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Sagittal discrepancies in Skeletal Class II and Skeletal Class III malocclusions in patients orthodontically treated at Wits Oral Health Centre over a five-year period

Mphahlele, Mahloko Boiketlo

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SAGITTAL DISCREPANCIES IN SKELETAL CLASS II AND SKELETAL CLASS III MALOCCLUSIONS IN PATIENTS ORTHODONTICALLY TREATED AT WITS ORAL HEALTH CENTRE OVER A FIVE-YEAR PERIOD

MAHLOKO BOIKETLO MPHAHLELE

STUDENT NUMBER: 745921

SUPERVISOR

DR. MOSIDI E. MAKOFANE; BDS, MDS, MDENT (Ortho)

CO-SUPERVISOR

DR. VUYO BOMVANA; BSC, BDS, MDENT (Ortho)

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Master of Science in Dentistry

August 2024

Declaration

I, Mahloko Boiketlo Mphahlele, declare that this research project **"Sagittal discrepancies in skeletal class II and skeletal class III malocclusions in patients orthodontically treated at Wits Oral Health Centre over a five-year period"** is my own, unaided work. It is being submitted for the degree of Master of Science in Dentistry at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



Sign

20th Day of August 2024

Dedication

To my loving parents, Mokganyetse and Leshitishe Mphahlele, for their unwavering support in everything I do. To my siblings - Bohlale, Mahlasedi, Hunadi, and Kamogelo - for their encouragement and support.

Abstract

Background: The discrepancy in the sagittal relationship between maxilla and mandible may influence the patient's appearance and quality of life.

Objectives: Assessment of the sagittal discrepancies in patient records at Wits Oral Health Centre.

Materials and Methods: This was a retrospective, descriptive, cross-sectional records review of 150 pre-treatment lateral cephalometric radiographs presenting with Skeletal Class II (SCII) and Skeletal Class III (SCIII) malocclusion over a five year period. Five angular and one linear parameters were measured. All statistical tests were performed at a 5% level of significance.

Results: Mandibular retrognathia was found in SCII malocclusion in all the races. Maxillary retrognathia was common in SCIII in Blacks. Statistically significant differences were found between Blacks and Indians in parameters ANB and Angle of Convexity, and between Blacks and Whites in the SNB, ANB, and Angle of Convexity, in SCII malocclusion. No gender differences except the Wits appraisal, were found in SCII malocclusion and were found in SCIII malocclusion concerning the ANB, Facial angle, and Angle of Convexity.

Conclusion: A retrognathic mandible was a common discrepancy in SCII, while a retrognathic maxilla was common in SCIII. The South African Black female with SCIII malocclusion had a more prognathic profile than the South African Black male.

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Abbreviations

%	Percentage
A	A-point
ANB	A-point - Nasion – B- point angle
AO line	Perpendicular line from the functional occlusal plane to A-point
B	B-point
BO line	Perpendicular line from the functional occlusal plane to B-point
FGFR2	Fibroblast Growth Factor Receptor – 2
FH	Frankfort – Horizontal plane
LCR	Lateral cephalometric radiograph
MM	Mosidi Makofane
N	Nasion
Or	Orbitale
OSA	Obstructive sleep apnoea
P	P-value
Po	Porion
Pog	Pogonion
S	Sella
rTEM	Relative Technical Error of Measurement
SCI	Skeletal Class I
SCII	Skeletal Class II
SCIII	Skeletal Class III
SN - line	Sella – Nasion line
SNA	Sella – Nasion – A-point
SNB	Sella – Nasion – B-point

TEM	Technical Error of Measurement
WOHC	Wits Oral Health Centre

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1. Background

An abnormal relationship between maxilla and mandible may present in three planes of space - transverse, vertical, and sagittal plane. The sagittal plane is of importance to orthodontics, as it is strongly associated with the facial profile of the patient (Traldi et al., 2015). The classical work of Sassouni describes the two variations of sagittal skeletal relationship of the maxilla and mandible – Skeletal Class II (SCII) and Skeletal Class III (SCIII) (Sassouni, 1969). According to Sassouni, the malocclusions are due to a disproportion in dimension and/or position of maxilla and mandible. Skeletal Class II occurs due to a large maxilla or/and a small mandible, or because of a retrusive mandible and/or protrusive maxilla. Skeletal Class III is as a result of a short maxilla and/or a large mandible, or a retrusive maxilla and/or a protrusive mandible (Sassouni, 1969). Mageet proposed a modification to the classification to aid in diagnosis and treatment planning (Mageet, 2016). The author divided SCII into three types: Type 1 (retrusion/retrognathism of the mandible), type 2 (protrusion/prognathism of the maxilla), and type 3 (a combination of both discrepancies). Skeletal Class III is also divided into Type 1 (retrusion/retrognathism mandible), type 2 (protrusion/prognathism of maxilla), and type 3 (a combination of both discrepancies) (Mageet, 2016).

Patients with SCII and SCIII malocclusion reportedly demonstrate higher difficulty in normal social activities such as smiling, laughing, and eating when compared to those with balanced occlusion (Bernabé et al., 2008). Distortions in speech have also been reported in patients with SCII and SCIII malocclusions (Lathrop-Marshall et al., 2022, de Almeida Prado et al., 2015). In adult patients, sagittal plane relation of maxilla and mandible strongly influences the perception of facial aesthetics by orthodontists and laypersons alike (Krooks et al., 2019). Furthermore, a suggestion towards decreased facial attractiveness as sagittal relationship between the jaws diverges from the normal has been described (Abu Arqoub and Al-Khateeb, 2011). In particular, position and prominence of mandible in sagittal plane are known to influence facial aesthetics and attractiveness (Johnston et al., 2005, Sena et al., 2017).

Beyond facial aesthetics, sagittal dimensions of maxilla and mandible are known to influence health of the patient. Patients with SCII due to mandibular retrognathia reportedly show a decrease in pharyngeal airway space proportions which may predispose the patient to obstructive sleep apnea (OSA) (Muto et al., 2008, Alves et al., 2012). On the other hand, a careful approach is required when preparing SCIII patients for orthognathic surgery.

Mandibular setback in such cases may lead to a decrease in the pharyngeal airway space and place the patient at risk of OSA post-surgery (Tselnik and Pogrel, 2000, Kitagawara et al., 2008). Such evidence emphasizes the importance of assessing sagittal dimension of maxilla and mandible when diagnosing and treating skeletal malocclusion in patients.

1.2. Prevalence of Skeletal Class II and Skeletal Class III malocclusion

A recent systematic review reported that distribution of Class II and Class III malocclusion globally was 23% and 4% in mixed dentition, and 20% and 6% in permanent dentition (Alhammadi et al., 2018). In Africa, this distribution is maintained, with Class II and Class III malocclusions estimated to be 10% and 4% respectively (Yemitan and Oyapero, 2022). These findings are consistent with those from a South African Black population in the Free State, which reported a distribution of 17.1% and 10.8% for Class II and Class III malocclusions respectively (Nyakale, 2021). These prevalence studies were mostly based on malocclusion defined by Angle's classification – which relates to dentition, and not maxilla and mandible.

Al Jadidi and colleagues (2018) reported a prevalence of around 10% SCII and 4% SCIII, in a random sample of Omani adolescents assessed by clinical examination only (Al Jadidi et al., 2018). In Brazil's population, studies on patients seeking orthognathic treatment, the prevalence of SCII ranges from 29% to 46%, while SCIII ranges from 47% to 55% of the samples (Boeck et al., 2011, Sato et al., 2014). In a Pakistani sample population at Punjab Dental Hospital, 47% of the sample presented with SCII, and 21% showed SCIII (Hamid and Asad, 2003). In South Aseer region of Saudi Arabia, at King Khalid University, a prevalence of 39% SCII and a higher prevalence of 49% SCIII has been reported (Almasri, 2014). Chan et al (2022) reported prevalence of 23,1% SCII and 27,4% SCIII in a Caucasian Chinese population sample consulting at National Dental Centre of Singapore (Chan et al., 2022).

These studies are mostly based on patients who are consulting for combined orthodontic and orthognathic surgical treatment and may not be reflective of the entire population of that country/region.

