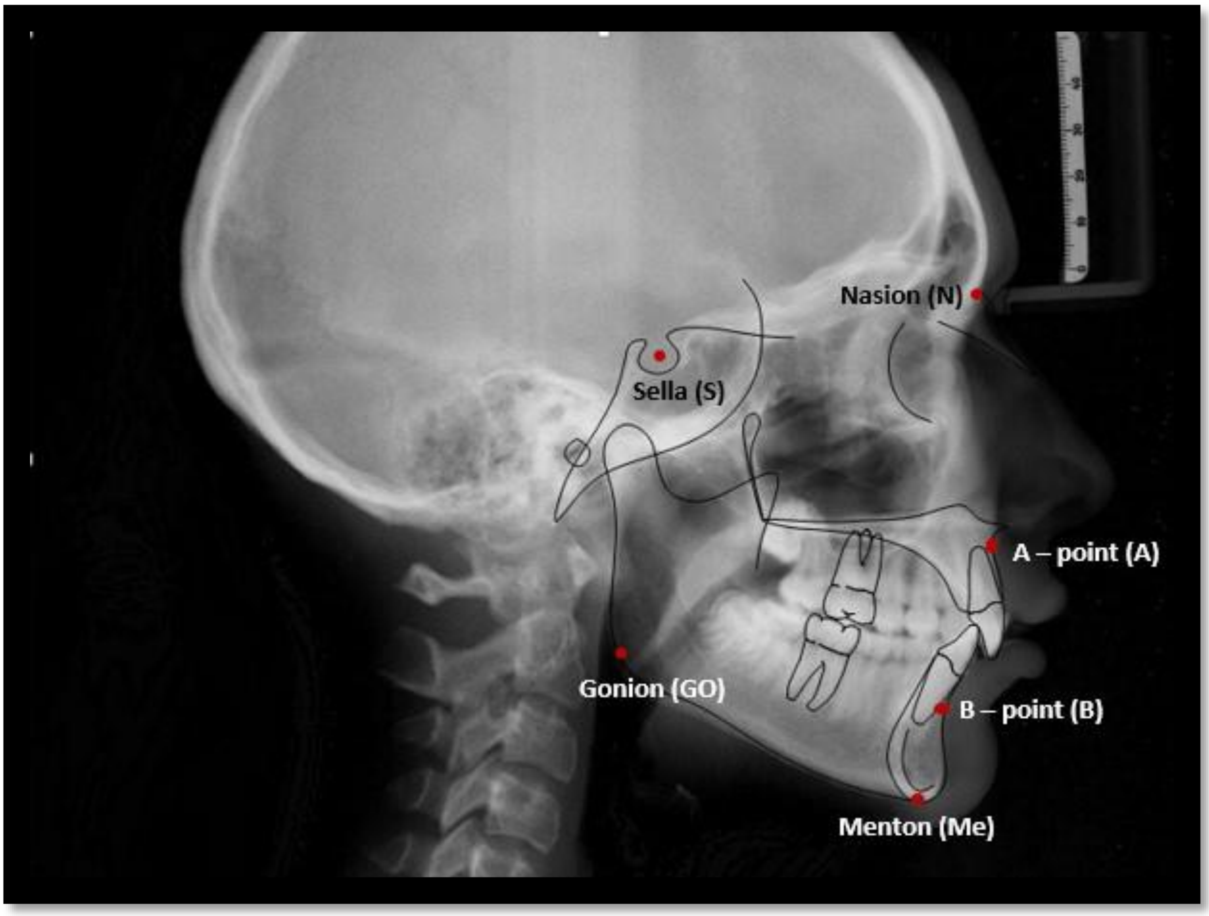


Figure 1: Lateral cephalogram. Relevant anatomical structures traced and showing the landmarks Sella, Nasion, A-point, B-point, Menton (Me) and Gonion (Go).

Sample size

Pre-treatment records of 57 patients who had been registered within the study period and accepted for treatment by the registrars were evaluated, provided those records met the inclusion criteria. On that basis, eight cases were excluded. The final sample was restricted to the 49 fully documented cases which satisfied the inclusion criteria.

Assessment criteria

The demographic information of race, age and gender, together with the DI, as determined from assessment of the dental study models and radiographs, were recorded for each patient. The dental study models were examined on a flat surface table and each discrepancy parameter was measured using an electronic digital calliper (Orthopli®, Pennsylvania, USA) as shown in Figure 2. Each measurement taken from the dental study model was done twice and the average recorded in the data sheet (Appendix 1).

