EVALUATION OF THE GOLDEN PROPORTION, RECURRING ESTHETIC DENTAL PROPORTION AND THE GOLDEN PERCENTAGE IN A KENYAN POPULATION

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DECLARATION

I declare that this thesis is my original work and has not been presented for the award of a degree or any other qualification of this or any other University.

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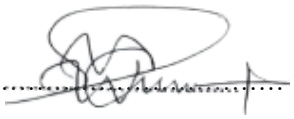
Signature:  **Date:** 24th June, 2023

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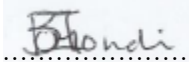
Signature:  **Date:** 24th June, 2023

DEDICATION

This thesis would not have been fruitful were it not for the support and guidance of several people. Among them is my dear husband and my family. I dedicate this thesis to them for their immense contribution to my success and for acting as a source of inspiration.

ACKNOWLEDGEMENT

First and foremost, I would like to thank the Almighty God for His enabling grace to carry out this study. His grace has been sufficient to me throughout my studies.

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LIST OF ABBREVIATIONS

BDS	:	Bachelor of Dental Surgery
CHS	:	College of Health Sciences
CI	:	Central Incisor
COVID-19	:	Coronavirus Disease 2019
DDS	:	Department of Dental Sciences
DSLR	:	Digital Single-lens reflex
GPT-9	:	Glossary of Prosthodontic Terms, ninth edition
IBM	:	International Business Machines Corporation
ICC	:	Interclass Correlation Coefficient
ICD	:	Inter-Canine Distance
LI	:	Lateral Incisor
MDS	:	Master of Dental Surgery
mm	:	Millimeters
MSc.	:	Master of Science
Nbi	:	Nairobi
NHP	:	Natural head position
PGS	:	Postgraduate Studies
PI	:	Principal Investigator

PPE	:	Personal Protective Equipment
RED	:	Recurring Esthetic Dental
SCI	:	Science
SPSS	:	Statistical Package for Social Sciences
UoN	:	University of Nairobi
WHO	:	World Health Organization
WHOQOL	:	World Health Organization Quality of Life

DEFINITION OF TERMS

Most of the terms defined herein were sourced from the Glossary of Prosthodontic Terms, ninth edition [1].

Aesthetics - the branch of philosophy dealing with beauty; in dentistry, the theory and philosophy that deal with beauty and the beautiful, especially with respect to the appearance of a dental restoration, as achieved through its form and/or color; those subjective and objective elements and principles underlying the beauty and attractiveness of an object, design, or principle.

Aesthetic dentistry - A procedure in dentistry that involves the application of principles of aesthetics to the natural or artificial teeth and restorations.

Anterior teeth - This refers to the maxillary and mandibular incisors and canines.

Maxillary anterior teeth - This refers to the maxillary central incisors, lateral incisors and canines.

Golden Proportion - The ratio between succeeding terms in a mathematical progression defining dimensions between larger and smaller length [2].

Golden Percentage - A measure of an individual tooth by dividing the width of each central incisor, lateral incisor and canine width by the total width of all the six maxillary anterior teeth and multiplying the resulting value by 100.

Recurring Esthetic Dental (RED) proportion - A measure of the ratio of the average width of maxillary lateral incisor to central incisor and that of the average width of maxillary canine to lateral incisor.

ABSTRACT

Background: One of the aims of Contemporary Aesthetic Dentistry in the 21st century is to ensure maintenance of symmetrical proportions between the widths of maxillary anterior teeth during replacement of missing teeth and/or restoration. Patients seeking dental treatment consider aesthetic proportions in maxillary anterior teeth a vital consideration [3]. Their primary concern is the creation of harmonious proportions between the widths of maxillary anterior teeth when restoring or replacing them based on their individual and specific needs [4]. In the search to create aesthetically pleasing restorations, these concerns have significantly improved steadily over the last decade through enhanced and more aesthetic materials, techniques and emerging technologies, albeit challenges [3]. Possibilities to address these concerns have been enabled whereby various mathematical proportions have been suggested in a bid to describe and/or relate the successive widths of maxillary anterior teeth [4]. These include the Golden Proportion [5], the Recurring Esthetic Dental (RED) proportion [6] and the Golden Percentage [7]. These proportions are important theoretical guidelines in aesthetic dentistry for the restorations and replacement of missing maxillary anterior teeth. The existence of these proportions have been tested among subjects of European and Asian origin [6,8,9]. The only study among the African population done in Cote d'Ivore, found no correlation between the teeth of the participants and the Golden Proportion [10]. While the Golden percentage and the Recurring Esthetic Dental (RED) Proportion were not evaluated. Therefore, the need for this study.

Objective: The aim of this study was to evaluate the existence of the Golden Proportion, the Recurring Esthetic Dental (RED) Proportion and the Golden Percentage and to determine their validity among Kenyans of African descent with natural well aligned teeth.

Materials and Methods: This study adopted an analytical cross-sectional research design. A total of 175 participants aged 18 – 35 years from the University of Nairobi, Faculty of Health Sciences (Departments of Dental Sciences, Nursing Sciences and Pharmacy) and patients visiting University of Nairobi Dental Hospital were recruited into the study. The participants were selected through simple random sampling method following the inclusion and exclusion criteria. The participants were briefed orally about the study and its objectives and requested to read and sign consent forms by PI.

Standardized frontal photographic images of the smile of 175 participants were taken in the Conservative Dentistry Clinic at the University of Nairobi Dental Hospital and the lecture halls in Kenyatta Campus and Chiromo Campus under natural lighting between 10am and 12 noon by PI using calibrated Nikon D3400 Camera, AF-S VR MICRO NIKKOR, 105 mm lens and a Nissin MF18 macro ring flash on a camera tripod from a distance of 60cm from the participants. The photographic images taken were coded per participant and transferred to a personal computer where a back-up file was created. Adobe Photoshop 7 software (Adobe Studios, USA) was used to analyse and take measurements of the frontal widths of maxillary central, lateral incisors and canines in triplicates. The Inter-canine distance of every 10^{th} participant was selected for inter-examiner validity. Interclass Correlation Coefficient was used to evaluate the capacity of agreement amongst two sets of measurements obtained from the principal investigator and the lead supervisor. Average widths of maxillary central and lateral incisors and canines were calculated and used to determine the existence and validity of the Golden Proportion, the Recurring Esthetic Dental (RED) proportion and the Golden Percentage theories.

Data analysis and presentation: Quantitative data was entered into Microsoft excel sheets, cleaned-up and analysed using the Statistical Package for Social Sciences (SPSS), version 22 (IBM Corporation). Data obtained was used to calculate frequencies, means and standard deviations of various variables and inferences were drawn from the values obtained. The validity test on the existence of the Golden Proportion, the RED Proportion and the Golden Percentage among Kenyans of the African descent with natural well aligned teeth was calculated using the Z-score/Z-statistics. A value of $\alpha=0.05$ was considered statistically significant. The results were presented in form of frequency tables, pie charts, and bar graphs.

Results: Out of the 175 participants, 107 (61.1%) were male while 68 (38.9%) were female. The mean age of all the participants was 22.4 ± 3.5 years. Majority of the participants **(**81.7%) were aged between 18 – 25 years. The Golden Proportion between maxillary central incisors and lateral incisors was found in 1.1% of both male and female participants; the Golden Proportion between maxillary lateral incisors and canines was

not found in both male and female. RED Proportion between maxillary lateral incisor and central incisor was found in 67.2% - 69.5% range, and RED Proportion between canine and lateral incisor was found in 81.5% - 84.0% range. The value of RED proportion was not constant and gradually increased moving distally. Further, the Golden Percentage was rather constant relative to tooth width. The width of the central incisor representing 22%, the lateral incisor 15%, and the canine 13% of the width of the six maxillary anterior teeth as viewed from the front.

Discussion: The present study intended to evaluate the existence of the Golden Proportion, the RED Proportion and the Golden Percentage and to determine their validity among Kenyans of the African descent with natural well aligned teeth. The findings of the present study revealed poor correlation between tooth dimensions and the Golden Proportion. These findings are similar to the findings reported from the previous studies [15,16,31,62]. Further the RED Proportion, was found not be constant and the ratio between central and lateral incisors and between lateral incisors and the canine increased distally, suggesting that the RED Proportion seem not to exist in natural dentition. These findings are similar to the findings reported by other investigators [9,14-16,62,63]. In addition, the present study found that the Golden Percentage exists in lateral incisors whose value corresponds to that proposed by Snow [7]. The findings of the present study revealed that the Golden Percentage theory in relation to lateral incisors was more applicable to the participants of this study. However, the width of the central incisors and the canines did not correspond with the values proposed by Snow [7]. Fayyad et al. [15] recommended a value of 23% for centrals, 15% for laterals, and 12% for canines and Murthy and Ramani [9] recommended a value of 22% for centrals, 15.5% for laterals, and 12.5% for canines [9,15].The findings of this study showed that the width of the central incisors is slightly smaller (22%) than that recommended by Fayyad et al. [15] while the width of the canines is slightly larger (13%). In the present study, a value of 22% for central incisors, 15% for lateral incisors, and 13% for canines can be adopted, as these percentages are more applicable to the natural dentition of Kenyan population of African descent.

Conclusion: Within the limits of this study, it can be concluded that the Golden Proportion, RED Proportion and the Golden Percentage theories were invalid determinants of anterior teeth proportions among Kenyans of African descent with natural well aligned teeth. Therefore, the Golden Proportion, RED Proportion and the Golden Percentage may not be used to formulate a smile design of all populations. Rather, the dental proportions should be considered based on a racial and ethnic background of a population.

Recommendations: From the findings of this study, the PI recommends that racial and ethnic background in different geographical regions should be considered to establish objectively quantifiable values helpful in aesthetic restorations.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Principles of aesthetic dentistry

Aesthetic dentistry is the branch of dentistry concerned with the preservation or restoration of a pleasing appearance of the teeth visible when the oral cavity is open. Obviously, this is an important goal of any restorative treatment in this zone. Dental aesthetics is a major contributor of oral health seeking behavior of patients globally. This may be driven by: dental diseases such as dental caries; discolorations arising from conditions such as dental fluorosis; developmental dental defects such as amelogenesis and dentinogenesis imperfecta; malocclusion; and, oral and maxillofacial trauma. Apart from the unsightly appearance, these conditions may also lead to tooth loss or edentulism, necessitating treatment by fixed or removable dental prostheses. Aesthetic dental treatment and rehabilitation is a major component of contemporary dental practice globally and is exceedingly costly more so in developing countries [17].

Teeth proportions have always been a major concern for dentists and dental technicians when considering aesthetic aspects of dentistry. Over the years, it has been reported that facial aesthetics are most pleasant when the width of central to lateral incisors and lateral incisors to canines have a repeated proportion when viewed from the front [18]. Facial aesthetics is also enhanced when maxillary anterior teeth are dominant in the smile arch [19].

There are various methods used to measure the size and form of maxillary anterior teeth. Some of the proposed theories include the use of the Golden Proportion, the Golden Percentage and Recurring Esthetic Dental (RED) Proportion. These measurements were introduced as important concepts to contemporary aesthetic dentistry in the 21st century and are thought to be critical guidelines aimed at ensuring symmetrical proportions between the widths of maxillary anterior teeth during restoration and replacement [8]. Snow [7] reasons that there are several factors affecting the symmetry, dominance, and proportion of maxillary anterior teeth; therefore, the restorative dentist must consider the patient's subjective concerns when designing a natural smile along with the objective criteria [19].

According to Chiche and Pinault [20] and Rufenacht [21], careful scientific analysis of beautiful smiles has revealed repeatable, measurable, objective principles that can be applied to evaluate and improve dental aesthetics. Mancuso [22] stated that many authors have advocated using geometric or mathematical proportions to aid in establishing a mathematical model to improve dental aesthetics in predictable ways. There are various methods, models/guidelines used to measure the size and form of maxillary anterior teeth, including the Golden Proportion, the Golden Percentage and Recurring Esthetic Dental (RED) Proportion.

The size and form of maxillary anterior teeth are important to both dental and facial aesthetics [23]. There is however minimal scientific information in literature to use as a guide for choosing the proper size and shape of anterior teeth or even determining the normal relationships of these teeth among Africans.

1.2 The Golden Proportion

The Golden Proportion is known as mathematics of harmony since the ancient past. This is regarded as the blueprint for topographies in nature, art, architecture and humans for harmony and beauty [24]. Originally from the Greeks, the Golden Proportion is a mathematically constant ratio that defines the dimensions between larger and a smaller length. The proportion of the bigger part to the smaller part is 1.618:1.0 [25]. This relation between a smaller and a larger dimension is ideal and desirable for an aesthetic appearance. This Golden Ratio is a valuable tool for the evaluation of symmetry and dominance and is known as the standard for perfect beauty [25].

This study was modelled on the theory of the Golden Proportion advanced by Lombardi in 1973 [16]. Lombardi [16] was the first to suggest the application of the Golden Proportion in dentistry and it was later accepted as an aesthetic guideline for restoration of teeth. He proposed the existence of having proportionate teeth but rejected the idea of using Golden Proportion to create aesthetic teeth [26]. In his observation, Lombardi noted that a recurring ratio existed between all the teeth from the central incisor to the first premolar. The theory was used by Levin in 1978, in a study on dental aesthetics and the Golden Proportion, in a view to study the frontal widths of the maxillary anterior teeth and determine their relationship [5]. Levin [5] was the first to observe that the width of maxillary central incisor is in Golden Proportion to the width of the lateral incisor and width of lateral incisor is in Golden Proportion to the width of canine. The finding of the study showed that the visible width of the lateral incisor is 62% (0.618) of central incisor and the visible width of canine is 62% (0.618) of lateral incisor [27]. Later, Levin developed a tooth caliper based on this

observation. This proportion has been combined in a grid, called the diagnostic grid or the Golden Proportion grid which can be used to assist in perfecting the aesthetics of the anterior teeth [5]. Thus, since the introduction of the Golden Proportion, it has been largely accepted as an aesthetic guideline for restoration of anterior teeth [11,21,28,29].

The Golden Proportion theory postulates that if we take the lateral incisor as a factor of 1, then the central incisor would be 1.6. In addition, the visible part of that canine, usually the mesial part of the canine in that front photographic view, would be 0.6 [5,24,30].

Ward [6], Snow [7] and Preston [13] on their part contradicted the validity of the Golden Proportion theory of the maxillary anterior teeth. These authors proposed alternative principles for the aesthetic restoration of teeth in the frontal region: the Golden Percentage [7], Preston's Proportion [13] and the Recurring Esthetic Dental Proportion [6].