1.3. Aetiology of Skeletal Class II and Skeletal Class III malocclusion

1.3.1. Genetics and heritability

Da Fontoura et al (2015) evaluated several candidate genes and their association with skeletal patterns of malocclusion. The study reported a high association between single-nucleotide polymorphism in certain genes and SCII and SCIII malocclusions. Of note is polymorphism in Fibroblast Growth Factor receptor-2 (*FGFR2*), which is part of an essential signaling pathway

involved in development of craniofacial complex (da Fontoura et al., 2015). Another study in 2019 also found single-nucleotide polymorphism in *FGFR2* linked to an increased risk in SCII and SCIII development (Jiang et al., 2019). Some of the common craniofacial syndromes that present with a sagittal discrepancy relate to a mutation in *FGFR2* (Jiang et al., 2019). More recently, growth and development of mandible were associated with single-nucleotide polymorphism involving the myosin 1H gene (Gullianne et al., 2022). An association between polymorphism of myosin 1H gene and mandibular retrognathism has been reported in literature (Arun et al., 2016), as it has a role in mandibular prognathism (Milosevic et al., 2022). A study on four Colombian families with a common feature of SCII with a retrognathic mandible, found a common single-nucleotide polymorphism of an allele of noggin gene which plays a role in mandibular development (Gutiérrez et al., 2010). Moreover, most craniofacial syndromes and cleft lip and palate patients presenting with syndromic sagittal discrepancy of the jaws are highly influenced by genetics (Buchanan et al., 2014).

1.3.2. Environmental factors

A study comparing photographs of children with enlarged adenoids to those of a control group found an association between adenoid hypertrophy and a retruded, posteriorly rotated mandible (Koca et al., 2016). In children with isolated hypertrophy of adenoids, and those with hypertrophy of tonsils and adenoids, a retro-positioned mandible remains a constant finding (Huang et al., 2023). Isolated hypertrophy of tonsils was associated with protrusion of both maxilla and mandible (Huang et al., 2023). These findings were consistent with those of a study on patients with mouth breathing due to adenoid or tonsillar hypertrophy (Franco et al., 2015). Therefore, the airway dimensions of skeletal malocclusion with a sagittal discrepancy need to be assessed thoroughly during examination.

Incisor eruption may influence sagittal pattern of maxilla and mandible. In an Egyptian population, Fahim and ElAbbasy (2019) studied the effect of palatal displacement of maxillary lateral incisors on development of SCII malocclusion. The study consisted of two groups, one group of patients with palatally displaced lateral incisors without crossbite (Group A), and the other with a crossbite (Group B). The group with palatally displaced maxillary lateral incisors without crossbite showed statistically significant cephalometric measurements in comparison to Group B. The results implied that growth of mandible may be restricted by palatally displaced maxillary lateral incisors without a crossbite, contributing to SCII malocclusion (Fahim and ElAbbasy, 2019). Hormonal imbalances such as growth hormone deficiency and excess may influence the growth and size of the mandible (Khare et al., 2013).

1.4. Assessment of maxilla and mandible in sagittal dimension

1.4.1. The use of lateral cephalometric radiograph

The lateral cephalometric radiograph (LCR) was first introduced to orthodontics by Broadbent in 1931, who described the use of a modified craniostat as a head holder and x-ray technique to assess changes in the facial growth of living child (Broadbent, 1931). In modern age, lateral cephalometry X-ray technique has been developed for simplicity while keeping much of principles described by Broadbent. Currently, LCR remains an important tool used by most orthodontists to aid diagnosis and treatment planning (Durão et al., 2015).

The lateral cephalometric radiograph is traced for landmarks and then analysed to assess sagittal jaw relationship. Some common landmarks included in the analyses are (Broadbent, 1931, Downs, 1948):

- Sella: The midpoint of sella turcica
- Nasion: The frontonasal suture, where frontal and nasal bones meet.
- Porion: The most superior aspect of external auditory meatus
- Orbitale: The most inferior border of orbit
- A point: The deepest point on the concavity of maxilla
- B point: The deepest point on the concavity of mandible
- Pogonion: The most protrusive point on mandible
- Condylion: the posterosuperior aspect of condyle (McNamara Jr, 1984).

These landmarks may be traced onto lateral cephalometric radiograph, either manually or digitally using various computerized cephalometric software programs. Erkan and colleagues (2012) compared manual tracing method with four computerized cephalometric tracing software programs. No statistical differences were found between manual and computerized methods. Among these four software programs, the differences in angles between Dolphin Imaging software (Dolphin Imaging, Chatsworth, California, USA) and manual tracings were the smallest (Erkan et al., 2012). At Wits Oral Health Centre (WOHC), the manual tracing method and the Dolphin Imaging software are used by registrars and consultants to aid diagnosis and treatment planning.



Figure 1: Lateral cephalometric radiograph (LCR)

1.4.2. Downs' analysis

In 1948, Dr. William B. Downs presented his method for analysis of facial relationships and emphasized the importance of assessing skeletal pattern independent of dentition. The author describes facial angle to study sagittal relation of mandible to the face. The Frankfort-horizontal (FH) was chosen as a reference plane as it runs across the face and would therefore be ideal for such an assessment (Downs, 1948). The FH reference plane is represented by a horizontal line running through orbitale and porion landmarks. A vertical line from nasion to pogonion determines the facial plane, which subsequently runs past the FH. The lower inside angle between the two lines is called Downs' facial angle (Downs, 1948).

Another measure presented by Downs is Angle of convexity. The author used this angle to assess the sagittal position of maxillary part of the face to the facial profile. The angle was found at intersection of two vertical lines – one from nasion and another from pogonion – both to point A, which represents the deepest point on maxilla (Downs, 1948).

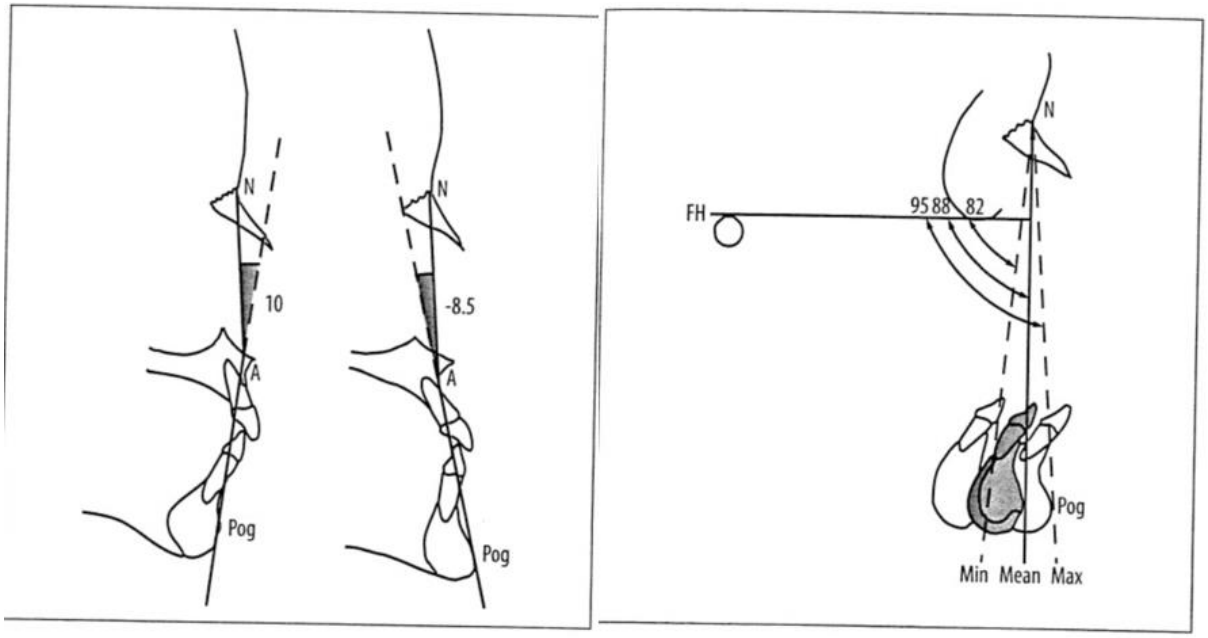


Fig 6-6 Angle of convexity.

Fig 6-5 Facial angle.

Figure 2: Downs' analysis for sagittal relationship of maxilla and mandible.