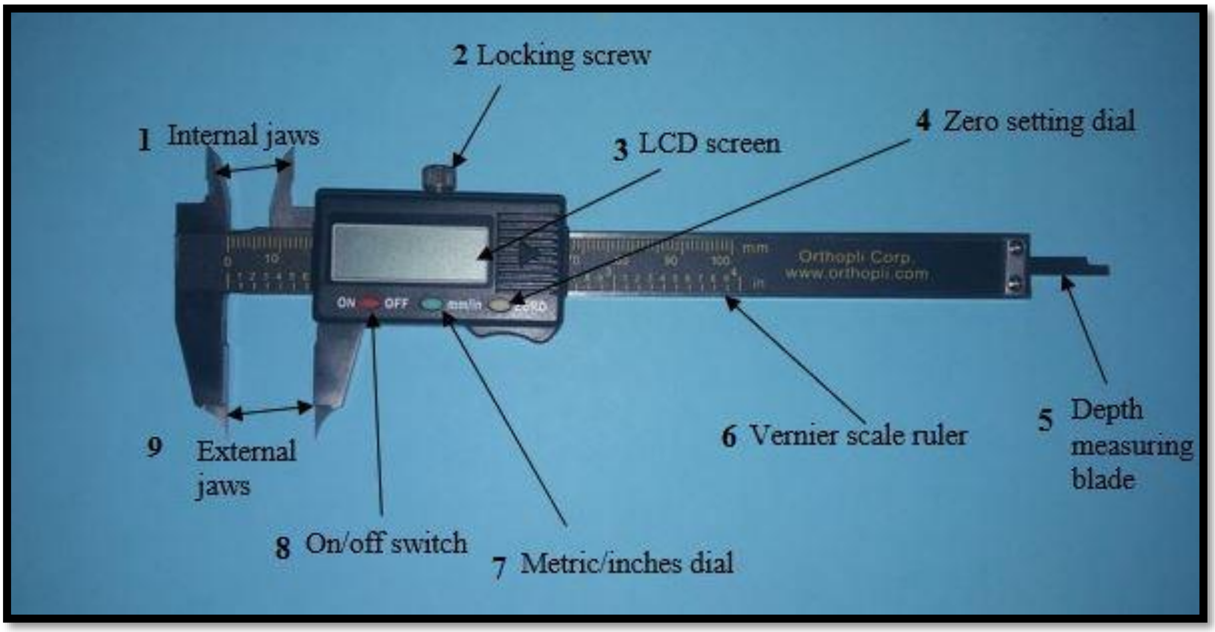
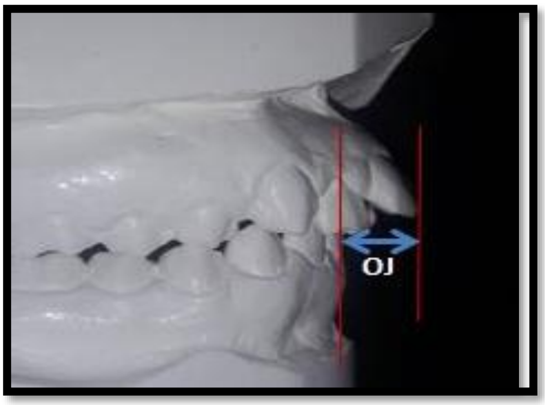
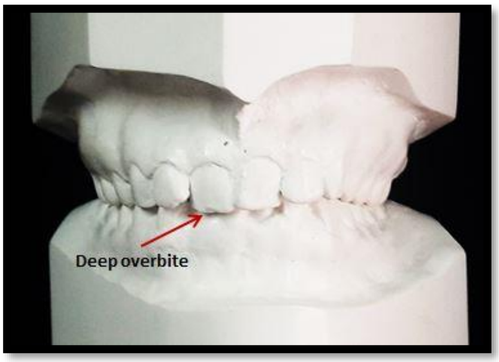
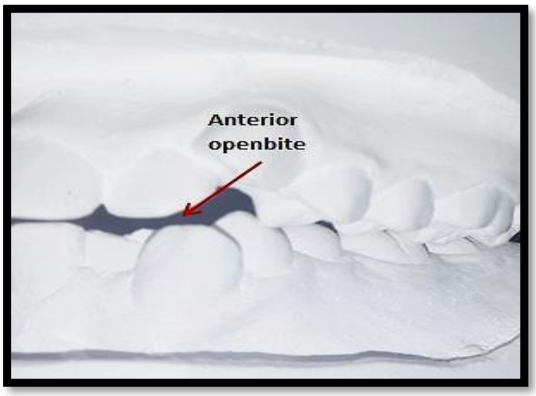


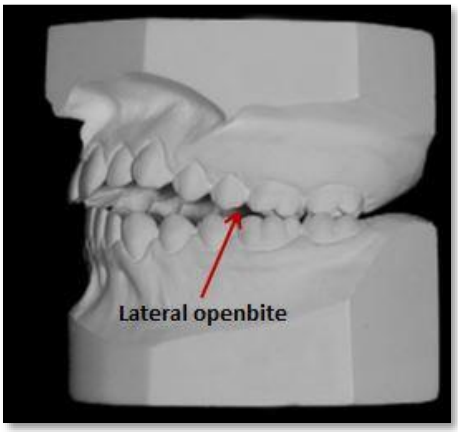
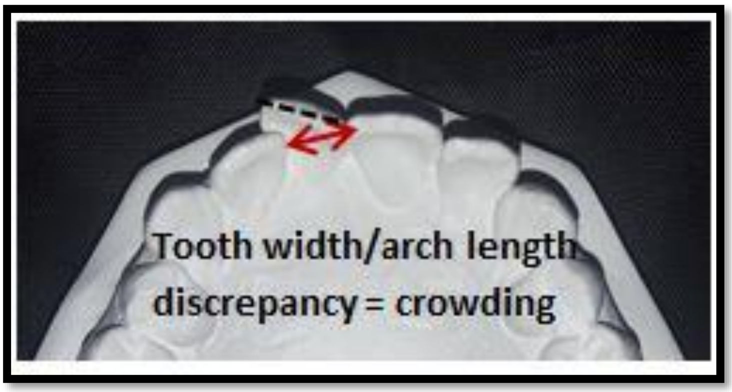
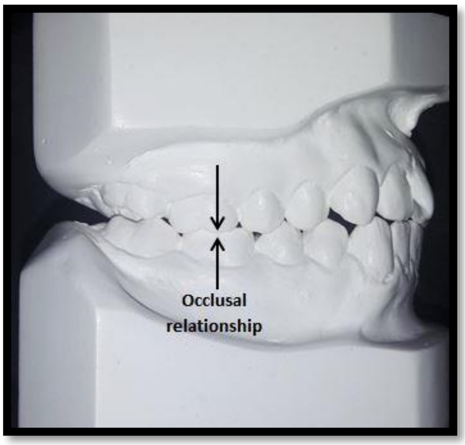
Figure 2: A digital calliper (Orthopli®, Pennsylvania, USA) - used to measure the features on the study models, and consists of the following parts:-