1.3 The Golden Percentage

Snow [7] in 1999 considered an analysis of individual tooth width where there is fixed proportion of each tooth's frontal view as percentage of the visible inter-canine width. He christened this the Golden Percentage and described it as: right canine 10%, right lateral incisor 15%, right central incisor 25%, and, left central incisor 25%, left lateral incisor 15%, left canine 10% [7].

1.4 Recurring Esthetic Dental (RED) Proportion

Ward [6] in 2001 introduced the Recurring Esthetic Dental (RED) Proportion after studying the Golden Proportion and finding that the lateral incisor appeared narrow and the canine

not prominent enough. He stated that clinicians may use a proportion of their choice as long as it remained consistent proceeding distally from the midline [6]. The Recurring Esthetic Dental (RED) Proportion is a measure of the average width of maxillary lateral incisor to central incisor and that of the average width of maxillary canine to lateral incisor. Values of the RED Proportion used are between 60-80% [25].

1.5 Summary and proposal guideline

From the aforementioned, it is clear that dental aesthetic guidelines are an important consideration during aesthetic restorative dental treatment. Several theories have been presented and tested and mostly among Caucasians and Asians; however, their validity remains questionable. Further, their existence and validity among Africans is unknown with scarce information on the same.

Due to increasing demand of aesthetic treatment among this population, including those in Kenya, local studies are necessary to increase the knowledge base on the same. This will not only improve patient care but also provide useful evidence for reference in future relevant studies. Therefore, the aim of this study is to evaluate maxillary anterior teeth proportions to determine the existence of aesthetic guidelines, specifically, the Golden Proportion, the Recurring Esthetic Dental (RED) Proportion and the Golden Percentage in a Kenyan population.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter focuses on three themes:

1. The relevance of maxillary teeth proportions in aesthetic dentistry.
2. The evaluation of the existence of the Golden Proportion, the Recurring Esthetic Dental (RED) Proportion and the Golden Percentage and the validity of these three maxillary anterior teeth proportions among Kenyans with natural and aesthetic smiles.

2.2 Maxillary anterior teeth proportions

Maxillary anterior teeth are dominant in the smile arch [19] and have significant impact in aesthetic dentistry. The facial aspects of these teeth have wide visibility when smiling [31]. These teeth are important in achieving pleasing dental aesthetics which is the primary consideration for patients. Al-Marzok *et al.* [32] emphasizes that the size and form of the maxillary anterior teeth are important not only to dental aesthetics, but also facial aesthetics. Thus, the creation of a harmonious proportion when restoring or replacing these teeth is of critical importance in aesthetic dentistry. Sulaiman *et al.* [31] and Wagh *et al.* [19] also note that dentists treating patients with missing or badly damaged anterior teeth, must determine the shape of the tooth and its proportion as well as the patient's subjective concerns when designing a natural smile along with the objective criterion to achieve optimal results.

Even with increased patient cosmetic demands, new materials and techniques have been introduced maximizing the likelihood of achieving optimal results [32-34]. Several authors [6,7,13,25] have advocated using geometric or mathematical proportions to aid in establishing a mathematical model to improve dental aesthetics in predictable ways. There are various such models or guidelines used to measure the size and form of maxillary anterior teeth, including the Golden Proportion, the Golden Percentage and the Recurring Esthetic Dental Proportion.

These methods have been described in literature as aesthetic guidelines or models or theories not only useful for restoring but also for replacing maxillary anterior teeth [23]. They are proportions to guide in aesthetic selection of the size of maxillary anterior teeth. There is a lot of research that has been conducted in relation to maxillary anterior teeth proportions. The review of the literature seeks to highlight the various aspects of the research on the anterior teeth proportions. It is noteworthy that most of these evaluations have been conducted among Caucasian and Asian subjects. Therefore, there is need for information to determine the relevance of the same among African populations.

2.2.1 Golden Proportion

The Golden Proportion is based on the theory that a relationship exists between aesthetically proportional parts [5,14,23,26]. These authors noted that this relationship exists between beauty in nature and mathematics. This guideline has been proposed in scholarly literature as an aesthetic guideline for restoring and replacing maxillary anterior teeth [11,21,28,29].

The Golden Proportion was first introduced to dentistry by Lombardi [26] in 1973. He described the proportion of the width of lateral incisors to central incisors and the width of the canines to the lateral incisors following a constant ratio. Lombardi [26] stated that the existing proportion between the width of the central incisor and the lateral incisor should be constant, progressing from the anterior to the posterior teeth [31]. As a result, the dental and facial aesthetics are optimized if the proportion between widths of maxillary anterior teeth is repeated when the patient is viewed from the front [32].

Similarly, Levin [5] introduced the use of the Golden Proportion in order to relate the successive width of maxillary anterior teeth as viewed from the facial aspect. He stated that the width of the central incisor should be in Golden Proportion to the width of the lateral incisor and similarly, the width of lateral incisor should be in Golden Proportion to the width of the canine [31]. When applied to smile design, the width of the maxillary lateral incisor, from the frontal view, should be in Golden Proportion to the width of the maxillary central incisor. The visible width of the maxillary lateral incisor should be 62% (0.618) of maxillary central incisor while the visible width of maxillary canine should be 62% (0.618) of maxillary lateral incisor [31,32,35]. This repeated ratio has been used by dental practitioners to determine the proportion of maxillary anterior teeth to achieve an aesthetically optimal restorative result, as shown in Figure 2.1.

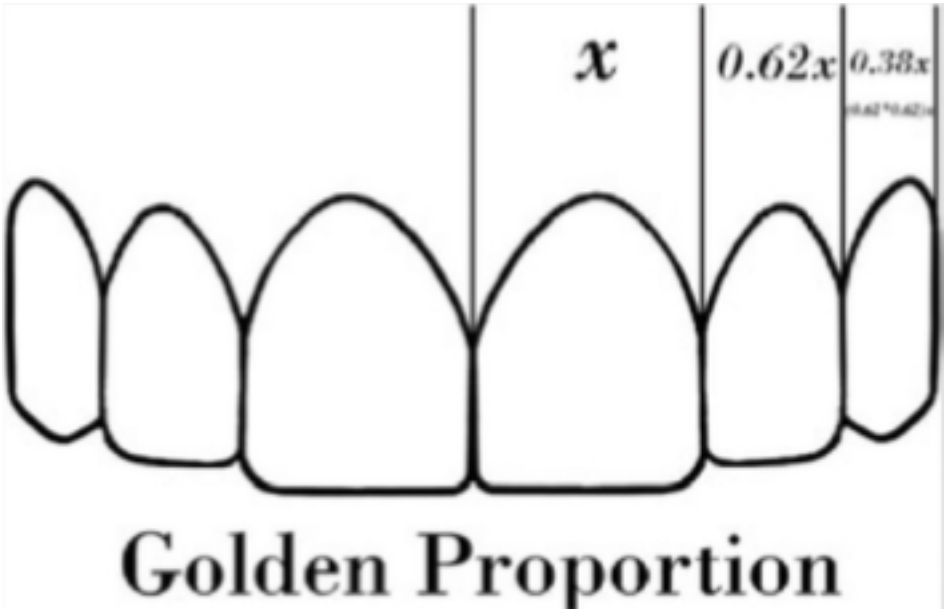


Figure 2.1: Illustration of the Golden Proportion in maxillary central and lateral incisors, and canines
(**Source:** Aziz and Hossain [16])

In the search for more aesthetic restorations, the Golden Proportion, introduced by Lombardi [26], has been proposed and used as an aesthetic guideline for restoring and replacing maxillary anterior teeth. Several studies have evaluated the existence and validity of the Golden Proportion.

Markovics *et al.* [36] conducted a study on aesthetic principles of the upper front teeth: application of Golden Proportion [5] and Golden Percentage [7] in a bid to examine the presence of the Golden Proportion provided by Levin [5, 27] and of the Golden Percentage provided by Snow [7]. The results revealed that the Golden Proportion between the lateral and the central incisor occurs in a higher proportion than between the canine and the lateral incisor. It was also reported that the values obtained by analyzing the Golden Percentage differ slightly from those proposed by Snow [7]. They concluded that with small

modifications and taking into account the ethnic differences, Snow's Golden Percentage is more valid and applicable than Levin's Golden Proportion.

Sulaiman *et al.* [31] conducted a study on the existence of Golden Proportion in maxillary anterior teeth of University of Malaya dental students. The study revealed that there was a statistically significant difference between the width of the right lateral incisors and 62% of the width of the right central incisors. It was observed that only 19% of the subjects had their right lateral incisors in Golden Proportion with the width of their right central incisors, of which 12.5% were male and 20.3% were female (p=0.00). In the study, a significant difference also existed between the width of the right canines and 62% of the width of the right lateral incisors. It was observed that only 17% of the subjects had the width of their canines in Golden Proportion with the width of their right lateral incisors, of which 23.1% were male while 12.2% were female (p=0.00).

Preston [13] in 1993 studied the existence of the Golden Proportion in individuals with natural dentition and found that only 17% of the maxillary lateral incisors were in Golden Proportion with the width of the maxillary central incisors. However, the Golden Proportion did not exist between the widths of the canine and that of the lateral incisors [7,8]. Further, similar finding were reported by Murthy and Ramani in their study on Golden proportion and Golden percentage among students of Asian origin. Sandeep *et al.* [35], Parnia *et al.* [34] and Mahshid *et al.* [8] studied the existence of the Golden Proportion among participants with natural dentition. All these researchers reported that the Golden Proportion did not exist within their study subjects.

It can therefore be concluded that the Golden Proportion existence is uncommon [7-9,15,34, 35, 37,38] and may not be essential for the perceived attractiveness of the smile.

Other scholars, namely Fayyad *et al.* [15] studied Geometric and mathematical proportions and their relations to maxillary anterior teeth. They concluded that the Golden Proportion did not exist in natural dentition and therefore was unsuitable method to relate the successive widths of the maxillary anterior teeth. Moreover, the only reported study among African subjects by Pesson *et al.* [10] found no correlation between the dimensions of the upper anterior teeth of the Ivorian melanoderm and the Golden Proportion. This assessment of the Golden Proportion is clear evidence that the existence and validity of this measurement remains questionable because it has not been found to be reproducible among subjects of various racial backgrounds. It is therefore necessary to carry out more studies on other African populations to grow and increase the knowledge base on the Golden proportion.

2.2.2 Recurring Esthetic Dental (RED) Proportion

The Recurring Esthetic Dental (RED) Proportion is a concept of proportional smile design based on a linear coefficient progression in which the width of each successive tooth as viewed from the front diminishes by the same proportion. The width of the lateral incisor is reduced by a selected percent from the width of the central incisor, and the width of each tooth distally is reduced by this same percentage from its mesial tooth.

Ward [6] proposed Recurring Esthetic Dental (RED) Proportion based on the different heights of the upper anterior teeth. He suggested that clinicians could use any of their

preferred RED Proportions if the ratio remained constant and proceeded distally from the midline. The RED Proportion offers great flexibility to match the features of teeth with facial proportions. Once the size of the central incisor is selected, it is multiplied by the selected RED Proportion to determine the frontal view width of the lateral incisor which is then multiplied by the same RED Proportion to determine the frontal view width of the canine [39]. The commonly used proportions range from 60-80% [25] as shown in Figure 2.2.

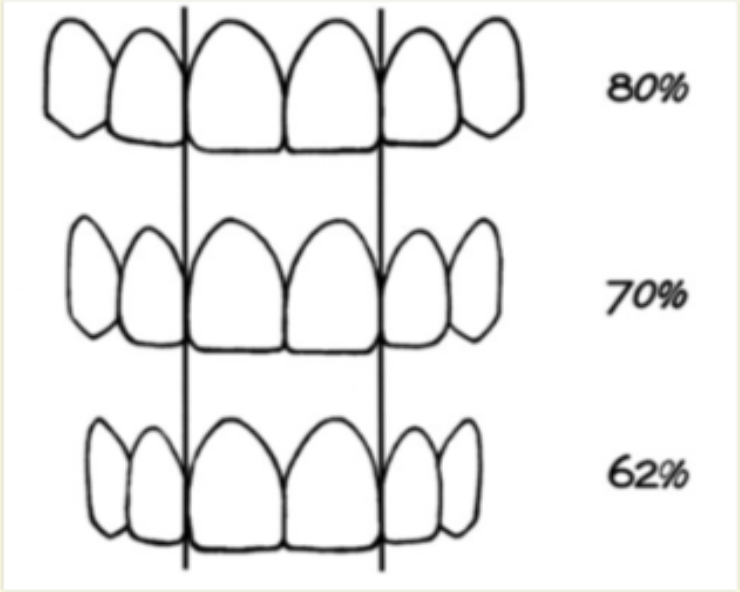


Figure 2.2: Illustration of the RED Proportion in maxillary central and lateral incisors, and canines
(**Source:** Dashti M *et al*. [18])

The Golden ratio is one of the RED Proportions for "tall" maxillary teeth. Ward [38] in his study on dentists' preferred proportions stated that when the Golden Proportion was used, the lateral incisor appeared too narrow and the canine was not prominent enough. He revealed that majority of dentists in North America preferred smiles created using the RED Proportion.

Fayyad *et al.* [15] conducted a study on geometrical and mathematical proportions and their relations to maxillary anterior teeth. The aim of the study was to investigate the existence of the Golden Proportion, RED Proportion, and the Golden Percentage between the widths of the maxillary anterior teeth in individuals with natural dentition of the Arabic origin. In their study, they took standardized frontal images of the smiles of 376 dental students. The images were transferred to a personal computer, where the widths of the maxillary anterior teeth were measured and calculated. The results revealed that the values of the RED Proportion were not constant, and the farther one moves from the midline the higher the values. They concluded that the theory of the Golden Percentage was found to be more applicable if the percentages are adjusted taking into consideration the ethnicity of the population.

Similarly, Murthy and Ramani [9] evaluated the relationship between the average width of maxillary lateral incisor to central incisor and that of the average width of maxillary canine to lateral incisor. The results of the study revealed that the ratio between central and lateral incisors and between lateral incisor and canine was not constant. However, the ratio increased as one moves distally. They concluded that the RED Proportion was not found to exist between maxillary anterior teeth since there was no evidence in the study to support the RED Proportion theory as applied to natural dentition.

Moreover, Shetty *et al.* [14] evaluated the existence of the RED Proportion in a group of Indian subjects with pleasant smiles. The teeth were divided into three categories, “small”, “medium” and “tall” based on the heights of the central incisors. The findings showed that from the three categories, none of the lateral incisor to central incisor width ratios

was similar to the RED Proportion. The ratios were also not similar to the canine to lateral incisor ratio. These findings were similar to those obtained by Murthy and Ramani [9] among students of Asian origin with natural dentition. Murthy and Ramani [9] concluded that the RED Proportion was non-existent in individuals with natural dentition. However, in this study, the theory of the Golden Percentage was found to be more applicable to the study individuals.