1.4.3. Steiner's analysis

In 1953, Dr Cecil C. Steiner argued that on LCR, porion proves more difficult to locate and as such, compromises accuracy of FH as a reference plane. The author preferred the use of sella-nasion line (SN line) – a horizontal line drawn from center of sella turcica to nasion – as a reference line. The author assessed sagittal relationship between maxilla and mandible by employing an analysis first introduced by Dr Richard Riedel the year before. The sagittal position of maxilla was measured by angle Sella-Nasion-A point (SNA) -indicated by angle between the SN line and a vertical line from point A to nasion. The mandible was measured by the angle Sella-Nasion-B point (SNB). The SNB angle was indicated by angle between SN line and a vertical line from nasion to point B. The difference between SNA and SNB angles (referred to as ANB angle) indicates the relationship between maxilla and mandible of the patient (Riedel, 1952, Steiner, 1953).

1.4.4. The Wits Appraisal

Dr Alex Jacobson argued that craniofacial complex may present variations that may render ANB angle inadequate. According to the Jacobson (1975), a variation in the anterior cranial base length may result in a variation in position of the nasion and as such, affect the accuracy

of SN line. Rotation of the jaws is also reported as another variation that may lead to inaccuracy of ANB angle. Jacobson then proposed the Wits appraisal, independent of cranial reference planes but rather using patient's functional occlusal plane. From the occlusal plane, two perpendicular vertical lines are drawn– one to point A (AO line) and another to point B (BO line). The horizontal distance between AO and BO lines were measured. When AO line is ahead of BO line, a positive reading results, and a tendency for SCII malocclusion is observed. When the AO line is behind the BO line, a negative reading results, and an SCIII malocclusion is indicated (Jacobson, 1975).

1.4.5. Harvold's Analysis and McNamara's analysis

In 1974, Harvold derived an analysis independent of cranial and occlusal reference planes, which focused on the unit lengths of maxilla and mandible. A line from posterior border of glenoid fossa of temporomandibular joint to inferior aspect of anterior nasal spine of maxilla is drawn to represent maxillary unit length. Mandibular unit length is derived from a line drawn from the same point of glenoid fossa to pogonion (Harvold, 1974).

McNamara modified Harvold's analysis in his method by using condylion and point A, to measure the "effective midface length". The "effective" mandibular length is found by a line from condylion to pogonion. The author further proposes that a relationship exists between the two effective length. Subtracting effective length of midface from that of mandible results in maxillomandibular differential. Additionally, the author introduced nasion-perpendicular – a line drawn from nasion down, at a right angle to FH. The maxilla's protrusion/retrusion is assessed by distance of point A to this line (McNamara Jr, 1984).

1.4.6. Reliability of assessment methods

The cephalometric analysis methods described do not come without individual shortfalls. The Downs' facial angle relies on FH as a reference plane and therefore may suffer from inconsistencies in porion locations (Steiner, 1953). Analyses such as Downs' angle of convexity, Steiner's analysis, and McNamara's analysis may suffer from their use of nasion, as nasion anatomic position may vary (Jacobson, 1975). The wits analysis may be limited by tooth eruption and identification of functional occlusal plane between clinicians (Haynes and Chau, 1995).

A study comparing various cephalometric analysis methods found equally good reliability in diagnosis of sagittal jaw relationship between them (Qamaruddin et al., 2018). Another study compared ANB with other sagittal jaw relationship analysis methods and found a high

correlation between the analyses (Nazir and Mushtaq, 2020). Such findings show that although each method may present its flaws, they can be used in conjunction to aid clinician in assessing sagittal jaw relationship. At Wits Oral Health Centre (WOHC), analyses described by Downs, Steiner, and the Wits appraisal are frequently used to aid assessment of skeletal class of the patient.

1.5. Race and Skeletal malocclusion

Cephalometric analyses have mostly been established on Caucasian White populations. The Downs' facial angle is normal for White patients when it is 88±4º, while Angle of convexity may range from 0 to 5º (Downs, 1948). Steiner's norms for White populations are SNA of 82º, SNB of 80º, and a resultant ANB of 2º (Steiner, 1953). Drummond (1968) used Steiner's analysis to study differences in African American population. The study found a statistically significant prognathic maxilla in African American compared to Caucasian population, leading to a greater mean ANB angle of 5.5º (Drummond, 1968).

In South African population, Jacobson (1978) reported that according to Steiner's analysis, the mean SNA is 86º and 84º in Black males and females respectively. The mean SNB is reportedly around 81º and 79º in Black males and females respectively (Jacobson, 1978). The findings suggested a more prognathic maxilla in South African Black population, and a more convex profile with a mean ANB of 5º compared to that of a White population (Jacobson, 1978). The convex profile with more protruded maxilla and mandible in Blacks compared to Whites is consistent with findings in studies on white and Black Brazilian populations (Freitas et al., 2010, Oliveira et al., 2021).

In Nigeria, a cephalometric study on anteroposterior relationship of maxilla and mandible was conducted on children of Hausa-Fulani ethnicity with Caucasian ancestry (Utomi, 2004). The study reported SNA and SNB angles close to Steiner norms for Caucasians – Indicating less prognathism of the jaws compared to South African patient (Utomi, 2004). Cephalometric norms of children of Igbo ethnicity in Nigeria found a more prognathic maxilla and a higher mean ANB than in Hausa-Fulani population (Ajayi, 2005).

1.6. Statement of purpose

The WOHC orthodontic unit provides treatment to a large pool of patients from all over the country, many of them presenting with some form of sagittal discrepancy of the jaws. The purpose of the study is thus to investigate the nature of sagittal discrepancy in SCII and SCIII

malocclusion patients consulting for treatment at the WOHC's orthodontics unit. Such a project would contribute to our knowledge of components of skeletal malocclusion seen in the South African population.

1.7. Aim of the study

To evaluate sagittal discrepancies in Skeletal Class II and Class III malocclusions in patients orthodontically treated at Wits Oral Health Centre over a five-year period.

1.8. Objectives of the study

1. Assess the contribution of sagittal positioning of maxilla and mandible in development of Skeletal Class II and Class III malocclusions.

2. To determine whether there is a difference in skeletal discrepancies among South African patients of Black, White, and Indian descent.

3. Assess for gender differences in sagittal positioning of jaws in each skeletal malocclusion.

CHAPTER TWO: MATERIALS AND METHODS

2.1. Study design

The study was a retrospective, cross-sectional records review assessing pre-treatment lateral cephalometric radiographs of Skeletal Class II and Skeletal Class III malocclusion assessed from 1 January 2018 to 31 December 2022. The study was designed for this specific five-year period to allow for as many patient records as possible.

2.2. Inclusion criteria

The inclusion criteria for the study was as follows:

- Diagnosed as Skeletal Class II and Skeletal Class III malocclusions.
- Pre-treatment radiographs that were taken between 01 January 2018 to 31 December 2022
- Had not received orthodontic treatment before diagnosis.
- Selected radiographs were of Black, White and Indian patients.
- The radiographs had to be of such adequate quality that anatomical structures and cephalometric landmarks could be easily identified and traced (as shown in Figure 1).

2.3. Exclusion criteria

The patients excluded from the study are:

- Those who suffered craniofacial fractures.
- Those who have congenital anomalies.
- Any radiographs that do not meet the inclusion criteria will not be selected for the study.

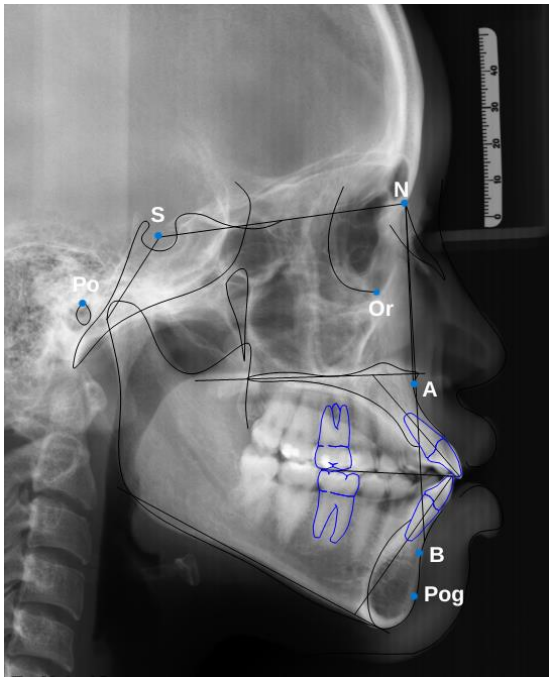


Figure 3: LCR with cephalometric landmarks.