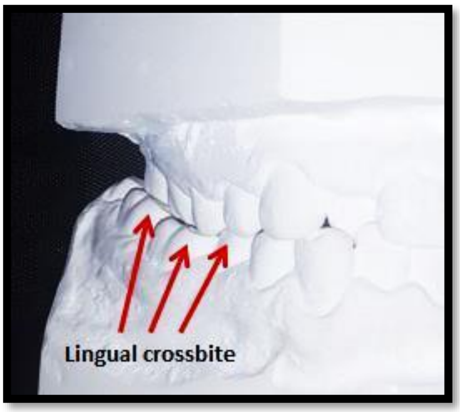
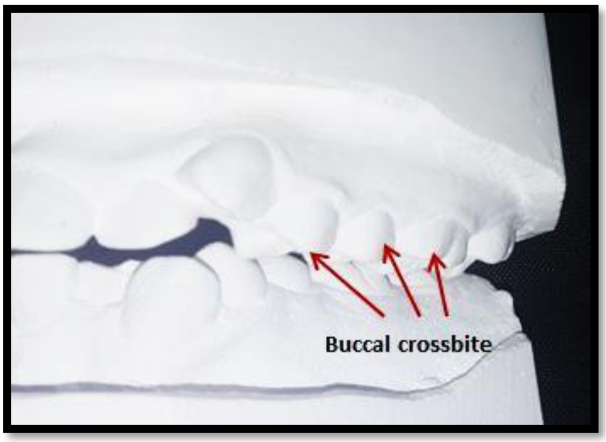
1. These jaws measure internal dimensions such as the length between the upper and lower incisors in an anterior openbite.
2. The locking screw used to set the calliper at a desired measurement.
3. The liquid crystal display (LCD) screen displays the measurement in imperial or metric scale.
4. This dial resets readings to zero.
5. This measures depth and is used in overjet measurements.
6. This is a sliding platform carrying the Vernier scale. It also houses the depth measuring blade and allows for analogue measurements.
7. The instrument allows for measurement of both metric (mm) and imperial (inches) scales.
8. On and Off switch
9. External jaws measure external length/diameter such as mesiodistal widths of teeth.

Table 2: Parameters measured on the dental study models in calculating the DI

(Adapted from ABO. www.americanboardortho.com) [54]

Occlusal trait	Illustration	DI scoring scale
Overjet (OJ): anterior posterior relationship of upper and lower incisors		Points (pts) range from zero to five, scored on the severity of the measured OJ. Negative OJ score equals one point (pt) per mm per tooth.
Overbite (OB): vertical overlap of those antagonist incisors which present the greatest discrepancy		Pts range from zero to five, scored on severity.
Anterior openbite (AOB): non-contact of anterior teeth		Edge to edge is scored at one pt per tooth. A further one pt per mm per tooth of non-contact is scored.

Lateral openbite (LO): non-contact of teeth distal to the canines		If equal to or greater than 0.5 mm, two pts per mm per tooth are scored
Crowding (CS): more crowded arch only recorded		Pts range from zero to seven with increasing space deficiency measured in mm.
Occlusal relationship (OR): Angle Classification (CI, CII, CIII)		CI – end to end equals zero; end to end CII/CIII equals two pts per side; full CII/CIII is four pts per side and beyond four attracts additional pts per mm.

Lingual crossbite (LXB): reverse buccal relationship of molars and/or premolars		One pt per tooth
Buccal crossbite (BXB): severe linguoversion of lower molars and/or premolars.		Two pts per tooth

The lateral cephalograms were traced manually (as in Figure 3) by the investigator (VB). The angular cephalometric parameters for the DI were measured with a cephalometric tracing template (Ormco ® Corporation, California, USA), shown in Figure 4, and these data were recorded. The measuring procedure followed the protocol summarized in Table 2 and is published by the ABO (detailed approach to the Assessment is available on the ABO website).[54] The data were recorded according to the ABO procedures, each item being accorded a score depending on the severity of the feature.

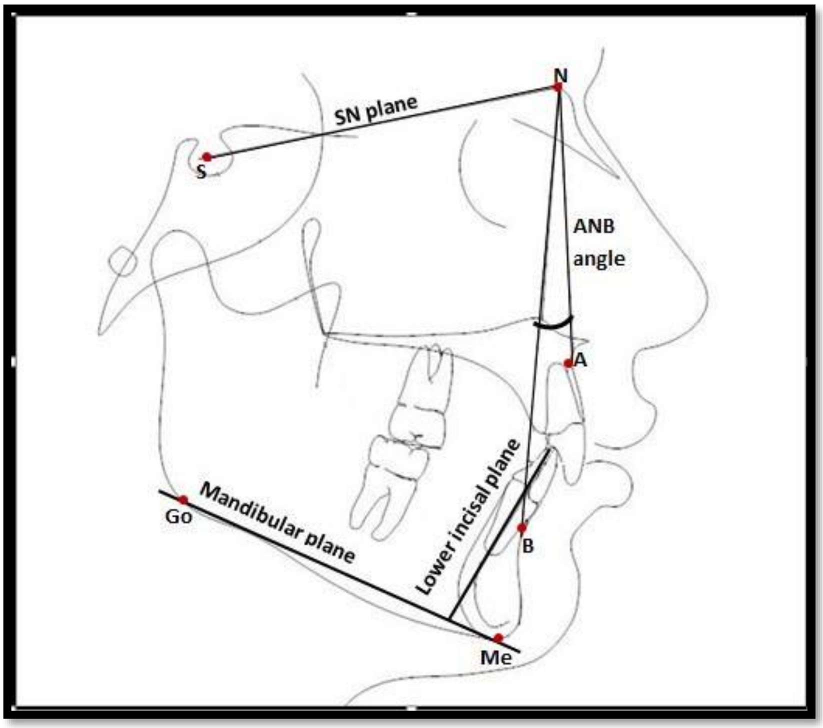


Figure 3: Lateral cephalometric tracing used for measuring the DI parameters.

The data (measured in degrees) were collected from the lateral cephalograms and included the following parameters:

1. ANB angle (it is the angle formed between A and B points with the vertex at N).[40]
   Point A – the deepest point of the concavity between the anterior nasal spine and the alveolar-upper incisal junction.
   Point B - the deepest point of the concavity between the alveolar-lower incisal junction and the most anterior point on the mandibular symphysis.
   N – the frontonasal suture at its most superior point.
   For measurements of ANB above plus six degrees (+ 6^0) and below minus two degrees (-2^0) – four points are scored and extra points are added for every degree above six degrees or below minus two degrees.[54]

2. SN-MP angle (MP plane is the mandibular plane constructed from the cephalometric landmarks Go and Me – Downs analysis).[55]

   S – the centre of Sella Turcica, determined by inspection.

   Me – the lowest point in the median plane of the chin.

   Go – The outermost point on either side of the lower jaw at which the mandible angles upward.