2.2.3 Golden Percentage

The Golden Percentage proposed by Snow [7] analyses the widths of individual maxillary anterior teeth as a percentage of the total frontal width of the six anterior teeth. According to this theory, the canine, lateral incisor and central incisor are 10%, 15% and 25% of the total width of all six maxillary anterior teeth, as shown in Figure 2.3.

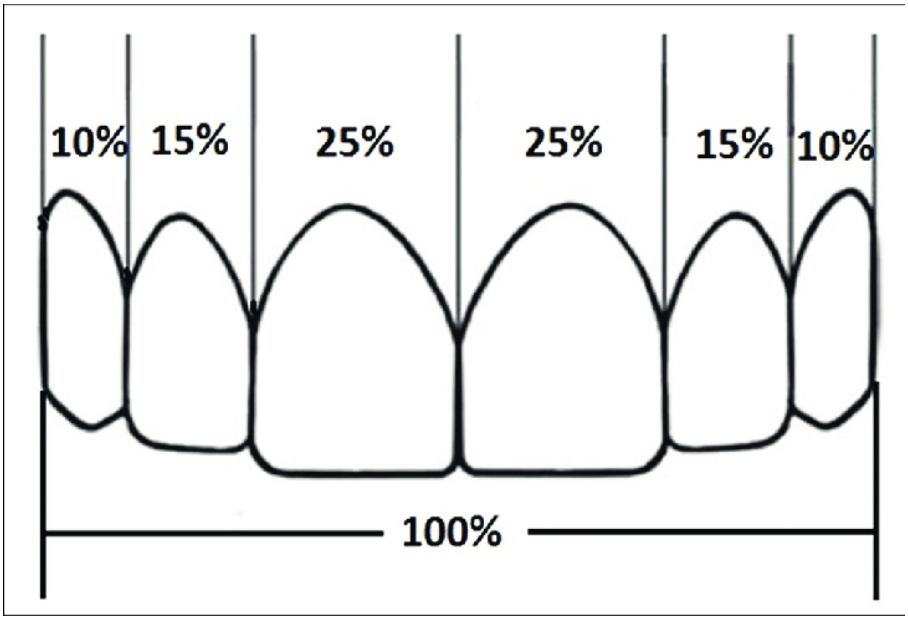


Figure 2.3: Illustration of the Golden Percentage in maxillary central and lateral incisors, and canines
(**Source:** Aziz and Hossain [16])

In the clinical application of smile design, the arch form determines the relative width proportion of anterior teeth. Snow [7] discovered that narrower arch would have relatively larger central incisors and relatively narrower canines, more closely resembling the theoretical Golden Percentage. He compared this with the wider arch form which had relatively narrower central incisors and relatively wider canines and found that this relation less closely approximates the Golden Percentage.

It is likely that an individual's anthropometric measurements, determined by the genetic make-up, influences the existence or absence of the Golden Percentage of their maxillary anterior teeth. Strict adherence to the Golden Percentages produces values of 10%: 15%: 25%. These ratios have however been reported to produce an undesirable central incisor dominance [41].

Murthy and Ramani [9] evaluated the existence of the Golden Percentage on 56 subjects with natural dentition of the Asian origin. Standardized frontal images of the subjects were taken and each image digitally measured. The values of the lateral incisor were in agreement with those suggested by the Golden Percentage theory. However, the figures obtained for the central incisor were slightly lower while the canines had a slightly higher value than those suggested by Snow [7].

In another study Mahak *et al.* [40] evaluated the Golden Percentage in standardized photographs of 100 subjects of North Indian population using a computer software. They found the Golden Percentage to be applicable in over 99% of the subjects.

Preston [13] however did not find any examples of the Golden Percentage in any of the participants in his study which was supported by Markovics *et al.* [36] whose findings failed to confirm the applicability of Snow's theory of Golden Percentage. However, both groups concluded that with minor modifications, the Golden Percentage is more applicable than the Golden Proportion. Fayyad *et al.* [15] also arrived at similar conclusion stating that, the Golden Percentage theory is more applicable to relate the successive widths of the maxillary anterior teeth if the percentages are adjusted taking into consideration the ethnicity of the population.

From these findings, therefore, it remains unclear which of these maxillary anterior teeth proportions is valid, especially for African populations where data is scarce to non-existent. The genetic and anthropometric variation of Africans in comparison to that of other study subjects is an interesting perspective from which to approach investigations on the existence and validity of these anterior tooth proportions for aesthetic dental considerations.

2.3 Aesthetic dentistry and aesthetic guidelines determined from tooth proportions

Dental appearance is an important component of pretty faces and beautiful smiles in modern society [42]. This kind of beauty is also known as aesthetics and refers to "a perceptual experience of pleasure or attraction" [43]. According to Alhammadi *et al.* [43] aesthetics is the true value behind attraction thus a fundamental motive for patients seeking dental treatment. In the past, functional demands were the major reason for seeking dental treatment. This has changed over time and dental aesthetics has persisted

in the routine work of dentists and has become a preferred reason for several patients seeking dental treatment in modern society [44,45]. Some of the main contributing factors of dental aesthetics include the shape, color and the arrangement of the maxillary anterior teeth [23]. Thus, an understanding of the factors that affect the attractiveness of pretty faces and beautiful smiles is an important step in creating beautiful and attractive smiles [46].

The aim of dental aesthetics is to create beauty, making the patient satisfied and improving self-esteem [47,48.] Arguably, to achieve ideal dental aesthetic outcomes, consideration of aesthetic guidelines and principles cannot be over emphasized [45]. Smile design is the intentional evaluation of the presence and absence of desired aesthetic features of a smile and the precise application of dental treatment to achieve the desired results. These features include the axial inclination of anterior teeth, incisal embrasure, incisal edge placement, gingival emergence patterns, dominance [49] and symmetry [20] among others. The collective influence of these aesthetic features creates the final impact of a smile [42].

Visual dominance of a tooth in the arch is determined by its relative proportions of width and height and its position within the dental arch. The dental arch is curved. On progressing distally, less of each tooth is visible when viewed from the front. The central incisors are the widest anterior teeth. This, combined with their location at the front, makes them the most predominant teeth hence are the focus of most dental aesthetic considerations [26].

Anterior tooth proportions are therefore an important consideration in aesthetic dental treatment. A study by Ariemba *et al.* [50] investigated the correlation between inner canthal width and the mesio-distal widths of the maxillary anterior teeth in a Kenyan population

of African descent. This study, however did not measure the teeth proportions among the Kenyan population. There is therefore scanty information on the existence of the theories of the Golden Proportion, the Recurrent Esthetic Dental (RED) Proportion and the Golden Percentage among Kenyans of African descent.

2.4 Maxillary anterior tooth proportions among Kenyan populations

Although several theories on aesthetic dental guidelines have been proposed, questions on their validity and relevance abound. There are some conflicting reports which indicate that majority of the smiles considered aesthetic do not coincide with the Golden Proportion [6,8,13,51]. Further, Fayyad *et al.* [15] and Murthy and Ramani [9] concluded that the RED Proportion did not exist in upper anterior teeth in the natural dentition. It is noteworthy that majority of the studies evaluating the existence and suitability of maxillary anterior teeth proportions have been performed among the European and Asian population [6-9,23,51,52].

In one study, Pesson MD *et al.* [10] investigated the existence of the Golden Proportion among a Melanoderm population in Cote d'Ivoire. They concluded that there was no correlation between the teeth of the study subjects and the Golden Proportion. Further, the only similar study conducted among the Kenyan population, measured the relationship between the nasal, inner-canthal and mesio-distal widths of the maxillary anterior teeth but did not consider the teeth proportions[50].

2.5 Literature Gap

The demand for aesthetic restorative dental treatment, both fixed and removable, is on the rise globally with different studies having found an important consideration to anterior teeth proportion guidelines. Consequently, in recent years there has been an increased focus on the application of the Golden Proportion, the Golden Percentage and the Recurring Esthetic Dental Proportion as established guidelines to improve and provide predictable dental aesthetics. These guidelines are useful for restoring, and replacing maxillary anterior teeth, including among patients in Kenya. They are also, an essential guide in the selection of the size of maxillary anterior teeth [23,32].

Prior studies have widely investigated the Golden Proportion, the Golden Percentage and the Recurring Esthetic Dental Proportion and their relation to maxillary anterior teeth [6,8,9,13,15]. However, the results obtained are inconclusive or even contradictory. Consequently, many scholars have concluded that these proportions remain questionable and may not be essential for the perceived attractiveness of the smile because their validity is indistinct and uncommon, pointing to need for further research in that area [34,36-38,53]. In this study, the researcher seeks to evaluate the existence of the Golden Proportion, the Recurring Esthetic Dental (RED) Proportion and the Golden Percentage as well as determine their validity among Kenyans of African descent with natural well aligned teeth.

CHAPTER THREE

3.0 PROBLEM STATEMENT, JUSTIFICATION AND OBJECTIVES OF THE STUDY

3.1 Problem statement

There is increased awareness of aesthetic dental treatment among patients today. This has resulted in patients seeking to resolve common aesthetic dental concerns including the contour, colour and alignment of teeth. Alignment of teeth is commonly addressed through orthodontic treatment. However, the form, size, and shape of teeth can only be changed through restorative procedures.

The Golden Percentage, the Golden Proportion and the Recurring Esthetic Dental (RED) Proportion are some of the theories commonly applied in smile design. Further, they are also commonly used in replacement and restoration of teeth. However, there is conflicting information about their existence and validity among patients with natural aesthetic smiles. Furthermore, these theories have mostly been tested among subjects of European and Asian origin.

There is scarcity of information in literature that has evaluated the existence of the Recurring Esthetic Dental (RED) Proportion and the Golden Percentage among subjects of African descent, including in Kenya. The only study available was carried out in Cote d'Ivore among subjects of African descent which found no correlation between the teeth of the subjects involved and the Golden Proportion. Therefore, the purpose of this study is to contribute to this scarce knowledge base by evaluating the existence and validity of

the Golden Proportion, Recurring Esthetic Dental (RED) Proportion and the Golden Percentage among the Kenyan population of African descent.

3.2 Justification of the study

The comparison of the frontal width of teeth within the dental arch reveals a regressive series [52]. The Golden Percentage, the Golden Proportion and the Recurring Esthetic Dental Proportion are some of the theories applied during aesthetic restorative dental and prosthodontics procedures [27]. The choice of the relative width of teeth is one among the many features that play a role in determining the outcome of a smile [50].

According to the World Health Organization's definition of quality of life, oral health is not only the absence of disease and dysfunction but includes its influence on one's social life and dento-facial confidence [54]. Dental treatment that results in improved dental appearance has a positive effect on the patient's self-esteem and overall quality of life [55].

In order to achieve success in smile design, it is important to select the most appropriate maxillary anterior teeth proportion and to produce symmetry and dominance with the most natural and aesthetic result. Therefore, the existence and validity of the Golden Percentage, the Golden Proportion and the Recurring Esthetic Dental Proportion among Kenyans is an important consideration yet there is hardly any information on the same.

3.3 Research questions

This study sought to answer the following research questions:

1. What is the frequency of occurrence of the Golden Percentage, Recurring Esthetic Dental (RED) Proportion and Golden Percentage in a Kenyan population of African descent?
2. Are the Golden Percentage, Recurring Esthetic Dental (RED) Proportion and Golden Percentage valid measures of maxillary anterior dental aesthetics among a Kenyan Population of African descent?

3.4 Study Objectives

3.4.1 Broad Objective

To evaluate the existence of the Golden Proportion, the RED Proportion and the Golden Percentage and to determine their validity among Kenyans of African descent with natural well aligned teeth.

3.4.2 Specific Objectives

1. To evaluate the existence of the Golden Proportion among 18-35-year-old Kenyans of African descent with natural well aligned teeth according to Andrews' six keys of occlusion [56].
2. To evaluate the existence of the RED Proportion and Golden Percentage among 18-35-year-old Kenyans of African descent with natural well aligned teeth.
3. To determine the validity of Golden Proportion, RED Proportion and Golden Percentage among 18-35-year-old Kenyans of African descent.

3.5 Study Variables

The study variables are summarized in Table 3.1.

Table 3.1: Study variables and measurable outcome

Variable Name	Type/ Category	Measurable Outcome
Age	Socio-demographic (continuous)	Age of subject (years)
Gender	Socio-demographic (categorical, nominal)	Gender of subject – Male (1) or Female (2)
Anterior tooth proportions		
Frontal width and height of maxillary central incisors	Independent/ predictor (continuous)	Width/ height (mm)
Frontal width and height of maxillary lateral incisor	Independent/ predictor (continuous)	Width/ height (mm)
Frontal width and height of maxillary canine	Independent/ predictor (continuous)	Width/ height (mm)
Frontal inter-canine distance	Independent/ predictor (continuous)	Width (mm)
Anterior aesthetic guidelines		
Golden Proportion	Dependent/ outcome (continuous, discrete, nominal)	**%** proportions, validity – No-0 and Yes-1
RED Proportion	Dependent/ outcome (continuous, discrete, nominal)	**%** proportions, validity – No-0 and Yes-1
Golden Percentage	Dependent/ outcome (continuous, discrete, nominal)	**%** ratios, validity – No-0 and Yes-1

3.6 Hypotheses

1. H_0: The Golden Proportion, Recurring Esthetic Dental (RED) Proportion and Golden Percentage do not exist and are invalid determinants of anterior teeth proportions among Kenyans of African descent with natural well aligned teeth.

H_A: The Golden Proportion, Recurring Esthetic Dental (RED) Proportion and Golden Percentage exist and are valid determinants of anterior teeth proportions among Kenyans of African descent with natural well aligned teeth.

CHAPTER FOUR

4.0 MATERIALS AND METHODS

4.1 Research approach

This study adopted the quantitative research approach. Creswell [58] defines quantitative research approach as a formal, objective, systematic approach of testing objective theories, and obtaining quantifiable information of a phenomenon by investigating relationships between variables. The variables can then be subjected to measurements prior to analysis and interpreting by means of statistical procedures.

4.2 Study area

This study was conducted at the University of Nairobi, Department of Dental Science, Department of Medicine (Chiromo), Pharmacy and Nursing. The Department of Dental Sciences is situated off Arwings Kodhek road, opposite Lee Funeral Home, Nairobi. It is comprised of four clinical departments: Oral and Maxillofacial Surgery, Oral Radiology, Oral Pathology & Oral Medicine; Paediatric Dentistry & Orthodontics; Conservative & Prosthetic Dentistry; and Periodontology and Community & Preventive Dentistry. At the time of study (January 2021), the department had a population of 66 undergraduate students and 25 postgraduate students attending clinical sessions and an average of 200 new and continuing patients in the four clinical departments. At the Department of Medicine, there were 620 students, 410 in Pharmacy Department and 219 in Nursing Department.

