DETERMINING THE CHANGE IN MYOPIA AMONG PATIENTS IN SELECTED EYE CLINICS IN BENIN CITY

BY

ITOHAN JEMIMAH AIWEKHOE (Miss)

LSC1900007

DEPARTMENT OF OPTOMETRY

FACULTY OF OPTOMETRY

UNIVERSITY OF BENIN

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CERTIFICATION AND APPROVAL

DEDICATION

I dedicate this project to my Father in Heaven, my beautiful parents, to myopes, and to my project supervisor—Dr. P.N. Uwagboe—whose heart cares for myopes.

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I give thanks to my Lord, who kept and sustained me by His mighty Hand and Word. The One whose Grace was sufficient for me and whose compassion never failed towards me.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Myopia is a significant and growing public health concern globally, with increasing prevalence observed even in regions like sub-Saharan Africa. Despite this, data on the rate of myopia progression in Nigeria remain limited, particularly in urban settings such as Benin City. Understanding the pattern and rate of myopia progression in this population is critical for guiding clinical management, preventive strategies, and policy interventions. This study aimed to determine the rate and pattern of myopia progression among patients aged 6–25 years attending selected eye clinics in Benin City over a ten-year period. A retrospective observational study design was employed. Clinical records of 300 myopic patients (71.3% females, 28.7% males) from four major eye clinics in Benin City between 2014 and 2024 were reviewed. Data on age, gender, and spherical equivalent refraction (SER) at first and last visits were extracted. Annual myopia progression rates were calculated as changes in SER (diopters per year). Descriptive and inferential statistical analyses were conducted using t-tests and ANOVA, with significance set at $p < 0.05$. The mean age of participants was 15.87 ± 4.75 years. The overall mean annual myopia progression rate was −0.15 D/year. Progression was fastest among younger patients (6–10 years: −0.38 D/year) and slowed with increasing age ($p < 0.05$). Only 13% of patients showed significant progression (≥ −0.50 D/year). Myopia progressed slightly faster in females (−0.16 ± 0.21 D/year) than males (−0.13 ± 0.13 D/year), but the difference was not statistically significant ($p = 0.33$). Baseline severity influenced progression, with mild myopes showing the highest mean annual change (−0.17 D/year). Myopia progression among patients in Benin City was relatively slow compared with Asian populations but exhibited similar age-related trends, with faster progression in younger individuals. These findings underscore the need for early detection and routine monitoring of refractive changes in children to prevent high myopia and associated ocular complications. The study provides baseline data to inform localized myopia control strategies and public health planning in Nigeria.

CHAPTER ONE

1.0 INTRODUCTION

Myopia, also known as short-sightedness, is a common visual or refractive error of the eye in which parallel rays of light focus in front of the retina, which is the neurosensory and light sensitive tissue, when accommodation is relaxed, leading to blurred distance vision. Clinically, myopia is defined based on spherical equivalent refraction (SER), with a cut-off of ≤ –0.50 diopters (D) considered as myopia, and ≤ –6.00 D typically classified as high myopia (Verkicharla *et al*, 2020).

Globally, myopia has reached epidemic levels, particularly in East and Southeast Asia where prevalence among schoolchildren can exceed 80% (Wong *et al.*, 2020). The World Health Organization (WHO) projects that by 2050, nearly 50% of the world's population will be myopic, and 10% will have high myopia (Holden *et al.*, 2016). In Europe, the DREAM study reported continuous progression from childhood into young adulthood (Polling *et al.*, 2022). African populations historically have shown lower prevalence, but new evidence suggests an upward trend (Ezelum *et al.*, 2011).

The growing prevalence of myopia represents a significant public health concern. High myopia is associated with vision-threatening complications such as retinal detachment, myopic maculopathy, glaucoma, and cataract, contributing to irreversible vision loss and increased healthcare costs (The COMET Group, 2013). Even moderate myopia increases the lifetime risk of ocular morbidity, making the control of progression particularly important (Donovan *et al.*, 2012).