   For measurements above 38^0 two points are scored and below 26^0 one point is scored – and extra points are added for every degree above 38^0 or below 26^0.[54]

3. IMPA (derived from the Downs and Tweed analyses) –the angle formed by the intersection of the mandibular and lower incisal planes.[12,55]

   For measurements above 99^0– one point is scored and extra points are added for every degree above 99^0.[54]

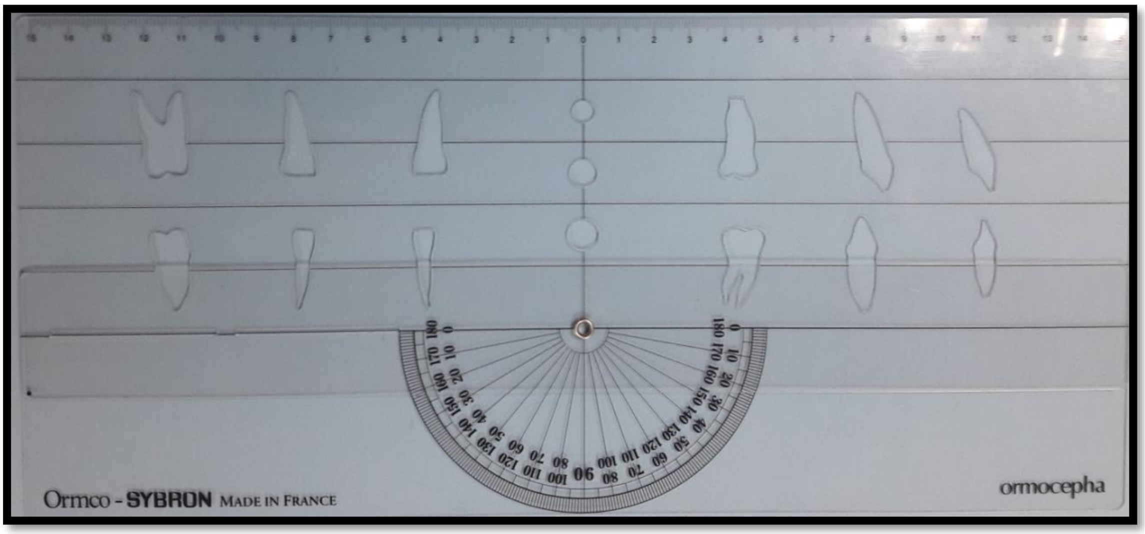


Figure 4: The tracing template (Ormco ® Corporation, California, USA)

Points are allocated accordingly with varying degrees of discrepancy from the normal as indicated in the official ABO discrepancy forms (Appendix 1).[54]

The following additional parameters – additional complexity score (ACS) – were also evaluated to be included in the DI score computation:

1. Supernumerary teeth (one point each)
2. Ankyloses of permanent teeth (two points per tooth)
3. Anomalous morphology (two points per tooth)
4. Impactions other than third molars (two points per tooth)
5. Missing teeth excluding the third molars (two points per tooth)
6. Spacing – four millimetres or more per arch (two points)
7. Midline maxillary diastemata – two millimetres or more (two points)
8. Tooth transposition (two points per tooth)
9. Midline discrepancy more or equal to three millimetres (two points)
10. Skeletal discrepancies (three points) and
11. Additional treatment complexities (two points each)

The data were recorded on adapted ABO forms, (Appendix 1). The forms are electronic and the DI scores were automatically calculated.[54]

Data analysis

The DI criteria were measured and data entered into the DI scoring sheet where each measurement was scored and tabulated on a Microsoft ® Excel spreadsheet. The data were then exported into STATA ® software (version 14.0; StataCorp, College Station, Texas, USA) for descriptive and inferential statistical analyses. The DI data were stratified into four categories which are shown in Table 3.

Table 3: Categories of DI scores

DI category	DI score ranges
Simple	10 of less (LE10)
Moderate	Greater than 10 but less than or equal to 20 (GT10LE20)
Moderately difficult	Greater than 20 but less than or equal to 30 (GT20LE30)
Very difficult	Greater than 30 (GT30)

The analyses were as follows:

1. Descriptive: summary of frequencies, percentages (%), mean, median, interquartile range (IQR), standard deviation, minimum, maximum and 95% confidence interval (CI).
2. Fisher's Exact Test, selected for the analysis due to the small sample size and numbers in each DI category, was used to compare differences in the distribution of the DI scores of the cases allocated amongst the registrars.
3. The associations between gender, race and malocclusion and the DI score were assessed using the Fisher's Exact Test. Due to the large majority of cells in the categorical distribution of age holding less than five cases, age was excluded from the analysis.
4. Multivariate regression analyses were performed to assess the relationship between the DI parameters and DI scores.

All statistical tests were conducted at $p \leq 0.05$ and 95% CI levels to determine significance.

Error of method

The investigator had been trained in the computation of the DI and was calibrated by an active ABO diplomate. The calibration involved ten randomly selected cases which were measured and fully scored by both calibrated researchers according to the ABO guidelines.[54] The DI scores were re-measured and re-measured until there was less than five percent difference between the data of the two sets of measurements. Furthermore, to assess the error of measurement, ten sets of records were randomly selected and re-measured two weeks later (intra-observer assessment). A colleague, who was also calibrated in the computation of the DI, assessed another randomly selected ten sets of records to enable a measure of the inter-observer variability. The reliability measurements were compared using the Kappa co-efficient.[56] The Kappa coefficient scores were 0.7261 (intra-examiner) and 0.7692 (inter-examiner) indicating substantial reliability of measurements.

Ethical considerations

This is a nested study for which the ethical approval M170117 (Appendix 2) to conduct the study had been granted by the Human Research Ethics Committee (HREC) (Medical) of the University of Witwatersrand, Johannesburg. Specific ethical clearance certificate for this component of the study was approved by the HREC (M191002; Appendix 3). Permission and ethical clearance for data collection was granted by the Chief Executive Officer of SMU Oral Health Centre and the SMU Research Ethics Committee (Appendices 4 and 5).

No identifiable patient information appears in the analysed data, and neither does any personal identification of the registrars nor of the clinicians who supervised the treatment of the patients.