S: Sella; N: Nasion; Po: Porion; Or: Orbitale; A: A-point; B: B-point; Pog: Pogonion.

2.4. Sample size and study setting

The sample size for the study was calculated using raosoft.com software to estimate a specified prevalence in a population. Data for this estimation were obtained from Chan et al (2022), who estimated prevalence of Class II and III skeletal malocclusions in Caucasian samples. Using a finite population of 150 Caucasian patients at 95% confidence interval and a 5% margin of error, a sample size of 98 was determined to estimate a prevalence of 23.1% for Class II malocclusions, while a sample size of 75 was determined to estimate a prevalence of 10.8% for Class II malocclusions (Chan et al., 2022). Using larger sample size, a total of 196 pre-treatment lateral cephalometric radiographs was estimated, to allow for ethnic comparisons. The database of patients treated by registrars in orthodontics department provided 150 patients with pre-treatment lateral cephalometric radiographs which met the inclusion criteria. Therefore, the final sample was kept at 150 satisfactory cases.

2.5. Data collection procedure

Each of the patients' LCRs were accessed from WOHC radiology database, and stored in SIDEXIS 4 software. The demographic data from each patient was recorded, limited to race, gender, and age. The racial groups were assigned letters P, T, and Y, to blind the statistician to

minimize bias. The LCRs were then imported into the cephalometric tracing software (Dolphin Imaging ® version 11.95, Chatsworth, California, USA) for assessment (figure 2).

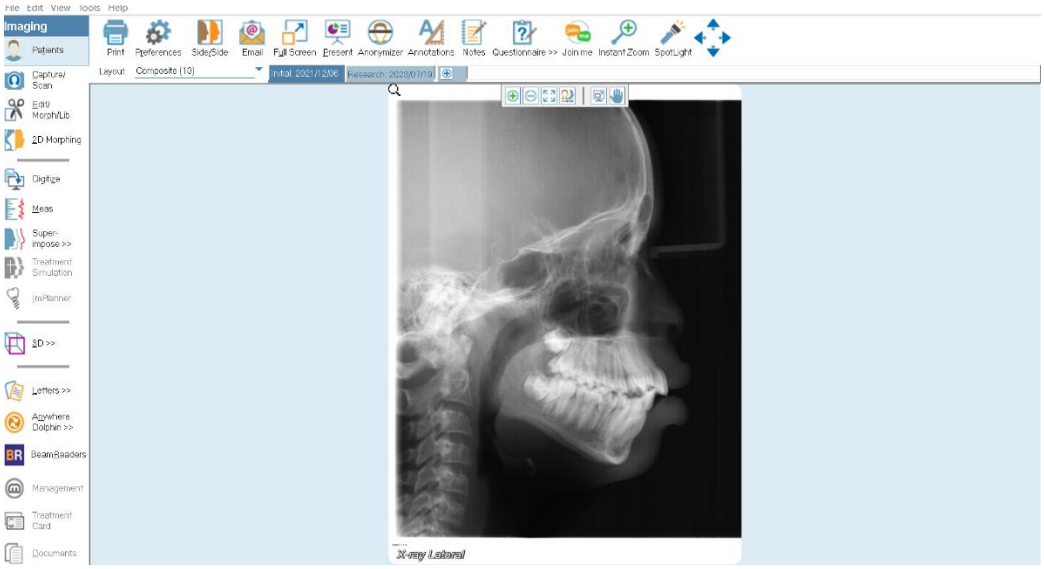


Figure 4: Dolphin Imaging software used for cephalometric tracing and analysis.

All anatomical structures and cephalometric landmarks relevant to the study (see Figure 1) were digitally traced. Following landmark identification, the following parameters were digitally measured:

1. SNA angle: The angle formed by SN plane and a line to nasion from A- point.
2. SNB angle: The angle formed by SN plane and a line to nasion from B- point.
3. ANB angle: The angle formed by lines from A and B as they meet at nasion.
4. Downs' Facial Angle: The angle formed by Frankfort-Horizontal reference line and a line from N to pogonion.
5. Downs' Angle of convexity: The angle formed between a line from A-point to N and a line from A-point to pogonion.
6. Wits appraisal: A linear measurement of distance between a vertical line to A-point and one to B-point, both drawn perpendicular to occlusal plane.

The above parameters are frequently used at WOHC orthodontic clinic to assess sagittal relationship between maxilla and mandible. Data produced by Dolphin Imaging software for each of the parameters were collected and recorded in the data collection form (Appendix A).

The data was then entered into a Microsoft Excel® spreadsheet and cleaned to prepare for data analysis. To avoid statistician bias, blinding of race was conducted by assigning each of the racial groups a code letter, only known by primary investigator.

2.6. Data analysis

Categorical variables were summarized as frequencies and percentiles. Continuous variables were assessed for normality and where this was violated (e.g. age), data were summarized as median and interquartile range. Normally distributed data were summarized as mean and standard deviation.

The statistical tests were conducted as follows:

1. Gender differences were assessed using a Mann-Whitney test for age, and independent t-test for all other continuous variables.
2. Race differences in age were assessed using a Kruskal Wallis test and Dunn test for multiple comparisons.
3. Race differences in other continuous variables were assessed using a one-way analysis of variance (ANOVA) with Bonferroni multiple comparison test. Due to a low sample of White and Indian patients, race differences for Skeletal class III malocclusion were excluded from the analysis. Continuous variables for Black subjects were assessed for normality and where this was violated, as in age, data were summarized as median and interquartile range. The normally distributed data were summarized as mean and standard deviation.

All analyses were performed in STATA version 15 (Statcorp, USA) at 5% level of significance.

2.7. Error of method

The principal investigator collected all the data for this study. The principal investigator was calibrated on the use of Dolphin Imaging software by secondary investigator Mosidi Makofane (MM). To avoid investigator errors due to fatigue, a maximum of ten records per day was set and adhered to, until all records were measured. A random set of ten records was selected and re-measured two weeks after, to test for intra-observer reliability. To test the inter-observer reliability, another investigator (MM) re-measured random set of ten records. Intra and inter-observer variation was assessed using technical error of measurement (TEM) and the results were presented as relative TEM (rTEM) for ten participants (Supplementary Table 1). The first step was to calculate absolute TEM (aTEM) which was estimated by obtaining square root of sum of squared difference between the two repeated measurements for each individual divided by sample size multiplied by two (2n). Secondly, a variable average value (VAV) was

calculated by working out average of two repeated measurements for each participant and obtaining average of averages. The rTEM was obtained by dividing aTEM by VAV and multiplying by 100 to obtain a percentage. Substantial intra-observer reliability was obtained for SNA, SNB, ANB, Facial angle, and Angle of convexity measurements (≤ 10% rTEM). Substantial inter-observer reliability was also observed for SNA, SNB, and Facial angle measurements (≤ 10% rTEM).

Table 1:Relative technical error of measurement for intra- and inter-observer variation in Skeletal Class II and Skeletal Class III malocclusions

Variables	Class 2		Class 3	
	Intra	Inter	Intra	Inter
	TEM%	TEM%	TEM%	TEM%
SNA	1,00	1,40	0,47	1,92
SNB	0,96	0,72	0,66	1,10
ANB	4,97	10,22	-10,23	-37,62
Facial angle	0,46	1,25	0,77	0,76
Angle of convexity	6,24	13,20	-8,18	-31,30
Wits appraisal	20,69	12,72	-8,44	-30,03

2.8. Ethics

Permission to access records was requested from and granted by CEO of Wits Oral Health Centre and Head of School of Wits School of Oral Health Sciences (Appendix B). Unconditional ethical clearance to conduct the study was granted Human Research Ethics Committee (Medical) of University of the Witwatersrand (**M221155**; Appendix C). Confidentiality and anonymity were maintained as there was no identifiable patient information recorded. During data analysis, the data were blinded by assigning letters to each racial group, to mitigate against racial bias.

CHAPTER THREE: RESULTS

The study sample comprised 150 pre-treatment patient records, obtained from orthodontic department at WOHC of patients treated between 1 January 2018 and 31 December 2022.