Progression of Myopia refers to the advancement of refractive power over time, categorized as stable myopia if the refractive error remains relatively constant or progressing myopia if there are significant increases in refractive error within a specific period.

Myopia progression is clinically relevant as early onset in childhood is strongly associated with faster progression rates and higher risk of developing high myopia in adulthood (Verkicharla *et al*., 2020). Longitudinal studies such as COMET have demonstrated that myopia continues to progress well into adolescence and stabilizes variably depending on age, gender, and baseline refractive error (The COMET Group, 2013; Donovan *et al*., 2012). This highlights the importance of monitoring progression early, especially in young individuals. In Nigeria, despite evidence of rising refractive error prevalence, data on myopia progression remain scarce. Benin City, being an urban area with diverse educational and lifestyle factors, is likely to experience increasing rates of myopia among young people, mirroring trends observed globally (Ezelum *et al*., 2011). Yet, no comprehensive local studies have quantified progression rates over time in this region. This creates a gap in evidence for clinicians and policymakers in planning effective eye care strategies.

Therefore, this study seeks to determine the rate of myopia progression in selected eye clinics in Benin City. The findings will not only provide baseline data for the region but also contribute to the broader understanding of myopia trends in sub-Saharan Africa. Ultimately, this research is justified as it will inform clinical management strategies, public health planning, and early interventions to mitigate the long-term burden of myopia in the Nigerian population.

1.1 BACKGROUND OF THE STUDY

1.1.1 REFRACTIVE ERRORS

Refractive errors are among the most prevalent visual disorders worldwide and represent a significant cause of correctable visual impairment. They occur when the optical system of the eye fails to focus incoming light precisely on the retina, resulting in blurred or distorted vision (World Health Organization, 2024). In an emmetropic eye, parallel rays of light entering the eye are bent (refracted) by the cornea and crystalline lens to converge exactly on the retina, allowing for clear vision at all distances. When this process is disrupted due to abnormalities in the shape of the eyeball, corneal curvature, or lens power, a refractive error develops (National Eye Institute, 2023).

The eye's refractive components—the cornea and the crystalline lens—are primarily responsible for bending light to focus it on the retina. The cornea contributes about two-thirds of the eye's total refractive power, while the crystalline lens provides fine-tuning for focusing on near or distant objects. When there is a mismatch between the optical power and the length of the eyeball (axial length), the focal point of light either falls in front of or behind the retinal plane, leading to blurred vision (WHO, 2024).

Refractive errors may also arise from irregularities in the corneal curvature or changes in the lens's flexibility. There are three main types of refractive errors, namely: Myopia, Hyperopia, and Astigmatism. An excessively curved cornea or elongated eyeball results in myopia, whereas a flatter cornea or shortened eyeball causes hyperopia (NEI, 2023). Astigmatism results from an irregular curvature of the cornea or lens, causing light rays to focus at multiple points on or around the retina instead of a single sharp focus which in turn leads to blurred or distorted vision at all distances. Astigmatism can occur independently or in combination with myopia or hyperopia.

Uncorrected refractive error is one of the most common causes of visual impairment and a significant cause of blindness worldwide (Bourne *et al.*, 2013).

1.1.1.1 SPHERICAL EQUIVALENT

Spherical Equivalent (SE): In optometry, the spherical equivalent is a single value that represents the overall refractive power of the eye, taking into account both sphere and cylinder (astigmatism) power. It is calculated using the formula: SE = Sphere + (Cylinder / 2) (Enaholo *et al.*, 2023). This measurement is particularly useful for comparing refractive errors across different studies and for prescribing certain types of contact lenses or assessing suitability for refractive surgery.

The spherical equivalent is also used clinically when the optometrist and ophthalmologist deal with patients that probably cannot tolerate lenses with a cylindrical lens correction. Spherical corrected lenses may not provide the best corrected visual acuity. However, they can provide enhanced vision without problems related to cylindrical lenses (Enaholo *et al*., 2023).