Chapter 3
Results

The sample in this study constituted 49 assessed cases that met the inclusion criteria, and which had been managed by a cohort of four registrars in the time period between 1 January 2011 and 31 December 2015.

Demographic distribution and associations with DI scores

There were 38 females (77.55 %) and 11 males (22.45 %) in the sample and the racial demographics shown in Table 4 indicated that Africans were the majority, whilst there were few Caucasians and Indians of Asian descent. The association between race and the DI categories was found not to be significant using the Fisher's Exact Test ($Pr = 0.108$; $p \geq 0.05$). Similarly there was no association between gender and DI, ($Pr = 0.379$; $p \geq 0.05$). The mean age was 17.06 years, standard deviation was 4.69 and range 9 to 28 years.

Table 4: **Distribution of DI categories according to race**

Race	**DI Category**				**Total**
	LE10	**GT10LE20**	**GT20LE30**	**GT30**	
African	0	5	13	24	42 (85.71 %)
Indian	0	0	2	0	2 (10.20 %)
White	0	0	0	5	5 (4.08 %)
Total	0	5	15	29	49 (100%)

Distribution of DI parameters.

Table 5: Descriptive analysis of points awarded for DI parameters

Parameter	*N*	Median	Interquartile Range		Range	
			25%	75%	Minimum	Maximum
OJ	49	3	2	5	0	13
OB	49	2	0	3	0	5
AOB	49	0	0	6	0	37
LO	49	0	0	0	0	12
CS	49	7	4	7	0	7
OR	49	4	0	6	0	8
LXB	49	0	0	0	0	5
BXB	49	0	0	0	0	8
ANB	49	1	0	5	0	12
SN-MP	49	0	0	8	0	24
IMPA	49	0	0	5	0	18
ACS	49	4	2	7	0	12
DI	49	33	26	39	12	74

The median DI score of the sample was 33. Interquartile ranges and the minimum to maximum scores are tabulated in Table 5 for the DI and component DI parameters.

Table 6: Multivariate regression analysis of DI parameters that influence the DI score

DI vs Parameter	Co-efficient	Standard Error	95% CI
ANB	1.061133	0.2571605	0.54286 - 1.579406
SN-MP	1.076864	0.1460323	0.7825553 - 1.371173
IMPA	0.9869609	0.2118555	0.5599942 - 1.413928
AO	0.6850182	0.1140177	0.4552306 - 0.9148058
DI Constant Variable	21.17675	1.355829	18.44426 - 23.90925

The multivariate regression analysis revealed that the component DI parameters that exerted the greatest effect on the DI score were the cephalometric parameters ANB, SN-MP and IMPA and the anterior openbite (AOB), as shown in Table 6.

Distribution and comparison of DI categories among the registrars

Table 7: Distribution of DI categories among the four registrars

Registrar ID	LE10	GT10LE20	GT20LE30	GT30	Total	Percentage (%)
SMU1	0	2	4	6	12	24.49
SMU2	0	0	5	7	12	24.49
SMU3	0	2	2	6	10	20.41
SMU4	0	1	4	10	15	30.61
Total	0	5	15	29	49	100

The DI score distribution among the registrars is shown above in Table 7. The Fisher's Exact Test (Pr = 0.707; $p \geq 0.05$) indicated that there were no statistically significant differences among the DI category scores of the cases allocated to the four registrars. Two registrars had a similar number of cases assessed (12 - 24.49% each), SMU4 provided the most cases assessed at 15 (30.61%) and SMU3 had the least cases assessed, ten (20.41%). There was no case in the LE10 category and the majority of the cases (29; 59%) were in the GT30 category.

Distribution of malocclusion (Class I, II, III) and its association with DI scores

The frequency and percentages of the malocclusion classifications are shown in Table 8 and were further analysed for association with the DI categories using the Fisher's Exact Test, which found no significant differences (Pr = 0.244; $p \geq 0.05$).

Table 8: Frequency and percentages of malocclusion (Class I, II, III)

Malocclusion	Frequency	DI categories			Percentage
		GT10LE20	GT20LE30	GT30	(%)
Class I	20	3	5	12	40.82
Class II division 1	11	0	2	9	22.45
Class II division 2	8	0	5	3	16.33
Class II subdivision left	2	1	0	1	4.08
Class II subdivision right	1	0	0	1	2.04
Class III	6	1	3	2	12.24
Class III subdivision right	1	0	0	1	2.04
Total	49	5	15	29	100

Chapter 4
Discussion

Orthodontic diagnosis and assessment of the initial malocclusion have developed under the influence and the contributions of many distinguished scholars in the profession. Angle's classification of malocclusion into Class I, II and III is still used presently, mainly because of its simplicity.[9] However, in modern orthodontics it is apparent that the system is not adequate to cover all the intricacies that encompass the full orthodontic diagnosis.

The orthodontist should have a complete arsenal at his/her disposal to enable full achievement of the objective of an excellent treatment outcome together with a satisfied patient. The initial assessment of the patient needs objective, valid and reliable measurements. As stipulated in the literature, the ideal index should firstly be able to produce consistent measurements when recorded at different times by different trained investigators.[23, 30] Secondly, it should accurately measure what it is intended to measure.[23, 30] Thirdly, it should allow modification when necessary. Fourthly, it must be able to produce quantitative data and lastly, it must be user-friendly.[23, 30] The ABO DI used in this study in the assessment of treatment difficulty and complexity, satisfies these requirements to a considerable extent.[2, 19, 45] The DI can also be a useful tool in the assignment of cases to enable appropriate clinical exposure for orthodontic registrars during their training to a range of the categories of malocclusion that they are likely to encounter in specialist clinical practice.

The reliability and validity of the DI has been established, making it the endorsed method of pre-treatment case assessment for both post graduate cases and for the ABO Board Phase III Examinations for orthodontic specialists seeking Board Certification.[2, 19, 45] The index has enabled a precise selection of categories of the cases for the examinations, namely, as mentioned previously, a specific number of cases in each of three DI score ranges for presentation.[19, 45] After five pilot studies had been conducted by the ABO, starting in 1999 and through to 2002, the decision was taken that examination candidates should present two cases with a DI score of 25 or higher, six cases of a DI of 16 or higher and lastly two cases with a DI of seven or higher.[19]

In South Africa, there are plans initiated by the Health Professions Council of South Africa (HPCSA) to have one unitary exit examination for dental speciality programmes.[57, 58] The option may be that the DI will be adopted by the HPCSA as an assessment criterion. Currently two South African post graduate programmes have routinely used the DI to assess treatment difficulty of their cases, of which one is SMU.