4.3 Research design

This study adopted an analytical cross-sectional research design. According to Setia [59] Cross-sectional study design is a type of observational study design. In a cross-sectional study, data is collected at a defined time. The participants in a cross-sectional study are selected based on the inclusion and exclusion criteria set for the study.

4.3.1 Inclusion criteria

1. Patients aged 18-35years who attended the University of Nairobi Dental Hospital and consented to participate in the study.
2. Undergraduate and postgraduate students at the University of Nairobi Dental Hospital, Chiromo, Departments of Medicine, Pharmacy and Nursing who consented to participate in the study.
3. Patients and students with natural dentition and well aligned teeth, as defined by Andrew's Six Keys of occlusion [56] (defined in 4.6).
4. Patients and students with no missing maxillary anterior teeth.
5. Patients and students of Kenyan origin and African descent.

4.3.2 Exclusion criteria

1. Individuals aged below 18 years and above 35 years of age.
2. Individuals with malformed anterior teeth.
3. Individuals with crowding of the maxillary anterior teeth.
4. Individuals with restorations on the maxillary anterior teeth.

5. Individuals with loss of tooth structure due to fracture, attrition and caries on maxillary anterior teeth.
6. Individuals missing any maxillary anterior tooth.
7. Individuals with a history of orthodontic treatment.
8. Non-Kenyans and Kenyans not of African descent.

4.4 Sample size determination

The study sample size was calculated using Fisher's formula for cross-sectional studies as shown below:

$$n = \frac{Z^2 x\ P(1-P)}{d^2}$$

Where,

n = Desired sample size

Z = value from standard normal distribution corresponding to desired confidence level (Z=1.96 for 95% CI)

P = expected true proportion (estimated at 13%, from a study conducted by Daniel [60] found 13% of the subjects had exhibited Golden Proportion for CI:LI)

d = desired precision (0.05)

$$n_0 = \frac{1.96^2 x\ 0.13(1-0.113)}{0.05^2} = 174$$

Therefore, the minimum sample size of **174 subjects** was required for the study.

4.5 Sampling technique/ procedure

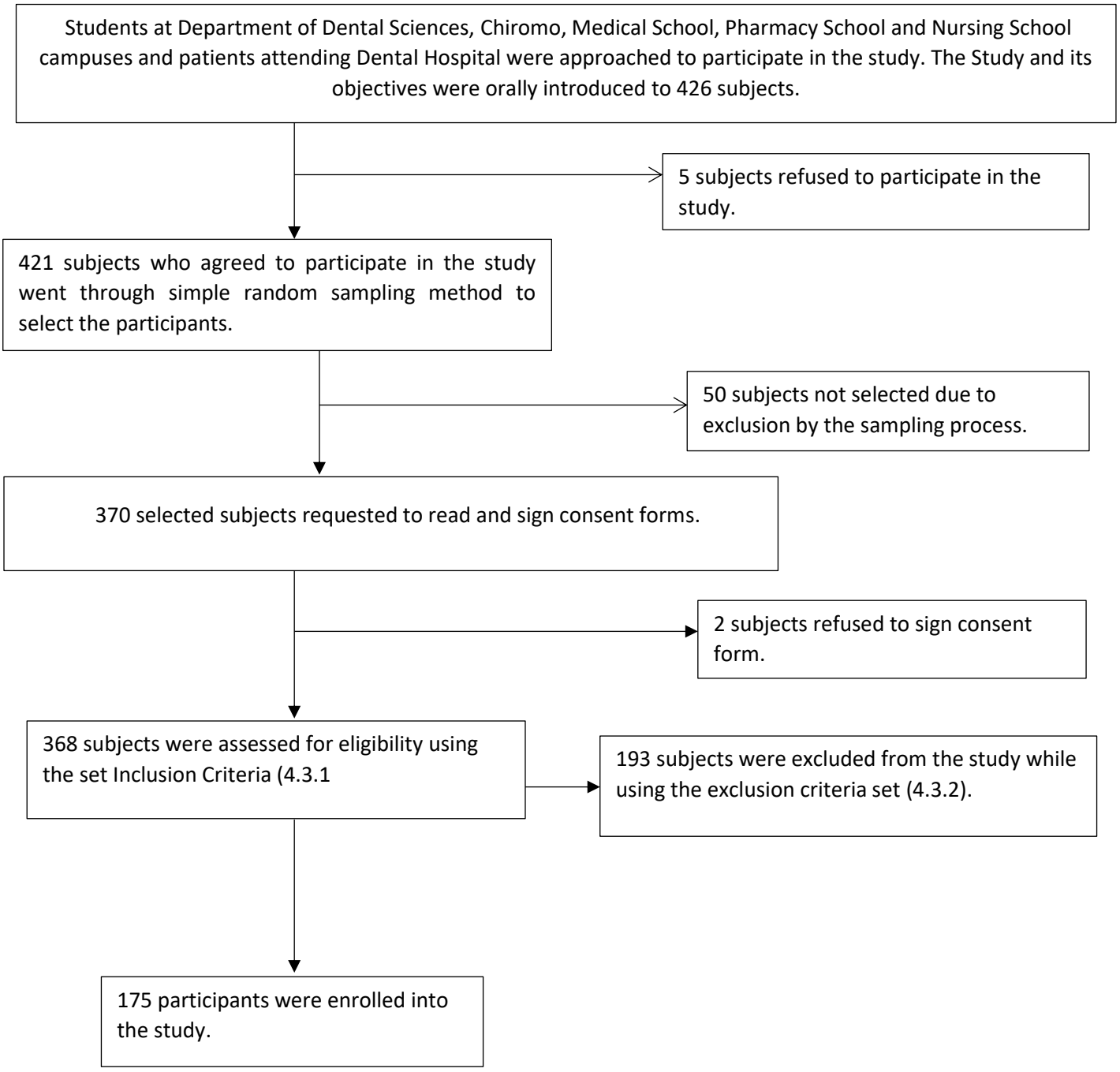
The principal investigator collected data at the location of the undergraduate and postgraduate students in the Faculty of Health Sciences (University Dental Hospital, Department of medicine (Chiromo campus), Pharmacy and Nursing and patients visiting the UON Dental Hospital.

The participant recruitment process is presented in Figure 4.1. The research assistants randomly approached groups of students in the lecture theatres and patients in the waiting rooms of various clinics at the University of Nairobi Dental Hospital. The research assistants briefed them orally about the study and its objectives. Those who were interested in participating were identified thus, applying simple random sampling to select the participants. The potential participants were approached individually by the research assistants and requested to read and sign consent forms (see Appendix I or II) during the same session, or to carry the consent form home and consult with a study counselor of their choice if necessary, prior to consenting to participate in the study. Potential participants who had completed the consenting process proceeded to be interviewed using the screening and recruitment form (Appendix VII). Examination was done by the PI in the Conservation clinic at UON Dental Hospital. For other study sites, the Lecture theatres were used. Those who meet the inclusion criteria and consented to the study were recruited to participate in the study.

4.6 Data collection Instruments and techniques

After recruitment, participants were again briefed on the study and its objectives. They were subjected to an oral interview to gather information on socio-demographic characteristics. They were then invited to the Conservation clinic at the University of Nairobi Dental Hospital or lecture theatres in Chiromo and Kenyatta campuses for photography. The participants were asked to display their widest smile so as to reveal all maxillary anterior teeth. Photographs were taken under natural lighting between 10am and 12 noon, with participants seated in an upright position on an ordinary chair. All photographs of the participants' smiles were captured by the PI.

Figure 4.1: Recruitment and Enrollment flowchart



4.6.1 Precautions against COVID-19 during data collection

Data was collected during the COVID-19 pandemic hence strict guidelines applicable to dental practice currently in place at the University of Nairobi Dental Hospital were applied. The following precautions were undertaken to ensure safety of both the participants and the PI.

1. All students and patients were subjected to temperature screening at the point of entry.
2. All patients were screened further at the triage tent to establish recent medical and travel history as per COVID-19 screening protocols.
3. Wearing of masks, hand washing and sanitization was mandatory.
4. Once the patients were cleared, they underwent routine oral diagnosis, including dental and relevant medical history, and oral examination. Thereafter, they were referred to the appropriate dental clinic for comprehensive treatment planning and management. The PI begun the recruitment process of patient subjects by introducing them to the study and its objectives. Those who consented to be part of the study were referred to Conservative Clinic screening to ensure they met the inclusion criteria.
5. At the conservation clinic, the PI and nurse assistant donned appropriate PPEs recommended for dental practice, including gown, non-sterile gloves, head and foot caps, N95 and surgical masks, goggles and face shields. Patients were required to rinse their mouth using a 0.2% chlorhexidine gluconate mouthwash (Remidin, Indoco Remedies Limited) prior to oral examination, using a sterile examination tray, against the inclusion criteria. Those who met the inclusion criteria were recruited to participate in the study. An appropriate time was scheduled for photography. Set

photographs taken 1.5 meters physical distancing was allowed between the participant and the PI. To ensure adequate time for disinfection of the examination chair between participants, the PI aimed to examine and take photographs for a maximum of 6 participants per session in the morning.

4.6.2 Photography Procedure

The participants were seated on an ordinary chair with their heads in the natural head position so that they look forward. Natural head position (NHP) is a standardized and reproducible position of the head in an upright posture, with the eyes focused on a point in the distance at eye level [61]. The participants were asked to focus on a point on the wall, located at eye level. Standardized frontal image of each participant's smile was taken, using calibrated (Nikon Service Centre, Nairobi) digital camera NIKON D3400, macro lens AF-S VR MICRO NIKKOR, 105MM with manual setting in the following manner:

1. To obtain a sharp image of the face, the camera was adjusted to fit from the tip of the nose to the tip of the chin. The distance between the photographer and the subject was also fixed at a working distance of 60cm.
2. The camera was set to a focal length of 22 and shutter speed of 1/100.
3. The participants were asked to display their widest smile and the photograph captured during the smile. Three images were taken per participant.
4. The images were transferred to a computer and measurements taken using Adobe Photoshop 7 software (Adobe Studios, USA).
5. The participants were serialized, and Microsoft excel 2013 (Microsoft Corporation) was used for data entry and cleaning.

4.6.3 Measuring maxillary anterior teeth

Adobe Photoshop 7 software (Adobe Studios, USA) was used to take three measurements of the described tooth parameters and their means calculated. A digital Vernier caliper was used to measure the actual width of sample teeth of one of the participants and compared against the measurements obtained from Adobe photoshop. A conversion ratio of 0.1357 was obtained. A data collection form (Appendix IV) was used to record measurements of each photograph in millimeters (mm). These were used to calculate the existence of the Golden Proportion, RED Proportion and Golden Percentage.

1. The widths of the maxillary incisors were measured at the mesio-distal contact points of the teeth as shown in Fig. 4.1.
2. The width of the canine was measured from the mesial contact point to the distal most point visible from the frontal view.
3. The frontal inter-canine width was taken from the distal most visible point on the right canine to the left one.

Figure 4.2: Illustration of the measuring points
(**Source:** Snow SR [7])

4. The heights of the teeth were measured from the gingival zenith to the tip of the incisor/ cusp tip of the canine.

4.6.4 The Golden Proportion

To determine the Golden Proportion, the width of the upper lateral incisor was multiplied by 1.62 and compared with the width of the adjacent upper central incisor. The value of the calculated ratio was compared with the value of the Golden Proportion theory, which is set as 1.618 or 1.62 or 62%. Similar values indicate that the width of the upper lateral incisor is in Golden Proportion to the width of the central incisor. Further, the width of the upper canine was multiplied by 1.62 and compared with the width of the adjacent lateral incisor. Similar values indicate that the width of the canine is in Golden Proportion to that of the lateral incisor. The values of the Golden Proportion theory were rounded off to two decimal places (1.62). According to Preston [13,16], the Golden Proportion is in the range of 1.61–1.63, and the same range was considered in this study for both upper right and left anterior teeth.

4.6.5 The Recurring Esthetic Dental (RED) Proportion

The RED Proportion was calculated by dividing the width of each upper lateral incisor by the width of the adjacent central incisor and the resulting number multiplied by 100. Similarly, the width of each upper canine was divided by the width of the adjacent lateral incisor and the resulting number multiplied by 100. If the values obtained were constant, it indicates that the central incisor, lateral incisor, and canine are in RED Proportion. According to Ward [6] and Alhabahbah et al. [62], the values of the RED Proportion used are between 60% and 80%, and the same range was considered during data evaluation

4.6.6 The Golden Percentage

The Golden Percentage was calculated by dividing the width of each central incisor, lateral incisor and canine by the frontal inter-canine width and multiplying the resulting value by 100 for each tooth. The values obtained were rounded off to the nearest whole number. If the values from canine to canine are 10%, 15%, 25%, 25%, 15%, and 10% it means that the six maxillary anterior teeth are in Golden Percentage.

4.6.7 The Width/height ratio

The width/height ratio was obtained by dividing the values of the widths by that of the heights for each of the maxillary anterior teeth.

4.7 Data analysis and presentation

The data collection forms (Appendix IV) were serialized. For confidentiality purposes, names and contacts of the subjects were not recorded. Data was entered into a computer spreadsheet, coded and analyzed using Statistical packages for Social Sciences (IBM, version 22) for windows and Microsoft Excel (Microsoft, 2013). The parametric statistics analysis done included frequencies and means. The information obtained was presented as descriptive statistics in form of frequency tables and pie charts. A $P<0.05$ has been considered a desired precision. A Z-score test was done to evaluate the validity of the maxillary anterior teeth proportions.

Table 4.1: Descriptive Statistics for study variables

Variable Name	Descriptive Statistics
Age	Means, Median, Standard Deviations
Gender	Percentages, proportions
Anterior tooth proportions	
Objectives 1, 2 & 3: To evaluate the existence of the Golden Proportion, RED Proportion & Golden Percentage	
Frontal width of maxillary central incisors	Means, Median, Standard Deviations
Frontal width of maxillary lateral incisor	
Frontal width of maxillary canine	
Frontal inter-canine distance	
Anterior aesthetic guidelines	
Objective 4: To determine the validity of these three maxillary anterior teeth proportion guidelines	
Golden Proportion	Percentages, Proportions
RED Proportion	
Golden Percentage	

4.8 Data reliability and validity

Data collected was representative of the population as it was collected from volunteer students who come from different parts of the country. Additionally, patients who seek treatment at the Department of Dental Sciences come from Nairobi and its environs which is cosmopolitan. The PI carried out all the measurements to eliminate inter-examiner variation after being trained and assessed by Nikon Service Centre, Nairobi. The camera and its accessories were serviced and calibrated by NIKON Service Centre, Nairobi. The PI ensured the camera settings were correct and remain constant prior to taking any photograph. The PI was calibrated by the lead supervisor to ensure standardization of photographs and measurements. Measurements of each tooth was done thrice, and the mean calculated.