3.1. Distribution of demographic data by classification

Table 2 shows demographics of the study sample. The median age of the sample was 14 years, while interquartile range was 12 – 17 years (Q1 -Q3). The sample comprised 84 Skeletal Class II (56%) and 66 Skeletal Class III (44%) cases. Of the Skeletal Class II cases, male patients made up most of the sample (n= 46, 54.8%), followed by females (n= 38, 45.2%). Females made up most of Skeletal Class III cases (n= 38, 57.6%), followed by males (n= 28, 42.4%). The racial demographics of the sample showed mostly Black patients in both Skeletal Class II (71.4%) and Skeletal Class III (94.4%), and low samples of White and Indian patients.

Table 2: Descriptive statistics of the sample stratified by gender, race and age

Variable	**Total**	**Class 2**	**Class 3**
N	150	84 (56%)	66 (44%)
Gender			
Female	76 (50.7)	38 (45.2)	38 (57.6)
Male	74 (49.3)	46 (54.8)	28 (42.4)
Race			
Blacks	121 (80.7)	60 (71.4)	61(94.4)
Indians	13 (8.7)	12 (14.3)	1 (1.5)
Whites	16 (10.7)	12 (14.3)	4 (6.1)
Age$^{\partial}$	14,0 (12,0 - 17,0)	14,0 (12,0 - 17,0)	14,5 (12,0 - 17,0)

$^{\partial}$data summarised as the median and interquartile range (Q1 – Q3)

3.2. Race differences for Skeletal Class II Characteristics

The descriptive statistics for Skeletal Class II parameters in each racial group are presented in Table 3 in terms of means and standard deviations. ANOVA with Bonferroni multiple comparisons test revealed statistically significant differences between Black and Indian samples in variables ANB ($p<0.05$) and Angle of convexity ($p<0.001$). Statistically significant differences were also found between Black and White samples in variables SNA ($p < 0.05$), ANB, and Angle of convexity ($p < 0.001$). No significant differences were found between the Indian and White samples ($p > 0.05$).

Table 3: Race differences for Skeletal Class II Characteristics

Variable	**Blacks (P)**	**Indians (T)**	**Whites (Y)**
N	60	12	12
Age$^{\partial}$	14,5 (12,0 - 18,5)	13,5 (12,5 - 15,0)	12,5 (12,0 - 14,5)
SNA	85,5 (4,5)^{*B}	82,7 (4,3)	81,7 (3,3)
SNB	78,0 (4,3)	76,8 (4,3)	76,8 (3,7)
ANB	7,5 (2,0)$^{*A;***B}$	5,9 (2,3)	4,9 (2,0)
Facial angle	87,2 (3,9)	86,0 (4,3)	87,9 (2,8)
Angle of convexity	15,4 (4,8)$^{**A;***B}$	10,6 (5,2)	6,4 (5,0)
Wits appraisal	4,1 (3,1)	3,5 (4,0)	4,8 (2,5)

$^{\partial}$data summarised as median and interquartile range (Q1 – Q3)

**p < 0.05; **p < 0.01; ***p < 0,001*

Race differences: A = P vs. T; B = P vs. Y; C = T vs. Y

3.3. Race differences for Skeletal Class III patients

In Skeletal Class III sample, the Indian and White patient groups made up less than 10% of total sample (Indian = 1.5 %; White = 6.1 %), hence racial comparisons could not be carried out. Therefore, Table 4 presents descriptive statistics from Black patient group regarding means and standard deviations.

Table 4: Descriptive statistics of Skeletal Class III characteristics for Black patients.

	Female	Male
Age$^{\partial}$	15,0 (14,0 - 20,0)	14,0 (11,0 - 16,0)
SNA	81,7 (4,7)	81,8 (3,2)
SNB	82,0 (4,8)	80,6 (3,5)
ANB	-0,3 (3,3)	1,2 (2,4)
Facial angle	91,6 (3,7)	89,4 (3,6)
Angle of convexity	0,0 (7,3)	3,4 (6,0)
Wits appraisal	-6,3 (3,6)	-5,8 (3,5)

$^{\partial}$*data summarised as the median and interquartile range (Q1 – Q3)*

3.4. Gender differences in skeletal class II and skeletal class III malocclusion

Means and standard deviations of skeletal characteristics in female and male patients are presented in Table 5a (Skeletal Class II) and Table 5b (Skeletal Class III). The independent t-test for gender comparisons revealed statistically significant differences in Wits appraisal for Skeletal Class II sample ($p<0.05$). In Skeletal Class III patients, statistically significant differences were observed between genders in ANB, Facial angle, and Angle of convexity ($p<0.05$).

Table 5: Gender differences for Skeletal Class II (a) and Skeletal Class III (b) characteristics

(a)

Variable	**Female**	**Male**	**P-value**
N	38	46	
Age[∂]	15,0 (13,0 - 19,0)	13,0 (12,0 - 15,0)	***0.009***
SNA	85,0 (4,7)	84,3 (4,4)	0.469
SNB	78,2 (4,7)	77,2 (3,8)	0.286
ANB	6,8 (2,2)	7,0 (2,3)	0.616
Facial angle	87,8 (4,2)	86,6 (3,4)	0.143
Angle of convexity	13,1 (5,7)	13,7 (6,0)	0.642
Wits appraisal	3,2 (2,6)	4,9 (3,4)	***0.013***

[∂]data summarised as the median and interquartile range (Q1 – Q3)

(b)

Variable	**Female**	**Male**	**P-value**
N	38	28	
Age[∂]	15,0 (14,0 - 18,0)	14,0 (11,5 - 16,0)	0.215
SNA	81,9 (4,5)	81,9 (3,2)	0.960
SNB	82,4 (4,8)	81,0 (4,1)	0.200
ANB	-0,5 (3,2)	1,0 (2,7)	***0.047***
Facial angle	91,7 (3,7)	89,8 (4,0)	***0.050***
Angle of convexity	-0,7 (7,3)	2,9 (6,6)	***0.044***
Wits appraisal	-6,2 (3,5)	-6,1 (3,6)	0.840

[∂]data summarised as the median and interquartile range (Q1 – Q3)

CHAPTER FOUR: DISCUSSION

4.1. Distribution of the study sample

The study distribution in terms of skeletal classification showed a higher percentage of patients with SCII (56%) than those with SCIII (44%). Similar to the current study, a greater percentage of SCII than SCIII was found in a study looking at skeletal malocclusion prevalence in patients consulting at a dental school in Pakistan (Hamid and Asad, 2003). Similarly, a study with a large sample was conducted in India to evaluate nature of malocclusions that are present in a tertiary institution and the results showed significantly more SCII cases than SCIII cases (Nainan et al., 2013). Boeck et al (2011), in Brazil, conducted a study on records of patients who had undergone orthodontic-orthognathic treatment. The authors reported a higher sample with SCIII than SCII, albeit the difference was only 2 patients (79 SCII and 81 SCIII patients) (Boeck et al., 2011). Their finding shows a close to even distribution of SCII and SCIII patients treated at their institution, which contrasts with the current study. Such a contrast may be due to their study focusing only on patients who required orthognathic treatment, while current study included all patients with sagittal discrepancy, regardless of treatment plan.

When stratified by race, more Black patients (80.7%) than White (10.7%) and Indian patients (8.7%) were observed in the study sample. Furthermore, 71.4% of the SCII sample is made up of patients of African descent, while Indian and White patients make up 14.3% each. The Black patients were vast majority (94.4%), while only four Indian patients and one White patient were in SCIII sample. In the Brazil study on patients who had undergone orthodontic-orthognathic treatment, an interestingly similar demographic of White, Black, and Indian patients appeared (Boeck et al., 2011). The SCII group in the Brazil study consisted mostly of White patients, with only two Blacks and no Asian patients. Similarly, the SCIII group consisted mostly of White patients, with seven Black patients and only one patient of Asian descent (Boeck et al., 2011). The finding is in contrast with that of current study and may be attributed to difference in racial populations between South Africa and Brazil.

According to gender distribution of sample, a near-even spread was observed in the total sample, with 76 females and 74 males. In a study on prevalence of skeletal malocclusion, Hamid and Asad (2003) found a higher percentage of females than males, and suggested that high percentage may indicate that females express more concern and seek orthodontic

treatment more than males. Such a finding was corroborated by the Brazil study, which also revealed a higher percentage of females consulting and receiving treatment for skeletal malocclusions than males (Boeck et al., 2011). However, such an implication was not supported by the current study's findings.