Distribution of cases by DI scores among the registrars

The sample data were analysed and found not to be normally distributed and hence medians and interquartile ranges were described for all DI parameters and DI scores, with DI having a median DI score of 33, IQR 26 to 39, with the range of 12 to 74. According to the DI scores the majority of the registrars' cases were in the very difficult category (GT30), amounting to 29, whilst none were simple cases (LE10). Exposure to complex cases while in training and under supervision could be an advantage. Indeed, Riolo and co-workers reported that the cases submitted by specialists for Phase III examinations had DI score ranges similar to those of post graduate student cases in 16 universities across the USA.[45] The four registrars in the current study had cases of similar difficulty and complexity, as determined by the results of the Fisher's test. From these results it may have been expected that the SMU registrars would have taken more time in managing these patients, given that the majority of cases were in the GT30 category. Some studies have indicated that higher DI scores contribute to longer treatment time per DI point score increase and in specific DI parameters.[2, 7, 30] However, no conclusion can be made from this present study regarding treatment time as this parameter was not part of the objectives. This could be relevant in any follow up study on this topic.

Demographic characteristics of Race and Gender and DI scores

In agreement with previous observations, the DI scores in this study were unaffected by gender and race.[44] Previously assessed pre-treatment records using the DI's of Mongolian and Aryan patients in Nepal showed that the scores of the different groups were not significantly associated by race.[44] The current study was in the South African setting where 42 records (85.71 %) of the total 49 were African, with five Caucasians (10.20 %) and two Indians (4.08 %) making up the difference. There was no statistical link between these demographics and the DI scores. With regards to gender, the sample had 38 females (77.55 %) and 11 males (22.45 %), and treatment difficulty and complexity (DI) were found to be unaffected by this parameter, in agreement with some previous assessments.[2] However, this was in contrast to the Mongolian and Aryan study.[44] When ICON was used as the index to assess complexity, a Nigerian study found that males were twice as likely to have a higher complexity score as compared with females.[44, 51] This also was found to be true where the PAR index was used.[48] In previous investigations age was not associated with any influence on the DI score.[2, 43] Descriptive analysis in the present investigation revealed a mean age of 17.06, a standard deviation of 4.69 and a range of 9 to 28. There were 17 patients in their growth spurt

DI component parameters and the relationship with DI Scores

Cephalometric parameters (ANB, SN-MP and IMPA) and AOB were shown by multivariate regression analysis to be associated with influencing the DI score. This is consistent with findings in other studies, particularly regarding ANB, IMPA and SN-MP. The association of the anterior openbite as found in this study is not confirmed by other investigations.[30, 44] Parrish and co-workers found that occlusal relationships, lateral openbite, tooth transpositions, crowding, overjet and overbite had an association with the DI score as well as affecting treatment time.[30] The observations in the Nepal study [44] found that the cephalometric parameters did influence the DI score, in agreement with this study. However the occlusal parameters observed in the Nepal study as those mainly increasing the DI score were overjet, crowding and occlusal relationships which was not seen in this study.[44]

Specific DI parameters have been reported to add related time periods (days, weeks or months) to additional treatment times.[30] Complications in occlusal relationship and lateral openbite added three and two weeks respectively; problematic cephalometric parameters (ANB, IMPA and SN-MP) adding about five days; crowding, overjet and overbite added one month.[30] Tooth transpositions contributed the most to additional treatment time, by six and a half months.[30] AOB was found to be the non-cephalometric DI parameter with the greatest influence on the DI score in the current study. This could be due to the number of cases (13) in the sample who exhibited the trait, and as well as how AOB is scored in DI. [54]

The AOB represents the lack of vertical contact between any of the six upper and six lower anterior teeth as presented by the case report of Dawjee and co-workers.[59] Prevalence in South Africa varies with different investigations that have been undertaken and range from 7.7 % to 8.27 %. [59, 60] There is no definitive limit on points scored for AOB in the DI, as a point is scored per mm per tooth and this can lead to high scores if all six anterior teeth do not contact with a high metric measurement per tooth.[54] The range of AOB scores in this sample was 0 to 37 pts, with 13 cases having AOB. However previous studies did not find that AOB influenced the DI score.[30, 44]

The ANB angle measures the anteroposterior (AP) relationship between the maxilla and mandible and gives the skeletal classification of the deviation from a normal AP relationship as described by Steiner.[40] Normal values for Caucasians are plus two degrees ($+2^0$), with Africans (in South Africa) measuring five degrees ($+5^0$) as a reference value.[40, 61] The two main factors contributing to the difference in Caucasian and African values are firstly that Africans have a shorter anterior cranial base which leads to a higher SNA angle.[61 ,62] Secondly, a higher mandibular plane angle coupled with backward and downward mandibular rotation amongst Africans shifts the B-point posteriorly which results in a higher ANB angle.[62] With the upper and lower thresholds for the ANB angle in the DI being plus six degrees ($+6^0$) and minus two degrees (-2^0) respectively, the African group will tend to attract a higher DI scoring for the ANB component. [54]

The mandibular plane angle represented by SN-MP in the DI has different values in different ethnic groups, with several investigations of different population groups having disparate normal values.[40, 61, 62] In South Africa, several cephalometric and craniometric studies among particularly the African population have indicated that the SN-MP is higher than the Caucasian norm values. South African values are equal to 35.5^0 (males) and 40.2^0 (females), respectively.

Given that in the current sample, 85.71% were African, the SN-MP will attract a score above 0 in most of the cases assessed.[61, 62] It has been suggested that this should be factored into the DI when assessing different ethnic groups, as this is otherwise seen as a weakness of the DI.[27,44,48] This consideration also applies to the IMPA which is greater in African ethnic groups with norms of 105 degrees.[61, 62] The IMPA scores were indeed found to be higher in this study. When the DI score is calculated, points are allocated for every degree of the IMPA above 99.[19, 54] Although the data analysis did not identify race as showing any significant effect on the DI scores, this particular outcome is indubitably associated with the disparate racial distribution of the sample.