1.1.2 MYOPIA

Myopia is a refractive error in which light rays focus in front of the retina when the intraocular muscle of the eye is relaxed, leading to reduced distance vision. It is defined clinically by spherical equivalent refraction (SER), where myopia is considered present at ≤ –0.50 diopters (D), and high myopia is typically defined at ≤ –6.00 D (Verkicharla *et al*., 2020).

Myopia results from an eye having excessive refractive power for its axial length. This may be due either to the eye having a relatively long axial length or to increased dioptric power of one or more of the refractive elements (Roosenfield, 2006)

1.1.3 CLASSIFICATION OF MYOPIA BY THE ANATOMICAL FEATURES

Myopia could be:

1. Axial, whereby the eye is too long for its refractive power.

An increase in axial length may occur in the anterior or posterior portions of the globe individually, or may occur throughout the eye (Roosenfield, 2006).

2. Refractive, whereby the refractive system is too powerful for the axial length of the eye.

Refractive myopia can further be divided into:

- Index myopia, in which one or more of the refractive indices of the media are anomalous.
- Curvature myopia, in which the reduced radius of curvature of one or more refractive surfaces produces increased dioptric power(Roosenfield, 2006).

1.1.4 CLASSIFICATION OF MYOPIA BASED ON SPHERICAL EQUIVALENT IN DIOPTERS

This is the most widely adopted and practical method used in clinical and epidemiological studies. The refractive classification depends on the degree of minus power (diopters) required to correct the myopic refractive error.

According to the IMI consensus (Flitcroft *et al*., 2019), World Health Organization (WHO, 2023), and American Academy of Ophthalmology (2022), the categories are as follows:

1. Low Myopia:

This is defined as a spherical equivalent refractive error between −0.50 D and −3.00 D (Flitcroft *et al*.,2019). Individuals in this category typically experience mild distance blur but can usually achieve normal vision with minimal optical correction. The ocular structures are generally healthy, with little or no risk of pathological changes. However, in young patients, even low myopia requires monitoring because it may progress during growth and academic years (Flitcroft *et al*., 2019).

2. Moderate Myopia:

This is defined as a spherical equivalent between −3.00 D and −6.00 D (Flitcroft *et al*., 2019). This category represents an intermediate level of myopia that may cause noticeable visual discomfort, especially for distance tasks, and requires constant optical correction. The risk of structural retinal changes begins to increase, as axial elongation and scleral stretching become more pronounced (Tideman *et al.*, 2016). Individuals with moderate myopia are more susceptible to developing complications if myopia continues to progress into adulthood.

3. High Myopia:

This is defined as a spherical equivalent of −6.00 D or greater (Flitcroft *et al.*, 2019). High myopia is associated with excessive axial elongation of the eyeball, which predisposes individuals to sight-threatening conditions such as myopic maculopathy, posterior staphyloma, retinal detachment, open-angle glaucoma, and early-onset cataract (Ohno-Matsui *et al.*, 2021). The functional impact on vision is significant, and many patients experience visual impairment even with optical correction due to associated retinal and choroidal thinning. The International Myopia Institute and the WHO recognize high myopia as a major cause of visual impairment globally, particularly in East and Southeast Asia (WHO, 2023).

1.1.5 CLASSIFICATION OF MYOPIA BASED ON AXIAL LENGTH

Beyond refractive power, myopia can also be classified based on axial length (AL) which is the distance between the anterior corneal surface and the retinal pigment epithelium. Axial elongation is the principal anatomical change underlying progressive myopia, making axial length measurement a key metric for assessing the severity of the condition (Tideman *et al.*, 2016).

The commonly accepted categories are:

1. Emmetropic/Non-Myopic Eye:

This group involves the axial length of the eye typically being less than 24.5 mm, indicating a normal ocular structure with no myopic elongation.

2. Low to Moderate Myopia:

This group involves the axial length of the eye ranging from 24.5 mm to 26.0 mm. This group shows mild to moderate elongation, often corresponding to low or moderate refractive myopia. The risk of pathological fundus changes remains relatively low, though continuous monitoring is necessary during school years or early adulthood (Flitcroft *et al.*, 2019).