These findings should be interpreted with caution as they do not reflect prevalence of the malocclusions in race and gender. While pre-treatment LCRs of patients who were allocated for treatment by the registrars were used, some patients were screened for orthodontic treatment at the WOHC orthodontic clinic without an LCR as it is not routine for screening. Secondly, because Skeletal Class I malocclusion patients were not considered for this study, the conclusion on prevalence of skeletal malocclusion in the population groups should not be drawn based on results from this study.

4.2. Skeletal Class II

4.2.1. The Maxilla

4.2.1.1. Sella-Nasion-A point Angle

To determine sagittal position of maxilla relative to cranial base,SNA angle was used. For the Black population, SNA was found to be a mean of 85.5º, indicating a normally positioned maxilla in comparison to cephalometric norms for South African Blacks (85.8º) (Jacobson, 1978). In 2014, Ifesanya looked at jaw patterns in patients presenting for orthodontic treatment at University College Hospital in Nigeria over three years. The results of the study revealed a slightly reduced SNA in SCII patients (Mean of 84.8º) when compared to patients that had a Skeletal Class I (SCI) relationship (Mean of 86.5º). Such a difference was statistically insignificant when SCII and SCI groups were compared (Ifesanya, 2014). The maxillary retrognathia found in the Nigerian population is in contrast with current study.

Concerning the Indian sample, current study found a mean of 82,7º, which is less than a degree above Steiner's norm for Caucasians and norm values for SNA reported in Indian populations (Steiner, 1953, Chiurupatya et al., 2015). A study in India looked at skeletal characteristics of patients presenting with Angle's Class II Division 1 and Angle's Class II Division 2 malocclusion. The study revealed that in both dental classes, maxilla appeared to be in a normal horizontal position similar to that in cephalometric norms (Prakash et al., 2010). The current study reflects a maxilla that is positioned close to orthognathic expectation in the Indian population. Another study compared cephalometric characteristics of patients with Angle's Class II Division 1 between an Indian population and a Chinese population. The SNA angle of

Indian sample in this study was within the population's cephalometric norms (Rana et al., 2017). Their finding also indicated a normal position of maxilla in SCII, which is similar to current study. Another study in South India looked at contributing factors to development of SCII and SCIII in an Indian population. The study reported a common finding of maxillary prognathism in 54% of SCII study sample and concluded that the main jaw discrepancy in SCII was maxillary prognathism (Abirami et al., 2020). The finding is contradictory to results of the current study. Such contradiction could be due to relatively low sample size in the current study.

The patients of White descent in the current study had a mean SNA of 81.7º which is less than a degree below Steiner's cephalometric norm for Caucasians, (82º), indicating a normal position of maxilla (Steiner, 1953). In Brazil, a study on White patients presenting with Angle's Class II Division 1 malocclusion was assessed for their cephalometric characteristics and compared to those of patients with ideal occlusion. The study found a normally positioned maxilla with SNA (a mean of 81.9º) within Steiner's norm and also similar to patients with an ideal occlusion (Freitas et al., 2005). The study sample in Brazil study was higher than that of current study, and their finding concerning sagittal position of maxilla was consistent with that of current study.

4.2.2. The Mandible

4.2.2.1. Sella-Nasion-B point Angle

To assess the sagittal position of mandible, SNB angle was used in the current study. For the Black sample, the mean SNB angle was 78º which is below Jacobson's norm for South African Blacks, indicating mandibular retrognathism in SCII South Africans of the Black race. When looking at jaw patterns in different skeletal malocclusions, Ifesanya (2014) assessed mandible using SNB angle and found a degree of mandibular retrognathism in SCII group compared to SCI group (Ifesanya, 2014). The finding is similar to the current study in the Black population.

Regarding the Indian sample, results show a mean SNB of 76.8º, which is below Steiner's norms for Caucasian populations (Mean SNB of 80º). The relatively low SNB mean suggests a tendency for mandibular retrognathism in SCII in South African patients of Indian descent. Sinha et al (2018) assessed the maxilla and mandible together with their contribution to development of SCII in an Indian population using Burstone's analysis. Like McNamara's analysis, a linear distance from Nasion perpendicular to A-point and pogonion are measured to assess position of maxilla and mandible respectively. The Indian study revealed majority of the cases assessed presented a tendency for mandibular retrognathism (Sinha et al., 2018).

Prakash and colleagues found a tendency of a statistically significant mandibular retrognathia when comparing mean SNB of Indian patients presenting with Angle's Class II malocclusion to that in patients with normal occlusion (Prakash, 2010). Such a finding is consistent with current study, although it was not part of the objectives to compare findings to a control group.

The South African patients of White descent in current study revealed a mean SNB of 76.8º, like that of patients of Indian descent. The mean SNB was below Steiner's cephalometric norms for White patients (80º) and indicates a mandibular retrognathism feature of SCII in White South Africans. McNamara (1981) assessed variations of maxilla and mandible in SCII malocclusion using both Steiner analysis and McNamara's analysis. The study found that mandibular retrognathism was a common feature of this malocclusion and on average, maxilla remained in an orthognathic position (McNamara Jr, 1981).

4.2.2.2. Facial angle

The mean facial angle for South African Blacks with SCII in this study was 87.2º, which is below norms described by Jacobson in his study on craniofacial skeletal pattern in South African Black patients (Jacobson, 1978). A retrognathic mandible then seems to be the mean finding in Black South Africans with SCII malocclusion. Similarly, mean facial angle for the Indian sample (86.0°) in the current study was below the cephalometric norms defined by Downs (Downs, 1948).

The mean facial angle for South African Whites with SCII in this study was 87.9°, which is close to mean norm described by Downs for Caucasian patients (Downs, 1948). Rosenblum (1995) studied 103 SCII patients stratified into three skeletal maturity levels, to assess which jaw influenced skeletal pattern. The author used Downs'facial angle and Steiner's SNB angle to assess position of mandible and found conflicting results between the two values. While SNB angle implicated mandibular retrognathism for most of SCII cases, when facial angle was used, the average result indicated an orthognathic mandible (Rosenblum, 1995). Such a finding is consistent with current study, indicating an orthognathic mandible when assessing with Downs' facial angle, but a retrognathic mandible when using Steiner's SNB angle.

4.2.3. The maxilla-mandibular relationship

4.2.3.1. A point-Nasion-B point Angle

The SCII sample showed an increase in mean ANB in each of the racial groupings in the current study. This is expected as the mean SNB in this study shows a tendency towards mandibular retrognathism. A retro-positioned mandible leads to a backward position of B-point on mandible, which increases ANB angle. Therefore, such a finding is expected when the tendency of SCII is mandibular retrognathism, as is in this current study. The study by Ifesanya (2014) found an increased ANB angle in Nigerian Black patients with SCII malocclusion, due to a reduced mean SNB, like current study (Ifesanya, 2014). Similarly, an increased mean ANB is reported in studies on Indian (Sinha, 2018; Prakash, 2010) and White populations (McNamara Jr, 1981).

4.2.3.2. Angle of Convexity

The current study found a high mean Angle of Convexity in all three racial groups, compared to established cephalometric norms. In his study, Downs explains that Angle of convexity indicates sagittal position of maxilla to facial profile, however, the influence of mandible cannot be ignored. A retro-positioned pogonion in mandibular retrognathia very well contributes to increased convexity of the facial profile and as a result, the angle of convexity (Downs, 1956). Mandibular retrognathism was a common finding between sagittal parameters in current study. Gasgoos et al (2007) found that there is an increase in facial convexity of Iraqi populations with SCII malocclusion when compared to SCI group, influenced by a significantly retro-positioned mandible (Gasgoos et al., 2007).

4.2.3.3. Wits appraisal

The Wits appraisal values for SCII patients in all three racial groupings were higher than mean values described by Jacobson for South African Caucasoid and Black populations (Jacobson, 1975; Jacobson, 1978). When testing for error of method, technical error of measurement associated with Wits appraisal was above threshold in both intra- and the inter-observer values. Due to high error of measurement, Wits appraisal values observed by the current study should be interpreted with caution as they may lead to incorrect conclusions. As reported by Jacobson in his 1988 paper on update of Wits appraisal, difficulty in determination of functional occlusal plane may present inaccuracies in Wits appraisal (Jacobson, 1988).