The incorporation of cephalometric parameters in the computation of the DI overall score sets it apart from other indices which are designed to assess treatment difficulty. Apart from dental traits contributing to malocclusion, the DI and the Probability Index make use of lateral cephalograms and panoramic radiographs to assess skeletal parameters in addition to dental parameters in the calculation of the index scores.[17, 19] The selection of a small number of cephalometric parameters (ANB, SN-MP and IMPA) influenced the overall DI score and were related to treatment time. These data reaffirm the decisions of the ABO.[30, 44] In certain malocclusions, for example bi-maxillary protrusion and Class II division 2, the data gained from lateral cephalograms were found to influence treatment planning.[63] In bi-maxillary cases the severity assessment was found to increase when lateral cephalograms were used and the measurements were helpful in viewing changes during treatment.[63] The mean DI score values were found in studies conducted at Indiana (USA) and Okayama (Japan) Universities to differ when cephalometric component parameters were included.[27] The ANB, SN-MP and IMPA have proven influence over the DI scores.[27, 44]

The DI components with the highest median scores were crowding, additional complexities, occlusal relationship and overjet. This agrees with previous studies which also had the samples having cephalometric parameters with higher mean scores.[30, 44]

Malocclusion classification (Class I, II, III) and DI scores

The frequency of the different malocclusions in this sample have been tabulated in Table 8. Most were Angle Class I relationships with subdivision malocclusions having the least cases represented in the sample. No association was found between malocclusion classification and the DI in the study, which is in contrast with three previous studies which found deviation from Class I did have an association with treatment difficulty assessment and furthermore affected treatment time.[30, 47, 48] Pyakurel and co-workers concluded that apart from the DI being unaffected by race or ethnicity and age, it was associated with Class II and III malocclusions and that male subjects had a higher DI scores as compared with females.[44] Parrish and co-workers observed that the association between DI component parameters with DI scores and treatment time in graduate orthodontic clinics revealed that deviation from Class I molar relationship, firstly, added points for occlusal relationship discrepancies to the DI score. Secondly, it increased treatment time by three weeks.[30]

The orthodontic registrars at SMU had most of their cases in the very difficult category and had a similar case allocation as adjudged by the DI. In agreement with previous studies, the DI was unaffected by race and gender. The cephalometric parameters of ANB, SN-MP and IMPA together with AOB were found to influence the DI score. Particularly with regards to race, the DI may be valid as an index in the South African setting. However some caution will have to be taken when interpreting these results as the sample size was small, therefore more studies will have to be undertaken involving a larger sample.

Chapter 5
Summary and Conclusion

The DI was the index employed for this nested study which is part of an overall project assessing treatment outcomes in South Africa. The DI forms an integral part of the ABO case report used in the ABO Board examination, applied to categorize the candidate's cases for the clinical examination. The DI validity and reliability has been proven with several studies having been conducted in both clinical and academic environments. However further efforts in the standardization of the cephalometric scores are needed to account for racial and ethnic differences. In training, orthodontic registrars should ideally be exposed to a variety of orthodontic patients which should ensure competency as a specialist upon graduation. The DI is a method that can be used for case selection or for screening in graduate programmes, a process used already by the ABO.

The study assessed 49 cases managed by the four registrars at SMU between 1 January 2011 and 31 December 2015. The summary of the findings are:

1. Similar spreads of DI category scores were recorded among the patients managed by the four registrars.
2. Most of the cases assessed (29) were very difficult (GT30).
3. None of the registrars had a case in the LE10 (simple) category.
4. There was no statistical association between DI score and race, gender and occlusal relationship (Class I, II, III).
5. The DI components found to exert the most influence on the DI scores were anterior openbite, ANB, SN-MP and IMPA.

The study concluded that all four registrars were exposed to cases of similar difficulty and complexity as adjudged by the DI. Most of the cases were in the very difficult category which could be viewed as providing adequate exposure to the challenges of orthodontics during their training. A standardized method of case selection for orthodontic registrar training would be ideal, and the DI, among other indices, could be used for this purpose.

Limitations and Recommendations

- The study sample was small due to many records being incomplete. In particular, it was not feasible to include a statistical assessment of the role of age.
- The standardization of patient case selection using an index (e.g. the ABO DI) for orthodontic graduate programmes will be great advantage for training and could create an excellent source for future research projects and studies.
- Further research projects assessing treatment difficulty coupled with evaluating treatment outcomes in the orthodontic programmes and in comparing performance at the four dental schools will be helpful in South Africa, especially in the process of standardization.
- The digitization of data and documents enabling electronic archiving of patient records would help in alleviating the problem of small samples.

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Appendices

Appendix 1: ABO Discrepancy Index scoring sheet

(Adapted from https://www.americanboardortho.com/)

Page 6

EXAM YEAR 2019 **ABO DISCREPANCY INDEX**

ABO ID # SMU01 **CASE#** **PATIENT** XXXXXXXX

TOTAL D.I. SCORE 33

For mm measures, round up to the next full mm.
Examiners will verify measurements in each category.

OVERJET

≥ 0 to < 1 mm (edge-to-edge)	= 1 pt
≥ 1 to ≤ 3 mm	= 0 pts
> 3 to ≤ 5 mm	= 2 pts
> 5 to ≤ 7 mm	= 3 pts
> 7 to ≤ 9 mm	= 4 pts
> 9 mm	= 5 pts
Negative Overjet (x-bite): 1 pt per mm per tooth	= __pts
Total	2

OVERBITE

> 1 to ≤ 3 mm	= 0 pts
> 3 to ≤ 5 mm	= 2 pts
> 5 to ≤ 7 mm	= 3 pts
Impinging (100%)	= 5 pts
Total	5

ANTERIOR OPEN BITE

0 mm (edge-to-edge), 1 pt per tooth	= __pts
then 1 pt per mm per tooth	= __pts
Total	0

LATERAL OPEN BITE

≥ 0.5 mm, 2 pts per mm per tooth	
Total	

CROWDING (only one arch)