4.9 Control of errors and biases

The participants who met the inclusion criteria were the only ones included in the study. All the data collection tools were pretested, and all instruments calibrated. The participants remained coded to the end of data analysis to avoid bias from the statistician and PI.

4.10 Ethical considerations

1. Ethical approval was obtained from Kenyatta National Hospital/University of Nairobi Ethics and Research Committee (KNH-ERC/A/173)
2. Permission to carry out the research was sought from the Chair of the University of Nairobi, department of Dental Sciences.
3. Informed consent was obtained from the participants before they were enrolled into the study and participation was voluntary with equal chance of participation.
4. Participants were at liberty to withdraw from the study at any point without any victimization if they desired to do so.
5. Patients and students with any identified treatment needs were referred for appropriate intervention.

4.11 Study limitations

1. Due to COVID-19 restrictions, direct measurements from the participants requiring sharing of instruments were not recommended.

2. Due to COVID-19 restrictions, data collection took longer than the anticipated three months due to reduced patient flow and closure of university campuses during some period of the pandemic.

CHAPTER FIVE - RESULTS

DATA ANALYSIS, PRESENTATION AND INTERPRETATIONS

5.1 Introduction

This chapter presents data analysis, presentation and interpretations made by the PI. The data obtained was analyzed to address the objectives of the study among Kenyan population of African descent aged between 18 and 35 years with natural well aligned teeth according to Andrew's six keys of occlusion namely, existence of Golden Proportion, RED Proportion and the Golden Percentage; and the validity of Golden Proportion, RED Proportion and Golden Percentage in this study group.

5.2 Demographic Characteristics

The sample size of 175 participants who had met the inclusion criteria for the study were used for data collection, translating to a response rate of 100%.

The Interclass Correlation Coefficient (ICC) was used to evaluate the degree of agreement between the two sets of measurements by the PI and Supervisor as shown in table 5.1.

Table 5.1: Interclass Correlation Coefficient

	Interclass Correlation	**95% Confidence Interval**	**p-value**
Average measures	0.994	0.826 – 0.999	<0.001

It was observed from the total sample chosen, 107 (61.1 per cent) were males with mean age 22.4 (ranged 18-35) years and 68 (38.9 per cent) were females with mean age 22.4

(ranged 18-33) years. The mean age for all the participants was found to be 22.4 (±SD 3.5) years, where the minimum observed age was 18 and the maximum was 35. The median age for all the participants was 22.0 (interquartile range (IQR) 20.0 – 23.0).

The gender distribution of the participants is as shown in figures 5.1

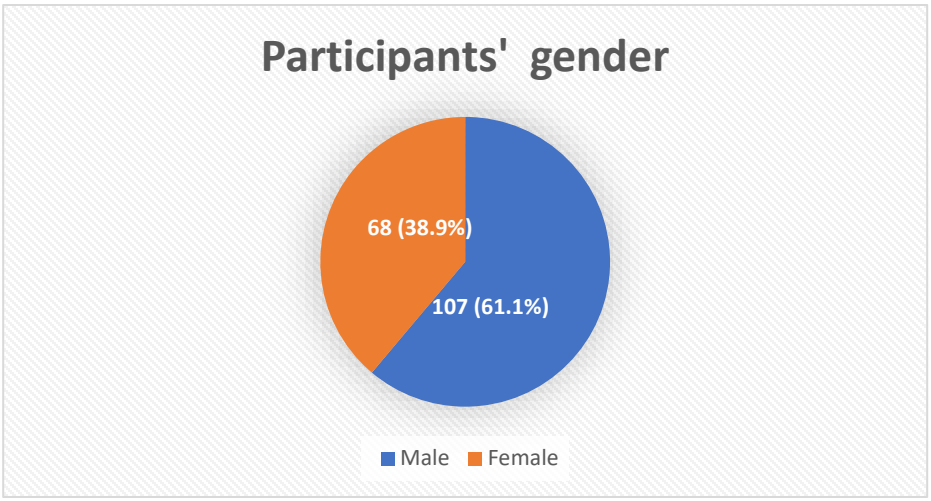


Figure 5.1: Participants' distribution by gender

The age distribution of the participants is as presented in figure 5.2.

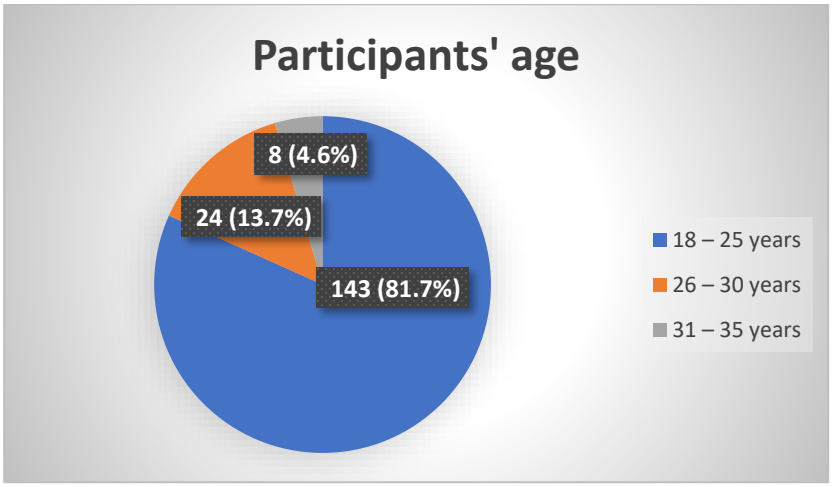


Figure 5.2: Participants' distribution by age

5.3 Means of the widths of maxillary anterior teeth

The mean values obtained for the maxillary anterior teeth are as shown in table 5.2.

Table 5.2: Descriptive analysis for means of the widths of maxillary anterior teeth in all participants.

	Mean	Std. Deviation	Median	IQR	Min value	Max value
Right Canine	4.900	0.761	4.872	4.315 – 5.509	3.121	6.527
Right LI	5.895	0.871	5.971	5.238 – 6.527	3.922	8.088
Right CI	8.595	1.015	8.726	8.129 – 9.187	6.256	11.032
Left CI	8.551	1.026	8.644	8.041 – 9.207	6.161	11.127
Left LI	5.896	0.876	5.917	5.333 – 6.527	3.487	7.816
Left Canine	4.834	0.787	4.872	4.268 – 5.428	3.216	6.785
ICD	38.695	4.629	39.244	36.761 – 41.823	28.036	49.815

Key: IQR - Interquartile Range; CI - Central Incisors; LI - Lateral Incisors; ICD – Inter-Canine Distance; Max – Maximum; Min - Minimum

The mean values and standard deviation for the widths of maxillary anterior teeth for 107 male and 68 female obtained are listed in table 5.3.

Table 5.3: Means values for the widths of maxillary anterior teeth by gender

	Right Canine	Right LI	Right CI	Left CI	Left LI	Left Canine
Male	4.905±0.769	5.906±0.851	8.504±1.029	8.461±1.056	5.860±0.906	4.841±0.814
Female	4.893±0.755	5.876±0.909	8.738±0.983	8.693±0.989	5.952±0.830	4.824±0.749
p-value	0.917	0.824	0.138	0.145	0.499	0.888

Key: CI - Central Incisors; LI - Lateral Incisors

5.4 Means of the inter-canine distance of maxillary anterior teeth

The mean values and standard deviation for the inter-canine distance of maxillary anterior teeth was 38.497±4.780 for male and 39.006±4.400 for female participants.

5.5 Means of the heights of maxillary anterior teeth

The calculated mean values for heights of the maxillary anterior teeth are presented in table 5.4.

Table 5.4: Mean values for heights of the maxillary anterior teeth

	Right Canine	**Right LI**	**Right CI**	**Left CI**	**Left LI**	**Left Canine**
Male	8.883±1.592	8.278±1.280	9.908±1.334	10.015±1.363	8.387±1.362	9.033±1.546
Female	8.476±1.249	7.937±1.166	9.653±1.352	9.689±1.349	8.193±1.222	8.543±1.276
p-value	0.062	0.077	0.222	0.124	0.342	**0.024**

Key: CI – Central Incisors; LI – Lateral Incisors

5.6 Means of the width/height ratio of maxillary anterior teeth

The calculated mean values for the width/ height ration of maxillary anterior teeth od all the participants are presented in table 5.5.

Table 5.5: Shows the mean values for width/height ratio of maxillary anterior teeth of all the participants

	Mean	Standard Deviation	Median	IQR	Min value	Max value
Right Canine	0.569	0.084	0.557	0.512 – 0.611	0.370	0.812
Right LI	0.730	0.092	0.725	0.678 – 0.787	0.559	0.959
Right CI	0.883	0.086	0.881	0.825 – 0.941	0.700	1.149
Left CI	0.871	0.089	0.859	0.815 – 0.922	0.679	1.151
Left LI	0.715	0.876	0.703	0.656 – 0.775	0.543	1.009
Left Canine	0.553	0.804	0.541	0.499 – 0.599	0.361	0.770

Key: IQR - Interquartile Range; CI - Central Incisors; LI - Lateral Incisors; Max - Maximum; Min - Minimum

5.7 Existence of Golden Proportion in maxillary anterior teeth

The first objective was to evaluate the existence of the Golden Proportion among 18-35-year-old Kenyans of African descent with natural well aligned teeth according to Andrews' six keys of occlusion. The results obtained as mean values, standard deviation for the anterior tooth proportions (CI:LI and LI:C) for male and female participants are shown in table 5.6.

Table 5.6: Mean values for anterior tooth proportions by gender

	CI to LI (Right)	LI to C (Right)	CI to LI (Left)	LI to C (Left)
Male	1.450±0.133	1.215±0.147	1.457±0.136	1.221±0.138
Female	1.503±0.159	1.211±0.160	1.471±0.129	1.246±0.154
Overall mean	1.471±0.145	1.214±0.152	1.462±0.133	1.230±0.145
p-value	**0.020**	0.864	0.470	0.259

Key: CI - Central Incisors; LI - Lateral Incisors; C - Canine

The Golden Proportion values were rounded off to the ratio 1.62 (from the value of 1.618).

The results are shown in Figure 5.3.

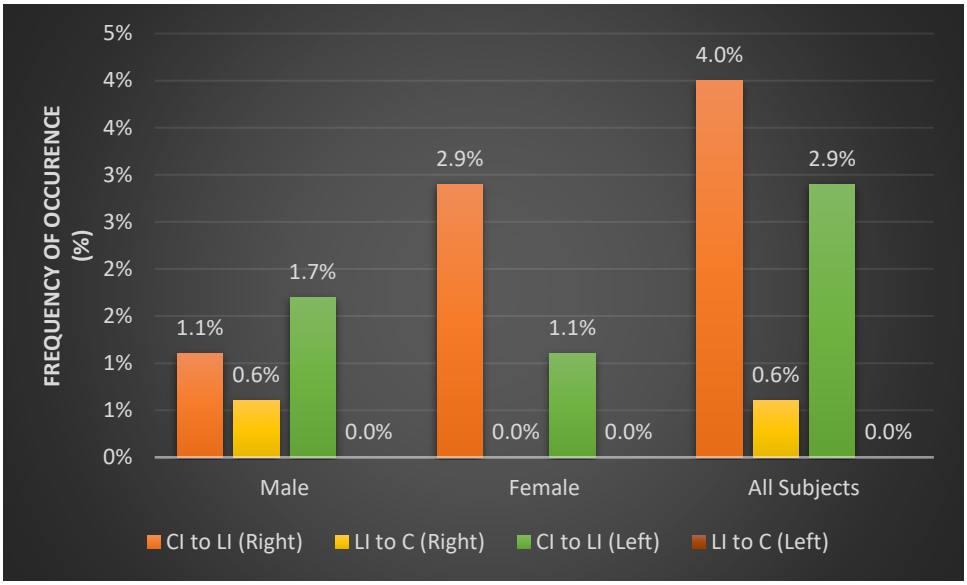


Figure 5.3: The frequency of occurrence of the Golden Proportion in all participants

Key: CI - Central Incisors; LI - Lateral Incisors; C - Canine

5.8 Existence of Recurring Esthetic Dental Proportion in maxillary anterior teeth

The second objective was to evaluate the existence of the RED Proportion among 18-35 years old Kenyans of African descent with natural well aligned teeth.

The mean values and standard deviation for the tooth proportions (LI:CI and C:LI) for males and females are shown in table 5.7.

Table 5.7: Mean values for the tooth proportions by gender

	LI to CI (Right)	C to LI (Right)	LI to CI (Left)	C to LI (Left)
Male	0.695±0.061	0.835±0.102	0.692±0.062	0.830±0.099
Female	0.672±0.066	0.840±0.112	0.684±0.057	0.815±0.099
Overall mean	0.686±0.064	0.837±0.106	0.689±0.060	0.824±0.099
p-value	**0.021**	0.764	0.401	0.307

Key: CI - Central Incisors; LI - Lateral Incisors; C – Canine

Frequency of occurrence of RED Proportion in all the participants are presented in figure 5.4.

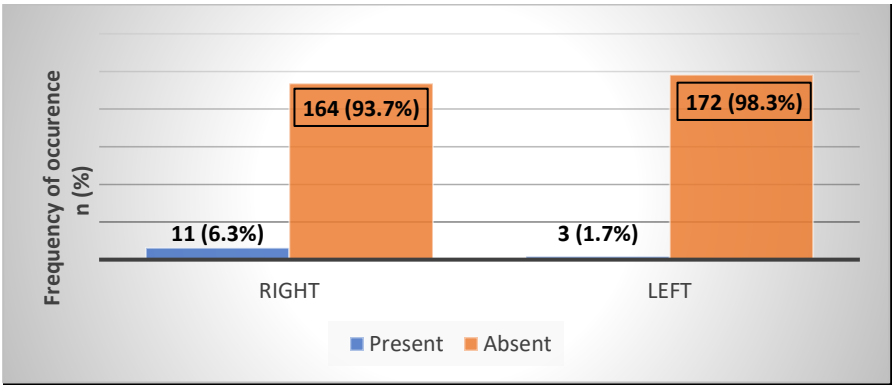


Figure 5.4: Frequency of occurrence of RED Proportion in all the participants.

The existence of RED Proportion in male and female participants are presented in figure 5.5.