4.2.4. Race differences in sagittal parameters

The current study compared SCII parameters between South Africans of Black, White, and Indian descent. The statistically significant difference between Black and White patients in parameters ANB ($p<0.05$) and Angle of Convexity ($p<0.01$) suggests that South African Black patients portray a more convex facial profile than patients of White descent in SCII malocclusion. Jacobson (1978) conducted a study comparing skeletal pattern of South African Black patients with exemplary occlusion, to that of patients of Caucasoid descent with same standard of occlusion. The study found significantly higher ANB in Black sample and attributed such findings to a relatively more forward-positioned maxilla as SNA angle was larger, albeit by a statistically insignificant margin (Jacobson, 1978). Jacobson's findings appear to be true for SCII malocclusion patients because current study found similar results, including a higher mean SNA in patients of Black descent than those of White descent, although it showed no statistical significance ($p > 0.05$). A shorter anterior cranial base, as is known to be found in Black subjects, may lead to a retro-positioned nasion and therefore influence SNA and consequently, ANB and convexity of the facial profile (Jacobson, 1975).

When comparing Black group to the Indian group, there were statistically significant differences in SNA ($p<0.05$), ANB, and Angle of convexity ($p<0.001$), indicating a more prognathic maxilla accompanied by a greater facial convexity in Black subjects. It appears that SCII Black patient tends to portray a more prognathic maxilla and convex profile than patients of White and Indian descent, in this study sample. Findings of the current study may however be limited by relatively low sample sizes in White and Indian groups.

4.2.5. Gender differences in sagittal parameters

No statistical gender differences were found in the sample, except a significant difference in Wits appraisal variable ($p<0.05$), which indicated a greater SCII in males than in females. Due to low sample sizes, gender differences in each racial group were not investigated. Qamar and Chaudry (2007) investigated gender differences in a Class II sample using data from a Pakistani population and reported no statistically significant differences other than a statistically significant greater cranial base length in male patients than females (Qamar and Chaudry, 2007). The results were like those found in current study, except that the anterior cranial base was not a variable in this study.

4.3. Skeletal Class III

The SCIII sample obtained for this study was made up of 94.4% Black subjects and a total of only four Indian and one White patient made up the rest, therefore due to low sample size in the two racial groups, racial differences were not analysed.

4.3.1. The Maxilla

4.3.1.1. Sella-Nasion-Apoint angle

The results of current study showed a mean SNA angle of 81.7º for females and 81.8º for males. Jacobson (1978) describes the expected mean SNA for South African Black females and males as 84º and 85.8º respectively (Jacobson, 1978). Such a finding as in current study then indicates that maxilla is retrognathic in South African Black patients with SCIII malocclusion. In a Nigerian population, SCIII patients were compared to those with normal skeletal relation of maxilla and mandible (Ifesanya, 2014). The study revealed a decreased mean SNA of 84.7º in SCIII compared to 86.5º found in normal skeletal relation. The finding indicated a retrognathic maxilla in Nigerian patients, and this is consistent with finding on South African Black patients in current study.

Although the current study did not have enough of a sample to study South African patient of Indian descent, a study comparing an Indian population with SCIII malocclusion to that with SCI reported a lower mean SNA in SCIII group, indicating a retrognathic maxilla (Prakash et al., 2010).

4.3.2. The Mandible

4.3.2.1. Sella-Nasion-B point Angle

The mean SNB for South African Black patients in current study was 82º for females and 80.6º for males. Jacobson (1978) reported that expected mean SNB for South African Black females and males were 78.4º and 80.8º respectively (Jacobson, 1978). The current study therefore indicates an interesting finding of mandibular prognathism in South African Black females with SCIII, while there is a normal position of mandible in the male counterparts. Ifesanya's study on Nigerian population with SCIII reported a higher mean SNB than normal SCI, indicating mandibular prognathism in their population.

In Asian populations, Gasgoos and colleagues conducted a study to compare cephalometric characteristics of patients across three skeletal classes. In their SCIII sample, the authors found a mean decrease in SNA angle compared to mean SNA in SCI sample. The authors indicated that such a finding alluded to maxillary retrognathia as a feature of SCIII in an Iraqi population

(Gasgoos et al., 2007). In another study, Abirami and colleagues looked at contributing factors to SCIII malocclusion in a population from South India. The study found a common mandibular prognathism in 60% of their SCIII sample (Abirami et al., 2020) The current study did not have enough patients from Indian population to compare with Indian or/and Asian studies, however, maxillary retrognathia is a feature of SCIII in South African Black population.

4.3.2.2. Facial Angle

Jacobson (1978) found that South African Black population norms for facial angle are 90.7º for males and 91.7º for females (Jacobson, 1978). The Black males in current study presented a mean facial angle that was 1.3º lower than described norm, indicating a slightly retrognathic mandible. On the other hand, mean facial angle for Black females with SCIII malocclusion was 0.1º smaller than norm, which indicates an orthognathic mandible.

In West Asia, Mouakeh (2001) reported a mean orthognathic mandible depicted by facial angle and SNB, in a group of Syrian children with SCIII malocclusion, consistent with the findings. The Syrian study also found a tendency for posterior inclination of the mandibular ramus, which may have masked mandibular prognathism in their study (Mouakeh, 2001). The effect of rotation or inclination of ramus of mandible was not an objective of the current study.

4.3.3. The maxillo-mandibular relationship

4.3.3.1. The A point-Nasion-B point angle And Angle of Convexity

The ANB and Angle of convexity also show decreased values compared to cephalometric norms. Therefore, in the current study, a mean retrognathic maxilla and orthognathic mandible were found to be sagittal pattern in SCIII subjects. The mean facial convexity in the subjects appears to be reduced, due to retrognathic maxilla. The findings were similar to studies investigating skeletal pattern of SCIII patients in a Syrian population (Mouakeh, 2001, Daraze et al., 2017). Studies are reporting a common finding of mandibular prognathism evaluated by a high mean SNB angle, accompanied by normal maxillary position, in Romania (Zegan et al., 2015). The findings in Romanian study have been supported by those in European countries, which may be linked to 15th-century dominance of Hapsburg family, who were distinguished by a prognathic mandible (Spalj et al., 2008, Staudt and Kiliaridis, 2009)

4.3.4. Racial differences in sagittal parameters

Jacobson and colleagues evaluated pre-treatment lateral cephalometric radiographs of South African patients with Class III malocclusion and reported significantly greater protrusion of

mandible and retrusion of maxilla than in normal Class I malocclusion (Jacobson et al., 1974). In the current study, mandibular prognathism was not found, instead, a decreased SNA angle showed a dominant feature of maxillary retrognathism. Jacobson and colleagues' methodology did not specify ethnicity of the sample, however, cephalometric norms used were those of a Caucasoid population. In the current study, 94% of sample was made up of Black subjects, therefore difference between the two studies may be due to ethnic influences. There are studies in literature indicating a common dominance of a prognathic mandible in SCIII malocclusion, in populations that use Caucasoid cephalometric norms (Spalj et al., 2008, Staudt and Kiliaridis, 2009, Rasool et al., 2015).

4.3.5. Gender differences in sagittal parameters

Comparison of sagittal parameters according to gender revealed slight significant differences in ANB ($p= 0.047$), facial angle ($p= 0.05$), and angle of convexity ($p= 0.044$). Such findings suggested that SCIII female patients have a slightly more concave facial profile with slight chin protrusion than male patients. Although statistically insignificant, the study also revealed a higher mean SNB angle in females, suggesting a slightly more prognathic maxilla. Such findings, however, may be influenced by length of anterior cranial base. South African females tend to have a shorter anterior cranial base which results in a posteriorly positioned nasion in comparison to that in their male counterparts. A posteriorly positioned nasion will therefore result in an increased SNB angle and consequently, a decreased ANB angle, portraying a concave facial profile with mandibular protrusion (Jacobson, 1978).

CHAPTER FIVE: CONCLUSION

5.1. Conclusion

This was a retrospective patient records review looking at sagittal position of both maxilla and mandible on how they relate to one another in patients with Skeletal Class II and III malocclusion. One hundred and fifty cases were assessed, comprising 84 Skeletal Class II and 66 Skeletal Class III patients. The findings of this study, within its limitations, are summarised as follows:

1. Mandibular retrognathism with a normally positioned (orthognathic) maxilla is a common feature in Skeletal Class II patients regardless of racial groupings in this study.
2. The patients in Black racial group tend to portray a more prognathic maxilla and a greater facial convexity than those of White and Indian descent.
3. There were no significant differences between male and female patients in Skeletal Class II, except for a greater Wits appraisal in males
4. The South African Black patients with Skeletal Class III showed a significantly retrognathic maxilla as the cause of sagittal discrepancy.
5. Female patients with Skeletal Class III tend to have a slightly more concave facial profile with slight mandibular protrusion than their male counterparts.