≥ 0 to ≤1 mm	= 0 pts
> 1 to ≤ 3 mm	= 1 pts
> 3 to ≤ 5 mm	= 2 pts
> 5 to ≤ 7 mm	= 4 pts
> 7 mm	= 7 pts
Total	7

OCCLUSAL RELATIONSHIP

Class I to End On	= 0 pts	
End-to-End Class II or III	= 2 pts per side	2 pts
Full Class II or III	= 4 pts per side	4 pts
Beyond Class II or III	= 1 pt per mm additional	__pts
Total		6

LINGUAL POSTERIOR X-BITE

> 0 mm, 1 pt per tooth	Total

BUCCAL POSTERIOR X-BITE

> 0 mm, 2 pts per tooth	Total

CEPHALOMETRICS (See Instructions)

ANB ≥ 6° or ≤ -2°	@4pts	= 4
Each full degree > 6°	__x 1 pt	= 5
Each full degree < -2°	__x 1 pt	= __
SN-MP		
≥ 38°	@2pts	= __
Each full degree > 38°	__x 2 pts	= __
≤ 26°	@1pt	= __
Each full degree < 26°	__x 1 pt	= __
1 to MP ≥ 99°	@1pt	= 1
Each full degree > 99°	__x 1 pt	= 3
	Total	13

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 0

20130116

Appendix 2: Ethical clearance certificate M170117

R14/49 «Tit init name»

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M170117

NAME: **(Principal Investigator)** Prof Tarisai C Dandajena et al

DEPARTMENT: Orthodontics and Paediatric Dentistry Witwatersrand, Pretoria, Western Cape, Sefako Makgatho Oral Health Centre Universities

PROJECT TITLE: Evaluation of Treatment Outcomes in Graduate Orthodontics Programmes in South Africa using the American Board of Orthondotics (ABO) Cast and Radiographic Examination (CRE)

DATE CONSIDERED: 27/01/2017

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR:

APPROVED BY:

Professor P. Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 12/05/2017

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary 3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand. I/We fully understand the the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. in this case, the study was initially review in January and will therefore be due in the month of January each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature Date 2017/5/16

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 3: Ethical clearance certificate M191002

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr V Bomvana

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M191002

NAME: **(Principal Investigator)**	Dr V Bomvana
DEPARTMENT:	School of Oral Health Sciences Department of Orthodontics Dental School University
PROJECT TITLE:	Treatment difficulty assessment of postgraduate orthodontic cases at a university clinic
DATE CONSIDERED:	2019/10/25
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Professors WG Evans and P Hlongwa
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2020/02/24

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the 3rd Floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to submit details to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **October** and will therefore reports and re-certification will be due early in the month of **October** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

25/02/2020
Date

PLEASE QUOTE THE CLEARANCE CERTIFICATE NUMBER IN ALL ENQUIRIES

Appendix 4: Permission for data collection at SMU

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

GAUTENG PROVINCE
REPUBLIC of SOUTH AFRICA

Office of the CEO: SMU OHC
Enquiries: Prof SJH Hendricks
Tel: (012) 529 4801
Email:Stephen.hendricks@smu.ac.za
:winile.mambana@smu.ac.za

07 Feb 2020

Dear Dr V Bomvana

PERMISSION TO CONDUCT RESEARCH

The SMU-Oral Health Centre/School of Oral Health Sciences hereby grants you permission to conduct research entitled:

Treatment difficulty assessment of postgraduate orthodontic cases at University Clinic on our facility

This permission is granted subject to the following conditions:

- That you obtain Ethical clearance from the Human Research Ethics Committee of the relevant University. ☑
- That the Institution incurs no cost in the course of your research ☑
- That access to the staff and patients at the SMU-OHC *will* not interrupt the daily provision of services. ☑
- That prior to conducting the research you will liaise with the supervisors of the relevant sections to introduce yourself (with this letter) and to make arrangements with them in a manner that is convenient to the sections. ☑
- Formal written feedback on research outcomes must be given to the Director: Clinical Services. ☑
- Permission for publication of research must be obtained from the Chief Executive Officer ☑

Yours sincerely

Prof SJH Hendricks

Dean/CEO: SMU-OHC
DATE: 12/2/2020

Appendix 5: Ethical clearance SMUREC

SEFAKO MAKGATHO
HEALTH SCIENCES UNIVERSITY

Postgraduate Studies, Research Development, Integrity & Ethics
Sefako Makgatho University Research Ethics Committee (SMUREC)

Dr V Bomvana
University of the Witwatersrand

Dear Dr Bomvana

RE: PERMISSION TO UTILIZE RECORDS OF ORTHODONTIC PATIENTS TREATED AT SEFAKO MAKGATHO HEALTH SCIENCES UNIVERSITY ORAL AND DENTAL HOSPITAL

SMUREC **NOTED** your letter requesting permission to utilize records of orthodontic patients treated at Sefako Makgatho University Oral Health Centre (SMU-OHC).

SMUREC **NOTED** that the researcher has received unconditional approval from the Human Research Ethics Committee (Medical) of the University of the Witwatersrand.

Study Title:	Treatment difficulty assessment of postgraduate orthodontic cases at a university clinic
Researcher:	Dr V Bomvana
Supervisor:	Prof G William
	Prof P Hlongwa
University:	University of the Witwatersrand
Research Type:	Master of Dentistry - Orthodontics
Ethics Approval Ref:	M170117

SMUREC **APPROVED** the request and provided permission to collect data at SMU. A letter of approval from the CEO of the SMU Oral Health Centre is attached.

Yours Sincerely,

PROF C BAKER
CHAIRPERSON SMUREC

07 November 2019

SEFAKO MAKGATHO
HEALTH SCIENCES UNIVERSITY
SMU Research Ethics Committee
Chairperson
Date: 07 November 2019

Molotlegi Street, Ga-Rankuwa
Pretoria, Gauteng
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Facsimile: +27 12 521 3749

Email: lorato.phiri@smu.ac.za

Appendix 6: Turnitin Report

9602108n:TREATMENT_DIFFICULTY_ASSESSMENT_OF_PO..

ORIGINALITY REPORT

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SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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