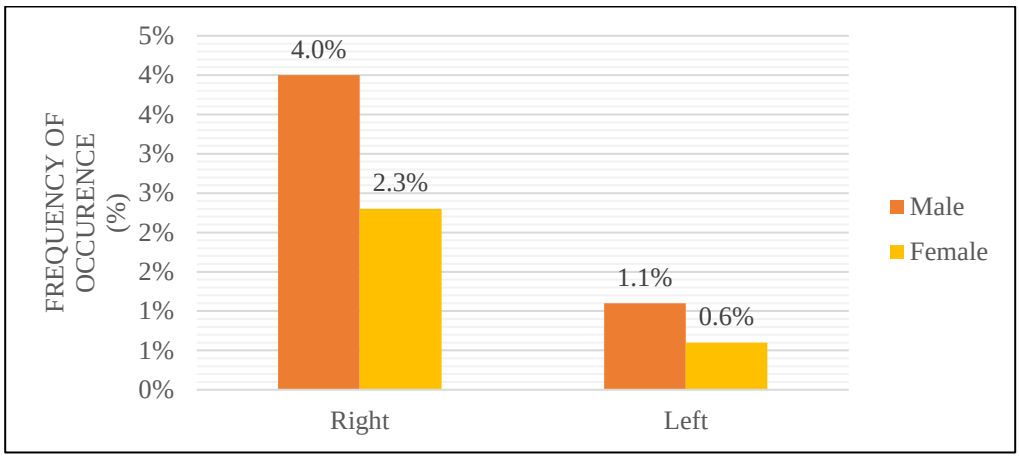


Figure 5.5: Frequency of occurrence of RED Proportion in male and female participants.

5.9 Existence of the Golden Percentage in maxillary anterior teeth

The third objective was to evaluate the existence of the Golden Percentage among 18–35-year-old Kenyans of African descent with natural well aligned teeth.

The mean values and standard deviation for the percentage tooth widths for male and female participants are presented in table 5.8.

Table 5.8: Percentage tooth widths by gender

	Right C	**Right LI**	**Right CI**	**Left CI**	**Left LI**	**Left C**
Male	12.76±1.38	15.35±1.13	22.15±1.16	22.00±1.03	15.18±1.12	12.58±1.30
Female	12.59±1.40	15.03±1.37	22.43±0.90	22.31±0.89	15.26±1.13	12.31±1.37
Overall mean	12.69±1.38	15.22±1.23	22.26±1.07	22.12±0.98	15.21±1.12	12.47±1.33
p-value	0.435	0.114	0.095	**0.043**	0.618	0.190

Key: CI - Central Incisors; LI - Lateral Incisors; C - Canine

Table 5.9 shows the findings of the study in relation to the presence of the Golden Percentage.

Table 5.9: Presence of the Golden Percentage in all participants

	Present, *n (%)*	**Absent,** *n (%)*
Canine (Right)	4 (2.3)	171 (97.7)
Lateral Incisor (Right)	53 (30.3)	122 (69.7)
Central Incisor (Right)	3 (1.7)	172 (98.3)
Central Incisor (Left)	2 (1.1)	173 (98.9)
Lateral Incisor (Left)	65 (37.1)	110 (62.9)
Canine (Left)	8 (4.6)	167 (95.4)

5.10 Validity of the Golden Proportion, RED Proportion and Golden Percentage.

The fourth objective was to determine the validity of Golden Proportion, RED Proportion and Golden Percentage among 18-35-year-old Kenyans.

A hypothesis testing was done using Z-score to determine the validity of Golden Proportion, RED Proportion and Golden Percentage among 18-35-year-old Kenyans using the results of this study. The level of significance is 5% (0.05).

5.10.1 Golden Proportion validity determination

Since there were 175 participants in the sample, a Z-score one sample test was used to determine whether the Golden Proportion was a valid determinant of maxillary anterior teeth proportions. The following assumptions of the one sample Z-test were taken into consideration;

1. Data is continuous
2. The data follows normal distribution
3. Everyone in the population has an equal chance of being selected
4. Population standard deviation is known

Given the considerations above, the following assumptions were validated for the test;

1. Data is continuous
2. Data is normally distributed as shown in table 5.10
3. Data is drawn by simple random sampling

The hypothesis for this study was as follows;

H_0: $\mu = 1.618$

H_1: $\mu \neq 1.618$

The Z-score one sample test to determine whether the Golden Proportion in the maxillary anterior teeth was valid is as indicated in table 5.10.

Table 5.10: Golden Proportion validity test

Maxillary teeth	**Mean**	**Z test statistics**	**P value**
CI to LI (Right)	1.47	-13.40	0.00
LI to C (Right)	1.21	-35.19	0.00
CI to LI (Left)	1.46	-15.48	0.00
LI to C (Left)	1.23	-35.48	0.00

5.10.2 RED Proportion validity determination

The sample for RED was 175 and therefore a two-sample Z score was used to check the difference in maxillary anterior teeth. The following assumption of the two sample Z test were taken into consideration;

1. The samples from each population must be independent of one another.
2. The samples must be drawn from normally distributed populations.

The hypothesis for this study was as follows;

H_0: $\mu_1 = \mu_2$

H_1: $\mu_1 \neq \mu_2$

The Z-score two sample tests to determine whether the RED Proportion in the maxillary anterior teeth was valid is as indicated in table 5.11.

Table 5.11: RED Proportion validity test

Maxillary teeth	**Z test statistics**	**P value**
Right	-16.15	0.00
Left	-15.47	0.00

5.10.3 Golden Percentage validity determination

A Z-score one sample test was used to determine whether the Golden Percentage was a valid determinant of maxillary anterior teeth. The following assumptions of the one sample Z test were taken into consideration;

1. Data is continuous
2. The data follows normal distribution
3. Everyone in the population has an equal chance of being selected
4. Population standard deviation is known

The hypothesis for this study was as follows;

H_0: $\mu_{13} = 10$; **H_0:** $\mu_{12} = 15$; **H_0:** $\mu_{11} = 25$; **H_0:** $\mu_{21} = 25$; **H_0:** $\mu_{22} = 15$; **H_0:** $\mu_{23} = 10$

H_1: $\mu_{13} \neq 10$; **H_1:** $\mu_{12} \neq 15$; **H_1:** $\mu_{11} \neq 25$; **H_1:** $\mu_{21} \neq 25$; **H_1:** $\mu_{22} \neq 15$; **H_1:** $\mu_{23} \neq 10$

Key: 13 = right canine; 12 = right lateral incisor; 11= right central incisor; 21= left central incisor; 22 = left lateral incisor; 23 = left canine.

The Z-score one sample test to determine the validity of the Golden Percentage in maxillary anterior teeth is as indicated in table 5.12.

Table 5.12: Golden Percentage validity test

Maxillary anterior teeth	**Mean**	**Z test statistics**	**P Value**
Canine (Right)	12.69	25.72	0.00
Lateral Incisor (Right)	15.22	2.39	0.02
Central Incisor (Right)	22.26	-33.89	0.00
Central Incisor (Left)	22.12	-38.72	0.00
Lateral Incisor (Left)	15.21	2.49	0.01
Canine (Left)	12.47	24.62	0.00

CHAPTER SIX - DISCUSSION

6.0 DISCUSSION OF THE FINDINGS

6.1 Introduction

This chapter presents a detailed discussion of data presented in chapter five in a bid to interpret and critically discuss the significance of the findings compared to the existing literature about the existence of the Golden Proportion, the RED Proportion and the Golden Percentage. This chapter connects the research questions and research hypothesis to literature review and the findings.

In this chapter, the findings are contextualized in relation to the previous empirical studies on maxillary anterior teeth. The participants of this study were Dental students, Medical students, Pharmacy students, Nursing students and patients attending University of Nairobi Dental Hospital.

The aim of the study was to evaluate the existence of the Golden Proportion, the RED Proportion and the Golden Percentage and to determine their validity among Kenyans of African descent with natural well aligned teeth. To achieve this, four main objectives and research questions were formulated as outlined in section 3.3 and 3.4 of chapter three.

In relation to the research objectives and research questions of this study, the discussion of the findings is presented under the following categories:

1. Existence of the **Golden Proportion** among 18-35 year old Kenyans of African descent with natural well aligned teeth according to Andrew's six keys of occlusion;
2. Existence of the **Recurring Esthetic Dental (RED) Proportion** among 18-35year old Kenyans of African descent with natural well aligned teeth;
3. Existence of the **Golden Percentage** among 18-35 year old Kenyans of African descent with natural well aligned teeth;
4. **The validity of Golden Proportion, RED Proportion and Golden Percentage** among 18-35 year old Kenyans.

6.2 Existence of Golden Proportion in maxillary anterior teeth

The main goal of this objective was to discover the existence of the Golden Proportion among 18-35 year old Kenyans of African descent with natural well aligned teeth according to Andrews' [56] six keys of occlusion.

The present study considered the range of 1.61-1.63 during the evaluation of data. Which had been suggested by Preston [13] and Aziz and Hossain [16] who reported that the Golden Proportion is in the range of 0.61-0.63. In the present study, the Golden Proportion between maxillary central incisors and lateral incisors was found in 1.1% for both male and female while the Golden Proportion between maxillary lateral incisors and canines was not found in all the participants. A similar study by Aziz and Hossain [16] among Bangladeshi population found 16% of males and 18% of females have Golden Proportion between the width of central incisor to the width of the lateral incisor, and 2% of males and 6% of females have the width of their lateral incisor in Golden Proportion to the width

of their canine which is higher than the findings of the current study. Further, Fayyad et al. [15], Aziz and Hossain [16], Suleiman et al. [31] and Alhabahbah et al. [62] reported higher Golden Proportion values than the results found in the present study. The inconsistency in the findings may be attributed to racial and ethnic diversities or differences in tooth forms in different geographic regions. For instance, a set of dental proportion values for participants of the African origin, might not conform to the typical dentofacial features of the participants of European, Asian, and Arab origins amongst others [63].

Although several other studies in the literature have proposed the application of Golden Proportion for achieving proportions and dental esthetics [5,11,21,26,28,29], the universal application of the Golden Proportion should be reconsidered because of the poor correlation between tooth dimensions as found by various other studies [8-10,13,15,31,34-36].

6.3 Existence of Recurring Esthetic Dental Proportion in maxillary anterior teeth

The main goal of this objective was to discover the existence of the RED Proportion among 18-35 year old Kenyans of African descent with natural well aligned teeth according to Andrews' [56] six keys of occlusion.

The present study reported that RED Proportion between maxillary lateral incisors and central incisors was found in 67.2% - 69.5% range, and RED Proportion between canine and lateral incisors was found in 81.5% - 84.0% range. In this study, the ratio between central incisors and lateral incisors and between lateral incisors and canine is not constant. The ratio increases as one moves distally. Similar results were reported by Murthy and

Ramani [9] in Asian population. However, they found RED proportion in the range of 69.50% - 70.33% between central incisor and lateral incisor which is higher than the findings of the current study. RED Proportion between canine and lateral incisor was found in 80% - 83% range which coincides with the findings of the current study. Further, Ward [6], Fayyad et al. [15], Aziz and Hossain [16] reported similar RED proportion values for the ratio between central incisors and lateral incisors with the results found in the present study, and lower RED proportion values for the ratio of the width of canine to the width of lateral incisors than the results found in the present study. The differences in findings may be attributed to non-constant ratio between central incisors and lateral incisors and between lateral incisors and canine.

The values obtained from the present study, suggest that the RED Proportion seem not to exist in natural dentition of Kenyans of African descent. This is because the ratio between central and lateral incisors and that of the lateral incisor and canine were not constant. The results revealed that the ratio increases as one moves distally. It can be concluded therefore that the RED Proportion theory as applied to the natural dentition may not be evident. This is also supported by several studies [9,15,16,62,63].

6.4 Existence of the Golden Percentage in maxillary anterior teeth

The main aim of this objective was to evaluate the existence of the Golden Percentage among 18-35 year old Kenyans of African descent with natural well aligned teeth according to Andrews' [56] six keys of occlusion.

The results of the present study suggest that the mean values for the percentage of central incisors is 22.19%. These values are lower than those suggested by Snow [7] who estimated a value of 25% for central incisors. However, the mean value for lateral incisors is 15.22% which is similar to those suggested by Snow [7] who recommended a value of 15% as the Golden Percentage for lateral incisors. In addition, the mean values for the percentage of canines is 12.58% which is higher than those suggested by Snow [7] who recommended a Golden Percentage value of 10%. The results of this study showed similar results as were reported by Murthy and Ramani [9] in Asian population, and Aziz and Hossain [16] in Bangladesh population. These authors [9, 16] found a percentage of 22.0% for centrals, 15.5% for laterals, and 12.5% for canines; and 22.67% for centrals, 15.36% for laterals, and 11.97% for the canines respectively. The results for the percentage of central incisors among participants of this study where similar to those reported by Fayyad et al. [15] in Arabic population (22.8-23.0%) for women's central incisors, while that for men was 22.6%. The mean values for the lateral incisor found in this study were also similar to those reported by Fayyad et al. [15] (14.6% - 15.2% for women and 14.59% - 15.09% for men). However, the present study had the mean values for the canine being higher than those reported by Fayyad et al. [15] (11.69% - 11.89% for female canines and 11.66% - 11.87% for males).

The similarity in the finding may be attributed to the existence of Golden Percentage in lateral incisors but not in the central incisors and the canines. This variation from the percentages of the central incisor and canine suggested by Snow [7] may be due to a variation in the shape of the dental arch of the Kenyan population resulting in a smaller percentage of the central incisor and a larger percentage of the canine. It can be concluded

therefore that the Golden Percentage theory in relation to lateral incisors was more applicable to the participants of this study. Based on the findings of the present study and compared with previous studies, there is evidence to support that the width of the central incisors is slightly smaller, while the width of the canines is slightly larger for the Kenyan population of African descent, the Indian and Bangladesh populations [9, 15,16]. The values obtained in the present study contradicts the Golden Percentage theory suggested by Snow [7]. The results on the percentages of the central and lateral incisors and canines of the present study are consistent with previous studies by Murthy and Ramani [9], Fayyad et al. [15] and, Aziz and Hossain [16].

In the present study, a value of 22% for central incisors, 15% for lateral incisors, and 13% for canines can be adopted, as these percentages are more applicable to the natural dentition of Kenyan population of African descent. The results from this study revealed 65(37.14%) of the participants had their right central incisor being 22% of the total frontal width of the six anterior teeth and 75(42.85%) for the left central incisor. In addition, 52(29.71%) of the participants had their right lateral incisor being 15% of the total frontal width of the six anterior teeth while 60(34.29%) was found for the left lateral incisor. Among the participants that had their canines being 13% of the total frontal width of the six anterior teeth, 36(20.57%) was recorded on the right while 32(18.29%) was recorded on the left side.