It is therefore important for clinicians to thoroughly assess sagittal dimension of a malocclusion, particularly relating to maxilla and mandible. Identifying problematic jaw in a skeletal malocclusion case will provide clinician with adequate information for diagnosis and therefore contribute to treatment planning of a case. The race of patient should also be considered when assessing relationship of maxilla and mandible as it may influence patient's facial profile.

5.2. Limitations

1. The study sample was lower than required, particularly for White and Indian racial groups. The sample size was too low to allow assessment of race differences in Skeletal Class III malocclusion.
2. A higher-than-desired error of method was observed particularly with Wits appraisal, therefore conclusion regarding Wits appraisal values in this study should be taken with consideration.

5.3. Recommendations

1. To increase study sample, extending the period of study should be considered. Furthermore, patients who are treated in undergraduate clinic and by consultants can be included to increase sample size.
2. To avoid high error of method with Wits appraisal, the recommendation is to repeat digital measurements of functional occlusal plane until there is a 95% level of agreement.

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Appendices

Appendix A: Data collection form

#: Race: Gender:					
PARAMETERS	**BLACKS**	**Norm.**	**CAUCASIANS** **(Whites; Indians)**	**Norm.**	**ANALYSIS**
SNA		87°		82°	
SNB		82°		80°	
ANB		5°		2±2°	
Facial angle		88-90°		88±4°	
Angle of convexity		6.7±4°		0-5°	
Wits Appraisal		-1 – 2mm		0±1 mm	
Skeletal Classification:					

Appendix B: Permission to conduct study at WOHC

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

School of Oral Health Science

Department of Oral Biological Sciences, 7 York Road, Parktown, 2193. Tel: 011 717 2045 Fax: 086 553 3890 Email: Julitha.Molepo@wits.ac.za

23 February 2023

Dr M. Mphahlele
Orthodontics Department
Faculty of Health Sciences
University of the Witwatersrand
Johannesburg

RE: PERMISSION TO CONDUCT RESEARCH

REFERENCE: HRRC/February/03/2023

It is my pleasure to grant final approval to conduct your research at Wits Oral Health Centre titled "Sagittal discrepancies in skeletal class II and class III malocclusions in patients orthodontically treated at Wits Oral Health Centre over a five-year period".

The Hospital Research and Risk Committee allocated a unique reference number to this application – Kindly quote this reference number in all future correspondence regarding this research.

Please note that the Hospital Research and Risk Committee should be informed of the estimated date the research will commence, as well as regular status reports until the research has been concluded. Within a month after conclusion of the research project, a written report must be submitted to the Head of School/CEO, summarizing the final result/outcome as well as the recommendations made based on the research concluded.

Regards,

(pp)

Prof J. Shackleton
Acting Head of School
Date: 23/02/2023

Dr M. Thekiso
Acting CEO
Date: 27/02/2023

Appendix C: Ethics Clearance certificate

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

R49 Dr MB Mphahlele

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M221155

NAME: (Principal Investigator)	Dr MB Mphahlele
DEPARTMENT:	School of Oral Health Sciences Department of Orthodontics Dental School University
PROJECT TITLE:	*Sagittal discrepancies in skeletal Class II and Class III malocclusions in patients orthodontically treated at Wits Oral Health Centre over a five-year period*
DATE CONSIDERED:	2022/11/25
DECISION:	Approved unconditionally
CONDITIONS:	
NOTE:	If contact information regarding student study participants is required, please contact the Registrar's office - <Nicoleen.Potgieter@wits.ac.za>
SUPERVISOR:	Drs M Makofane and V Bomvana
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2023/03/17

This Clearance Certificate is valid for 5 years from the date of approval. An extension may be applied for.

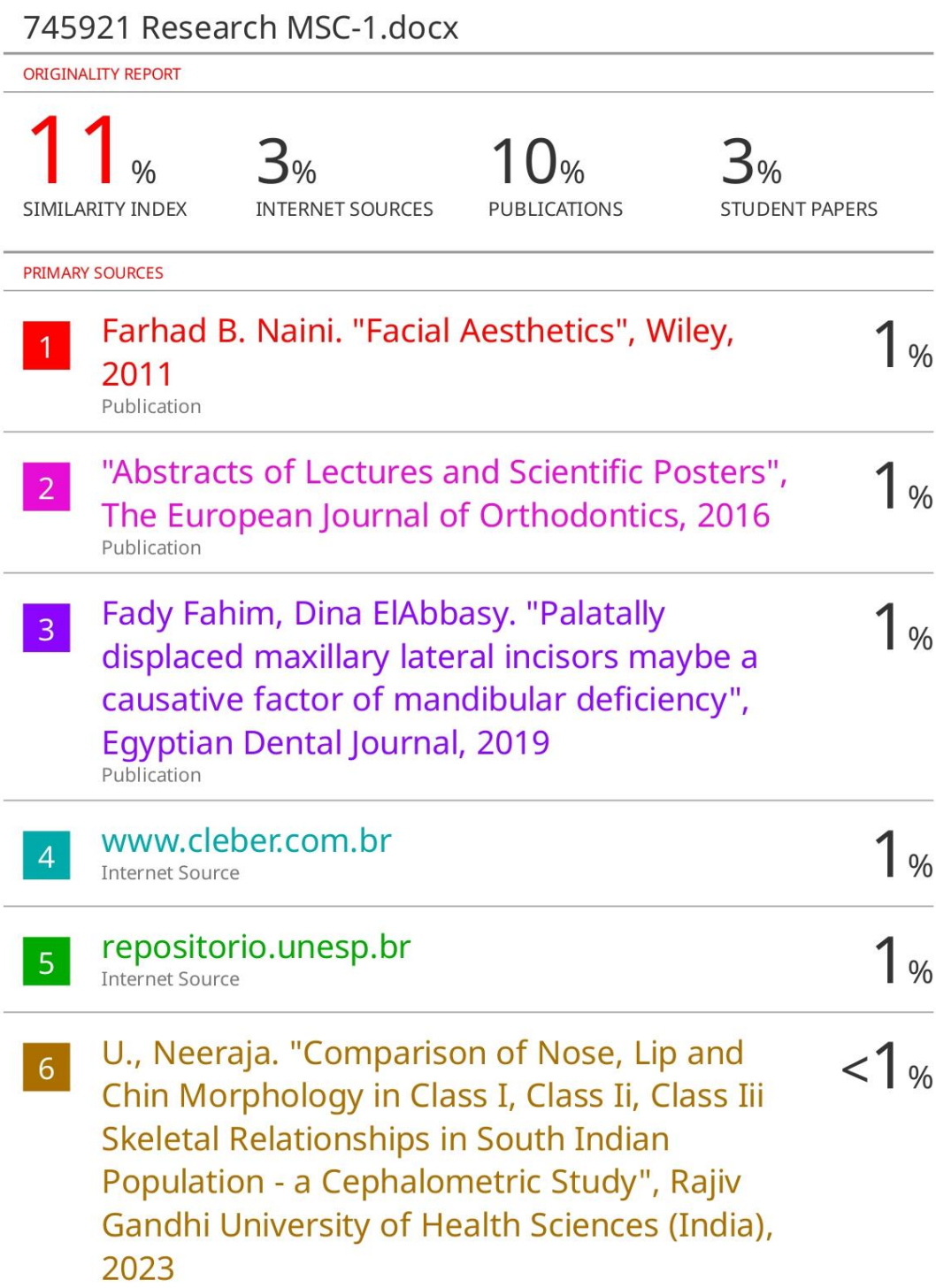
DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office secretariat 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 **November** and therefore reports and re-certification will be due in the month of **November** each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).

Signature of Principal Investigator — Date: 2023/03/18

Appendix D: Turnitin Report



745921 Research MSC-1.docx

ORIGINALITY REPORT

11%	3%	10%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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35	Lahori, Manesh, Rahul Nagrath, and Niti Malik. "A Cephalometric Study on the Relationship Between the Occlusal Plane, Ala-Tragus and Camper's Lines in Subjects with Angle's Class I, Class II and Class III Occlusion", The Journal of Indian Prosthodontic Society, 2013. Publication	<1%

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