3. High or Axial Myopia:

Axial length of 26.0 mm or greater is generally considered the threshold for pathologic myopia. At this point, the scleral wall is significantly thinned, the retina and choroid become stretched, and the risk of degenerative changes such as posterior staphyloma, lacquer cracks, and myopic choroidal neovascularization rises dramatically (Ohno-Matsui *et al.*, 2021).

1.1.6 CLASSIFICATION OF MYOPIA BASED ON PATHOLOGICAL CHANGES

Another essential way of categorizing myopia is by differentiating simple myopia from the pathologic (degenerative) forms. This classification emphasizes the clinical implications and long-term complications associated with ocular tissue changes.

A. Simple Myopia:

Represents the majority of myopia cases and is primarily due to a refractive mismatch rather than degenerative tissue alterations. Typically arises during school years and stabilizes in early adulthood. Ocular anatomy remains within normal limits, and vision is fully correctable with optical devices such as spectacles or contact lenses (Wong *et al.*, 2014).

B. Pathologic or Degenerative Myopia:

Occurs when excessive axial elongation leads to degenerative changes in the posterior segment of the eye. Characterized by features such as posterior staphyloma, chorioretinal atrophy, lacquer cracks, peripapillary atrophy, and myopic macular degeneration (Ohno-

Matsui *et al.*, 2021). This form of myopia often continues to progress even after skeletal maturity and is associated with irreversible visual loss. The condition is of increasing concern to global eye health agencies due to its contribution to uncorrectable visual impairment and blindness, especially in highly urbanized and educationally intensive societies (WHO, 2023).

1.1.7 PROGRESSION OF MYOPIA

The progression of myopia refers to the gradual increase in the magnitude of the refractive error over time, usually due to continued increase in the axial length of the eyeball and structural remodeling of the sclera, choroid, and retina (Flitcroft *et al.*, 2019). Myopia typically develops during childhood, progresses throughout adolescence, and stabilizes in early adulthood, although in some individuals, especially those with high educational or occupational visual demands, progression may persist into adulthood (Wu *et al.*, 2018). Understanding the pattern of myopia progression and its underlying risk factors is essential for developing effective prevention and control strategies.

Annual Progression rate of myopia

The annual progression rate of myopia refers to the average change in refractive error (measured in diopters per year, D/year) or axial length (in millimeters per year, mm/year) over a defined observation period. It quantifies how quickly myopia worsens in an individual or population over time.

Annual Progression rate: $\frac{\text{SER at follow up - SER at baseline ,}}{\text{Interval of years}}$ (Polling *et al.*, 2012).

Pattern of Myopia Progression Across Age

a. Childhood Onset and Early Progression

Myopia often begins during school age (6–12 years), coinciding with the period of rapid ocular growth and increased educational visual demand. The early onset of myopia is a significant predictor of faster progression and higher final refractive error in adulthood (Donovan *et al*., 2012). During this stage, the average rate of progression is approximately −0.50 D to −1.00 D per year, though this may vary with ethnicity, environment, and visual habits (Morgan & Rose, 2019). Early myopic eyes show excessive elongation of the axial length and thinning of the posterior sclera, resulting in reduced emmetropization control.

b. Adolescence and Continued Progression

During adolescence (approximately 13–18 years), myopia often continues to progress as the eye undergoes residual growth and hormonal changes that may influence scleral remodeling. Adolescents are also exposed to sustained near work activities, including digital screen use and reading, which increase the risk of further axial elongation (Guo *et al*., 2019). Educational pressures and limited outdoor exposure exacerbate this trend. Studies have shown that persons who develop myopia before age 10 are more likely to progress to high myopia by late adolescence (French *et al*., 2013).

c. Stabilization in Adulthood

Myopia progression typically stabilizes in the early to mid-20s, when ocular growth plateaus and the sclera becomes less malleable (Saw *et al*., 2021). However, adults engaged in visually demanding occupations such as computer-based work, academia, or microscopy may still experience late-onset or progressive myopia. In some cases, pathological elongation may persist into adulthood, leading to degenerative changes in the posterior segment of the eye (Ohno-Matsui *et al*., 2021).