Fayyad et al. [15], recommended a value of 23% for centrals, 15% for laterals, and 12% for canines and Murthy and Ramani [9] recommended a value of 22% for centrals, 15.5% for

laterals, and 12.5% for canines since these percentages are more applicable to natural dentition [9,15].

It should be noted that the present study utilized data from Kenyan participants of African descent, thus minor variations in the values obtained compared to previous studies [7,9,15,16] may be attributed to the ethnic background of the participants. This might also explain the minor differences in previous studies' conclusions regarding the presence and absence of the application of the Golden Percentage theory.

6.5 The validity of Golden Proportion, RED Proportion and Golden Percentage in maxillary anterior teeth

The last research objective was to determine the validity of the Golden Proportion, RED Proportion and the Golden Percentage among 18–35-year-old Kenyans. The main goal of evaluating the validity of the Golden Proportion, RED Proportion and the Golden Percentage is critical to presenting answers to otherwise challenging research problems.

According to Alhabahbah et al. [62] maxillary anterior teeth are the most prominent and important teeth in the smile. These teeth are important factors for dental esthetics and harmonic teeth arrangement [6]. Thus, understanding the ideal dimensions and proportions of maxillary anterior teeth is a significant component in creating an attractive smile during dental procedures [64]. Sah, et al. [63] and Condon et al. [65] observed that the size and shape of the maxillary anterior teeth especially when perceived from the front have considerable implications in esthetic diagnosis and treatment planning. These also have an effect on the space availability, stability of dentition, aesthetics and health of the periodontium [62].

Several factors such as age, gender, genetics, ethnic background, and environment have been reported in several studies as factors affecting the average dimensions of maxillary anterior teeth [62,66]. As a result, the dimensions of the maxillary anterior teeth may vary from one person to the other hence, the need to quantify the relationship between these dimensions by geometric proportions [62]. As discussed in the empirical studies, several theories have suggested the relationship of tooth dimensions such as Golden Proportion, Recurring Esthetic Dental Proportion (RED), and Golden Percentage [25].

The present study has underscored the importance of determining a mathematical or geometrical relationship between teeth to achieve an aesthetic restorative outcome. Substantial efforts have been made to establish common standards applicable in dental esthetics [28, 66]. Thus, it would be helpful if statistically reliable relationships existed to support existing relationship theories [15, 62]. In the present study, analyses of data using the Z-score/ Z-statistics hypothesis testing statistical technique in all the participants revealed that the P value for the Golden Proportion was less than 0.05, hence the null hypothesis was rejected. When compared to the ideal Golden Proportion theory, the mean ratios of the width of the maxillary anterior teeth indicated substantial differences (table 5.10). The findings revealed that the golden proportion did not exist among the study participants. Thus, it can be concluded that the Golden Proportion is an invalid determinant of anterior teeth proportions among Kenyans of African descent with natural well aligned teeth.

Moreover, the results revealed that the P value for the RED Proportion was less than 0.05, hence the null hypothesis was also rejected. When compared to the ideal RED Proportion theory, the findings of this study revealed that the difference between the maxillary

anterior teeth on the right and left side were significantly not constant (table 5.11). Thus, it can be concluded that the Recurring Esthetic Dental (RED) Proportion is an invalid determinant of anterior teeth proportions among Kenyans of African descent with natural well aligned teeth.

In addition, the P value for the Golden Percentage was equally less than 0.05, hence the null hypothesis was rejected. When compared to the ideal Golden Percentage theory, in overall, the findings of this study revealed that the maxillary anterior teeth's mean ratio deviated from the benchmark. The findings thus demonstrated that the Golden Percentage between the widths of maxillary anterior teeth was absent. However, the results revealed some level of association/validity for the lateral incisors on both the left and right sides which explains the significant presence (mean value of 33.7%) of the Golden Percentage, even though the overall results showed absence of the Golden percentage (table 5.12). Nonetheless, it can be concluded that the Golden Percentage is an invalid determinant of anterior teeth proportions among Kenyans of African descent with natural well aligned teeth.

Therefore, the major finding of this study, was poor correlation between tooth dimensions and the Golden Proportion. This finding is in accordance with previous studies [8,11,13,28] where no reliable relationships with the average natural dentition were found. Also, in this study the RED Proportion was not constant but the ratio increases as one moves distally. Therefore, based on the findings of this study and those from previous studies [9, 14-16], there is no evidence to support the RED Proportion theory as applied to the natural dentition of studied Asian, Indian, Arabic, Bangladeshi and Kenyan populations. The present study

found the Golden Percentage to exist in lateral incisors which corresponds to that proposed by Snow [7]. This finding is in accordance with previous studies [9, 15,16] where a reliable relationship was found. Thus, it can be concluded therefore that the Golden Percentage theory in relation to lateral incisors was applicable to the population of this study.

CHAPTER SEVEN

7.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This chapter provides a summary of major findings, conclusions and recommendation based on the objectives of the study.

7.2 Summary of the major findings

The existence of the Golden Proportion, the RED Proportion and the Golden Percentage and their validity among Kenyans of African descent with natural well aligned teeth was evaluated. Major findings of the study are summarized hereunder based on the objectives of the study.

7.2.1 Existence of Golden Proportion in maxillary anterior teeth

The findings revealed a poor correlation between tooth dimensions and the Golden Proportion. As it can be derived from the study, no reliable relationships in the average natural dentition were found.

7.2.2 Existence of Recurring Esthetic Dental Proportion in maxillary anterior teeth

It was established that the ratio between central and lateral incisors and between lateral incisors and canine is not constant. The results demonstrate that the ratio increases as one moves distally. Thus, there is no evidence to support the RED Proportion theory as applied to the natural dentition.

7.2.3 Existence of the Golden Percentage in maxillary anterior teeth

Arising from the findings, the Golden Percentage exists only in lateral incisors. The results demonstrate that the Golden Percentage theory in relation to lateral incisors was more applicable to the participants of this study; while the Golden Percentage theory in relation to central incisors as well as canines had a negative relationship thus less applicable to the participants of this study.

7.3 Conclusions

A number of conclusions can be drawn based on the findings of this study in line with the objectives of the study:

1. The Golden Proportion of 1.618:1 was not found to exist between the widths of maxillary anterior teeth in natural dentition of Kenyans of African descent
2. The RED Proportion was not found to exist between the widths of the six maxillary anterior teeth in natural dentition of Kenyans of African descent.
3. The values suggested in the Golden Percentage theory were not applicable in the participants of this study with exception of the values for the lateral incisors which were found to be applicable.
4. The results revealed that the Golden Proportion, Recurring Esthetic Dental (RED) Proportion and the Golden Percentage could not be used to formulate a smile design for the Kenyan population. Rather, the dental proportions should be considered based on a racial and ethnic background of a population.

5. The results revealed that the Golden Proportion, Recurring Esthetic Dental (RED) Proportion and the Golden Percentage were invalid determinants of anterior teeth proportions among Kenyans of African descent with natural well aligned teeth.

7.4 Recommendations

Based on the findings and conclusions of this study, the researcher makes the following recommendations:

1. Among the proportions evaluated in this study, the Golden Percentage theory for maxillary anterior teeth has been recommended for adoption if the values can be slightly modified taking into consideration the racial and ethnic background of the participants. In this study, a value of 22% for central incisors, 15% for lateral incisors, and 13% for canines has been recommended, as these percentages are more applicable to the natural dentition and might serve as a guideline to create harmonious proportions in maxillary anterior teeth for the Kenyan population of African descent.
2. The racial and ethnic background in different geographical regions should be considered to establish objectively quantifiable values helpful in aesthetic restorations.

7.5 Implications of the study

1. The higher institutions of learning can use the results to enable them influence teaching and learning.
2. The findings of this study can be used to anchor the adoption of distinct maxillary anterior teeth models as a means of aesthetics treatment planning by dental practitioners.

7.6 Areas for further research study

Further studies identified as potentially beneficial relative to this study include:

1. Similar studies carried out on a larger sample size prior to inferring the findings to the general population.
2. Further studies carried out to find out the statistical significance /effect of the age, gender, racial and ethnic background of the population when the Golden Proportion, the Golden Percentage, and the RED Proportion are applied.

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APPENDICES

APPENDIX I: PARTICIPANT INFORMATION AND CONSENT FORM (ENGLISH)

TITLE OF STUDY: *EVALUATION OF THE GOLDEN PROPORTION, RECURRING ESTHETIC DENTAL (RED) PROPORTION AND THE GOLDEN PERCENTAGE IN A KENYAN POPULATION.*

Principal Investigator: DR. MARION N. MOSOMI

University of Nairobi Dental Hospital

Introduction:

I would like to tell you about a study being conducted by the above listed researchers. The purpose of this consent form is to give you the information you will need to help you decide whether or not to be a participant in the study. Feel free to ask any questions about the purpose of the research, what happens if you participate in the study, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions to your satisfaction, you may decide to be in the study or not. This process is called 'informed consent'. Once you understand and agree to be in the study, I will request you to sign your name on this form. You should understand the general principles which apply to all subjects in a medical research:

i. Your decision to participate is entirely voluntary.
ii. You may withdraw from the study at any time without necessarily giving a reason for your withdrawal.
iii. Refusal to participate in the research will not affect the services you are entitled to in this health facility or other facilities. We will give you a copy of this form for your records.

May I continue? YES / NO

This study has approval by The Kenyatta National Hospital-University of Nairobi Ethics and Research Committee Protocol No**.**

WHAT IS THIS STUDY ABOUT?

The researchers listed above are interviewing individuals who have well aligned teeth and are Kenyans. The purpose of the interview is to find out the **anterior teeth proportions in a Kenyan population**. Subjects in this research study will be requested to smile, and the smile photographed. Afterwards, the proportions of their front teeth will be measured directly on the photographs.

There will be approximately **174** subjects in this study, who will be randomly selected. We are asking for your consent to consider participating in this study.

WHAT WILL HAPPEN IF YOU DECIDE TO BE IN THIS RESEARCH STUDY?

If you agree to participate in this study, the following things will happen:

You will have a normal medical and dental history taken, followed by an oral examination to confirm that the alignment of your teeth make you suitable to participate in the study.

Once this has been confirmed, you will be requested to smile and a photograph of your smile area will be taken, capturing only the features around your mouth and particularly your upper front teeth.

Only your age and gender will be recorded for the purpose of the study. You will not be requested for any additional personal information, although this will be recorded in your Dental Treatment file which is only accessible by authorized personnel at the department while you are receiving treatment.

The whole process will take approximately one hour.

ARE THERE ANY RISKS, HARMS DISCOMFORTS ASSOCIATED WITH THIS STUDY?

Medical research has the potential to introduce psychological, social, emotional and physical risks. Effort should always be put in place to minimize the risks. One potential risk of being in the study is loss of privacy. We will keep everything you tell us as confidential as possible. We will use a code number to identify you in a password-protected computer database and will keep all of our paper records in a locked file cabinet. However, no system of protecting your confidentiality can be absolutely secure, so it is still possible that someone could find out you were in this study and could find out information about you.

Also, answering questions in the interview may be uncomfortable for you. If there are any questions you do not want to answer, you can skip them. You have the right to refuse the interview or any questions asked during the interview.

We will do everything we can to ensure that this is done in private. Furthermore, all study staff and interviewers are professionals with special training in these examinations/interviews.

In case of an injury, illness or complications related to this study, contact the study staff right away at the number provided at the end of this document. The study staff will treat you for minor conditions or refer you when necessary.

ARE THERE ANY BENEFITS BEING IN THIS STUDY?

You may benefit by receiving free dental check-up and routine dental x-rays. We will refer you to a hospital for care and support where necessary. Also, the information you provide will help us better understand the some of the process involved while providing aesthetic dental treatment to Kenyans. This information is a contribution to science and formulation of policy in the country.

WILL BEING IN THIS STUDY COST YOU ANYTHING?

It will not cost you anything to participate in this study.

WILL YOU GET REFUND FOR ANY MONEY SPENT AS PART OF THIS STUDY?

You will not need to spend any money to participate in this research. In instances where this may be the case, you will obtain a refund.

WHAT IF YOU HAVE QUESTIONS IN FUTURE?

If you have further questions or concerns about participating in this study, please call or send a text message to the study staff at the number provided at the bottom of this page.

For more information about your rights as a research participant you may contact the Secretary/Chairperson, Kenyatta National Hospital-University of Nairobi Ethics and Research Committee Telephone No. 2726300 Ext. 44355, 44102 email uonknh_erc@uonbi.ac.ke.

The study staff will reimburse any charges for the calls made to these numbers if the purpose of your call is for study-related communication.

WHAT ARE YOUR OTHER CHOICES?

Your decision to participate in research is voluntary. You are free to decline participation in the study and you can withdraw from the study at any time without injustice or loss of any benefits.

CONSENT FORM (STATEMENT OF CONSENT)

Participant's statement

I have read this consent form or had the information read to me. I have had the chance to discuss this research study with a study counsellor. I have had my questions answered in a language that I understand. The risks and benefits have been explained to me. I understand that my participation in this study is voluntary and that I may choose to withdraw any time. I freely agree to participate in this research study.

I understand that all efforts will be made to keep information regarding my personal identity confidential.

By signing this consent form, I have not given up any of the legal rights that I have as a participant in a research study.

I agree to participate in this research study:	**Yes**	**No**
I agree to have photographs of my smile preserved for later study:	Yes	No

Participant printed name:

_____

Participant signature / Thumb stamp: _____Date: _____

Researcher's Statement

I, the undersigned, have fully explained the relevant details of this research study to the participant named above and believe that the participant has understood and has willingly and freely given his/her consent.

Researcher's Name: **DR. MARION N. MOSOMI**

Signature: _____ Date: _____

Role in the study: Principal Investigator

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APPENDIX II: PARTICIPANT INFORMATION AND CONSENT FORM (SWAHILI) – FOMU YA RIDHAA YA USAJILI WA UTAFITI

MADA YA UTAFITI: *TATHMINI YA UWIANO WA DHAHABU, UWIANO WA MENO YA KISITETIKI NA ASILIMIA YA DHAHABU INAVYOPATIKANA KWENYE MENO KATIKA IDADI YA WAKAZI WA KENYA.*

Mkuu wa uchunguzi na uhusiano wa taasisi: Dkt. MARION N. MOSOMI

Hospitali ya Kutibu Meno ya Chuo Kikuu cha Nairobi

Wachunguzi wenza na uhusiano wa taasisi: Haihusiki

Utangulizi:

Ningependa kukuambia juu ya utafiti unaofanywa na watafiti walioorodheshwa hapo juu. Madhumuni ya fomu hii ya idhini ni kukupa habari utakayohitaji kukusaidia kuamua ikiwa ni mshiriki wa utafiti huo au la. Jisikie huru kuuliza maswali yoyote juu ya kusudi la utafiti, nini kinatokea ikiwa unashiriki katika utafiti, hatari na faida zinazowezekana, haki zako kama kujitolea, na chochote kingine juu ya utafiti au fomu hii ambayo haijulikani wazi. Wakati tumejibu maswali yako yote kukuridhisha, unaweza kuamua kuwa kwenye somo au la. Utaratibu huu unaitwa 'idhini ya habari' Mara tu utakapoelewa na kukubali kuwa kwenye utafiti, nitakuomba utie sahihi jina lako kwenye fomu hii. Unapaswa kuelewa kanuni za jumla ambazo zinatumika kwa washiriki wote katika utafiti wa matibabu:

i. Uamuzi wako wa kushiriki ni wa hiari kabisa.

ii. Unaweza kujiondoa kwenye utafiti wakati wowote bila kutoa sababu ya kujitoa kwako.

iii. Kukataa kushiriki katika utafiti hakutaathiri huduma unazostahiki katika kituo hiki cha afya au vituo vingine. Tutakupa nakala ya fomu hii kwa kumbukumbu zako.

Naweza kuendelea? NDIO / LA

Utafiti huu umeidhinishwa na hospitali ya Kitaifa ya Kenyatta-Kamati ya maadili na utafiti Chuo Kikuu Cha Nairobi, Nambari ya itifaki:

Utafiti huu unahusu nini?

Watafiti walioorodheshwa hapo juu wanawahoji watu ambao wana **meno yaliyokaa sawa na ni Wakenya**. Kusudi la mahojiano ni kujua idadi ya meno ya nje katika idadi ya Wakenya. Washiriki katika utafiti huu wataombwa kutabasamu, na tabasamu hilo lilipigwa picha. Baadaye, idadi ya meno yao ya mbele yatapimwa moja kwa moja kwenye picha.

Kutakuwa na takriban washiriki **174** katika utafiti huu, ambao watachaguliwa bila mpangilio. Tunaomba idhini yako kuzingatia kushiriki katika utafiti huu.

NI NINI KITAKACHOFANYIKA IWAPO UTAAMUA KUWEKO KWENYE UTAFITI?

Ikiwa unakubali kushiriki katika utafiti huu, mambo yafuatayo yatatokea:

Utakuwa na historia ya kawaida ya matibabu na meno iliyochukuliwa, ikifuatiwa na uchunguzi wa mdomo ili kudhibitisha kuwa mpangilio wa meno yako hukufanya uwe mzuri kushiriki katika utafiti.

Mara hii ikithibitishwa, utaombwa kutabasamu na picha ya eneo lako la tabasamu itapigwa, ukinasa tu vitu karibu na mdomo wako na haswa meno yako ya mbele ya juu.

Umri wako tu na jinsia ndizo zitarekodiwa kwa madhumuni ya utafiti. Hutaulizwa habari yoyote ya ziada ya kibinafsi, ingawa hii itarekodiwa kwenye faili yako ya Matibabu ya Meno ambayo inapatikana tu na wafanyikazi walioidhinishwa Shuleni wakati unapokea matibabu.

Mchakato wote utachukua takriban saa moja.

JE, KUNA HATARI ZOZOTE AU MADHARA YANAYOHUSISHWA NA UTAFITI HUU?

Utafiti wa kimatibabu una uwezo wa kusababisha hatari za kisaikolojia, katika mahusiano, hisia na kimwili. Yafaa tujaribu tuwezavyo kupunguza hatari hizo. Hatari moja ambayo yaweza kutokea ni ukosefu wa siri. Yote utakayotuambia yatabaki kuwa siri.Tutatumia kodi fulani kukutambua katika tarakilishi iliyo na neno la siri. Data na nakala zetu zote tutazifungia kwa kabati. Hata hivyo, hakuna chombo cha kuhifadhi siri yako ambacho ni salama kabisa na huenda mtu akafumbua kwamba ulishiriki katika utafiti na apate habari kukuhusu.

Aidhaa kujibu maswali kwenye mahojiano huenda kukawa kugumu kwako. Iwapo kuna maswali hutaki kujibu waweza kuyaacha. Una haki ya kukataa mahojiano au swali lolote litakaloulizwa kwenye mahojiano.

Inawezekana liwe ni jambo la aibu kwako kufanyiwa uchunguzi. Tutahakikisha ya kwamba yote hayo yatafanyiwa mahali pa siri. Hali kadhalika watakaofanya mahojiano ni watu wenye weledi na ujuzi. Huenda usihisi vizuri wakati wa kukaguliwa kinywani. Pakitokea ya kwamba umejeruhiwa, umekuwa mgonjwa au shida nyingine inayohusiana na utafiti huu imetokea piga nambari utakayoona mwishoni mwa nakala hii haraka iwezekanavyo. Wahudumu watakutibu magonjwa madogo madogo au wakutume kwingineko iwapo itahitajika kufanya hivyo

KUNA MANUFAA YOYOTE KATIKA UTAFITI HUU?

Unaweza kufaidika kwa kupokea ukaguzi wa bure wa meno na eksirei ya meno ya kawaida. Tutakupeleka kwa hospitali kwa matunzo na msaada pale inapobidi. Pia, habari unayotoa itatusaidia kuelewa vizuri zaidi mchakato unaohusika wakati wa kutoa matibabu ya meno kwa Wakenya. Habari hii ni mchango kwa sayansi na uundaji wa sera nchini.

JE KUWEPO KATIKA UTAFITI HUU KUTAKUGHARIMU CHOCHOTE?

La, haisusiki.

TARUDISHA PESA ZOZOTE UTAKAZOTUMIA KATIKA UTAFITI?

Hakuna jambo lolote litakalokupelekea wewe kutumia pesa, lakini iwapo pesa zako zitumike, utaregeshewa.

IWAPO UKUMBANE NA MASWALI SIKU ZA USONI

Iwapo utakuwa na maswali Zaidi kuhusu utafiti huu tafadhali piga simu au utume arafa kwa nambari iliyoko mwishoni mwa nakala hii ili kuwasiliana na wahudumu wetu.

Kwa habari Zaidi kuhusu haki yako kama mshiriki wa utafiti waweza kuzungumza na katibu/Mwenye kiti, Hospitali ya Kitaifa ya Kenyatta-Kamati ya maadili na utafiti Chuo Kikuu cha Nairobi, Nambari ya simu 2726300 Ext. 44355, 44102 Barua pepe: uonknherc@uonbi.ac.ke.

Wahudumu watakulipa hela zako ukishatumia nambari hizi iwapo mawasiliano yatahusu utafiti.

CHAGUO LAKO LINGINE NI LIPI?

Uamuzi wako wa kushiriki katika utafiti huu ni wa hiari. Una ruhusa ya kukataa kushiriki katika utafiti na waweza kujiondoa katika utafiti bila hasara yoyote na bila kukiukwa kwa haki yako.

FOMU YA RIDHAA

Kauli ya mshiriki

Nimeisoma fomu hii ya ridhaa ama nimesomewa ujumbe. Nilipata fursa ya kujadiliana kuhusu utafiti huu na mtafiti. Maswali yangu yamejibiwa kwa lugha ambayo naielewa. Nimeelezewa manufaa na hatari ziliwepo. Naelewa kuwa ushiriki wangu kwa utafiti huu ni wa hiari na naweza kujiondoawa wakati wowote. Nimekubali kwa hiari kushiriki katika utafiti huu.

Naelewa juhudi zitafanywa ili kuuhifadhi habari yangu wa kibinafsi.

Kwa kutia sahihi fomu hii ya ridhaa, sijaiacha haki zangu kisheria kama mshiriki katika utafiti.

Nimekubali kushiriki katika utafiti huu: **Ndio** **La**

Nimekubali kupigwa eksirei ya mdomo: Ndio La

Jina la mshiriki lililochapishwa: _____

Sahihi ya mshiriki / alama ya kidole : _____ Tarehe : _____

Kauli ya mtafiti

Mimi, ambaye nimetia sahihi, nimetoa maelezo kamili kuhusiana na utafiti huu kwa mshiriki ambaye ametajwa hapo juuna naamini ya kwamba mshiriki ameelewa na akatoa ridhaa yake kwa hiari.

Jina la mtafiti: Dkt. Marion N. Mosomi **Tarehe**: _____

Sahihi _____

Kazi yake katika utafiti: Mkuu wa uchunguzi

Kwa habari zaidi zungumza na,

1. Dkt. Marion N. Mosomi
   Shule ya Kisayansi ya Meno, Chuo Kikuu cha Nairobi.
   Nambari ya simu – 0705873680, Barua pepe – mnmosomi@students.uonbi.ac.ke
2. Dkt. Susan W. Maina
   Shule ya Kisayansi ya Meno, Chuo Kikuu cha Nairobi.
   Nambari ya simu – 0723904561, Barua pepe – susan@uonbi.ac.ke
3. Dkt. Olivia M. A. Osiro
   Shule ya Kisayansi ya Meno, Chuo Kikuu cha Nairobi.
   Nambari ya simu – 0722861488, Barua pepe – oaosiro@uonbi.ac.ke
4. Dkt. Ben I. Omondi
   Shule ya Kisayansi ya Meno, Chuo Kikuu cha Nairobi.
   Nambari ya simu – 0722378299, Barua pepe – ben.omondi@uonbi.ac.ke

Katibu/ Mwenyekiti,
Hospitali ya Kitaifa ya Kenyatta-Kamati ya maadili na utafiti Chuo Kikuu Cha Nairobi,
Nambari ya simu. 726300-9 Ext 44355, 44102 Barua pepe: uonknh_erc@uonbi.ac.ke.
Kutoka sawa mbili mpaka sawa kumi na moja, juma moja mpaka juna tano.

APPENDIX III: ANDREWS' SIX KEYS OF OCCLUSION

Andrews' Six Keys to normal occlusion are a widely quoted set of static occlusal goals for tooth relationships in the intercuspal position[56]. These are:

1. Correct inter-arch relationships
2. Correct crown angulation
3. Correct crown inclination
4. No rotations
5. Tight contact points
6. Flat curve of Spee (0.0-2.5mm)

APPENDIX IV: DATA COLLECTION FORM

DATE: ……

SERIAL NUMBER: ……

GENDER: ……

AGE: ……

PHOTOGRAPH TAKEN AND FOUND ACCEPTABLE: ……

1. Dental chart and maxillary anterior teeth proportions

Tooth number	13	12	11	21	22	23
Width (mm)	Measurements					
Height (mm)	Measurements					
Inter-canine distance (mm)	Measurements					

APPENDIX V: BUDGET FOR THE RESEARCH

Budget Items	Quantity	Unit Cost	Amount (KES)
Expendable Supplies			
Purchase of stationary (Printing papers, binding materials, marker pens, folders etc.)	1	40,000	40,000
Reproduction of consent forms, screening and recruitment forms and data collection forms.	1	7,000	7,000
Research assistants	2	10,000	20,000
Data cleaning and analysis	1	20,000	20,000
Communication: Airtime and Internet bundles	1	40,000	40,000
Sub-total			**127,000**
Equipment			
DSLR Camera	1	50,000	50,000
Camera macro lens	1	100,000	100,000
Ring flash	1	45,000	45,000
Camera Stand	1	15,000	15,000
Sub-total			**210,000**
Documentation and printing costs			
Thesis copy editing	1	10,000	10,000
Thesis printing and binding	1	15,000	15,000
Sub-total			**25,000**
Grand Total	**362,000**		

Source of funding- Self

APPENDIX VI: WORK PLAN

Activity	Detail of Activity	Deliverable	Timeline
Concept development	Selection of Research topic and reviewing of literature on the selected topic.	Concept paper	June - August 2018
Departmental presentation of thesis concept paper	Present concept paper to members of the Department of Conservative and Prosthetic Dentistry.	Feasible research topic. Concept paper approved by the members of the Department	August 2018
Development of draft thesis proposal	Literature review on selected topic, drafting the objectives and research methodology.	Draft thesis proposal	September 2018 - November 2018
Development and correction of thesis proposal	Correct draft proposal based on comments from the supervisors.	Confirmed corrected proposal approved by supervisors.	December 2018 - March 2019
Corrections of proposal after presentation to Department	Correct the proposal based on comments given at departmental meeting.	Confirmed corrected proposal with feedback incorporated by members of the Department.	June - July 2020
Correction of proposal after presentation to faculty	Correct the proposal based on comments given at departmental academic meeting.	Corrected proposal with feedback incorporated by members of the faculty.	October 2020 - November 2020
Submission of proposal to KNH-UoN ERC	Proposal submitted to KNH-UoN ERC for ethical approval	Approved proposal from KNH-UoN ERC	January 2021
Pilot testing	Pilot testing of all research equipment and techniques.	Pilot testing report	March 2021

Data collection	Collection of data from participants	Raw research data	March 2021 - April 2021
Data processing and analysis	Data cleaning and coding.	Cleaned and coded research data	May 2021
Compilation of research findings	Compile findings, discussions, conclusions and recommendations.	Draft chapters on findings, discussions, conclusions and recommendations.	May 2021
Attend to comments	Attend to comments on chapters, from supervisors	Revised chapters on findings, discussions, conclusions and recommendations.	June 2021 - September 2022
Submission for supervisors' approval	Submission for supervisors' review and approval.	Complete Thesis	October 2022
Submission of Thesis for examination	Submission of Thesis to the office of Associate Dean Postgraduate Studies for examination	Examination thesis	October 2022
Thesis defense	Defend the research to postgraduate examination board.	Examination thesis	November 2022
Attend to examiners' comments	Correct thesis as per the examiners' comments	Final thesis	November 2022
Dissemination of research findings	Publish in an open access journal	Article	December 2022

APPENDIX VII: SCREENING AND RECRUITMENT FORM

DATE: ……

SERIAL NUMBER: ……

GENDER: ……

AGE (Date of birth or years): ……

Student/Patient: ……

Place of birth: ……

Parent origin: Father …… Mother ……

Screening Form: Tooth to tooth analysis						
	Six Maxillary anterior teeth					
	13	**12**	**11**	**21**	**22**	**23**
Decayed						
Filled						
Missing						
Cast restorations						
Attrition						
Fracture due trauma						
Correct inter-arch relationship.	Yes			No		
Correct crown angulation	Yes			No		
Correct crown inclination	Yes			No		
No rotations	Yes			No		
Tight contact points	Yes			No		
Flat curve of Spee (0.0-2.5mm)	Yes			No		
History of orthodontic treatment	Yes			No		
Meets Criteria	Yes			No		
Informed consent	Yes			No		
Recruitment	Yes			No		