FACTORS INFLUENCING THE PROGRESSION OF MYOPIA

The development and progression of myopia are the result of a complex interaction between genetic predisposition, environmental exposure, and lifestyle behaviors. These factors work synergistically to influence ocular growth, particularly the axial elongation of the eyeball, which is the main anatomical cause of myopia progression (Flitcroft *et al.*, 2019). Understanding these determinants is crucial for designing preventive strategies and interventions to reduce the burden of myopia worldwide

1. Genetic Factors

a. Hereditary Influence

Genetics plays a fundamental role in the susceptibility to myopia and its progression. Children with myopic parents have a significantly higher likelihood of developing and progressing in myopia compared to those with non-myopic parents. Studies have shown that children with one myopic parent have about two to three times greater risk, while those with two myopic parents have up to six times higher risk of developing myopia (Jones *et al.*, 2007). This suggests a heritable transmission of ocular growth tendencies, particularly those influencing axial elongation and refractive development.

b. Twin and Family Studies

Twin studies have consistently demonstrated the heritable nature of myopia, with heritability estimates ranging from 60% to 90% (Hysi *et al.*, 2020). Monozygotic twins, who share identical genetic material, exhibit much higher concordance rates of myopia compared to dizygotic twins, emphasizing the strong genetic contribution to its development and progression. Furthermore, family clustering of myopia severity has been reported, where children of parents with high myopia often experience more rapid progression and earlier onset.

c. Identified Genetic Loci

Advancements in molecular genetics have identified several loci associated with myopia susceptibility. Genome-wide association studies (GWAS) have implicated more than 160 genetic loci, including PAX6, ZFHX1B, and GJD2, which are involved in ocular growth regulation, scleral remodeling, and retinal signaling (Tedja *et al.*, 2019). These genes influence how the eye responds to environmental stimuli, such as defocus and visual strain, thus linking genetic predisposition with environmental triggers.

d. Ethnic and Population Variations

Ethnicity has also been observed to play a role, with East Asian populations demonstrating both higher prevalence and faster progression rates of myopia compared to European or African populations (Saw *et al.*, 2021). This difference likely reflects the combined influence of genetic susceptibility and intense educational environments characteristic of these regions.

2. Environmental Factors

a. Outdoor Activity and Light Exposure

Environmental influences, particularly time spent outdoors, are among the most significant modifiable factors affecting myopia progression. Numerous studies have demonstrated that children who spend more than 2 hours daily outdoors are less likely to develop or progress in myopia compared to those who spend minimal time outside (Wu *et al.*, 2018). Exposure to natural light stimulates retinal dopamine release, which in turn inhibits excessive axial elongation of the eyeball (Xiong *et al.*, 2017). This biological mechanism explains why outdoor play is protective against myopia.

In contrast, children living in urban areas—with limited access to outdoor spaces and increased exposure to artificial lighting—tend to exhibit higher rates of myopia progression.

Urban environments also correlate with higher educational pressures and greater screen exposure, both of which intensify near work demands (Morgan & Rose, 2019).

b. Educational and Environmental Pressures

The educational system and learning environment significantly influence myopia progression. Countries with highly competitive academic systems, such as China, South Korea, and Singapore, have some of the highest myopia prevalence rates globally, often exceeding 80% among school-leavers (Holden *et al.*, 2016). Prolonged hours of reading, homework, and indoor study reduce exposure to outdoor light and increase accommodative stress, leading to accelerated myopia progression (Guo *et al.*, 2019).

Environmental conditions such as poor lighting, small living spaces, and visual clutter can also contribute to sustained accommodative effort and ocular fatigue, further promoting axial elongation.

3. Lifestyle and Behavioral Factors

a. Near Work and Digital Device Use

The duration, intensity, and proximity of near work are major behavioral factors in myopia progression. Activities such as reading, writing, mobile phone use, computer gaming, and studying require continuous accommodation and convergence, resulting in sustained hyperopic retinal defocus that stimulates axial elongation (Guo *et al.*, 2019).

Recent research highlights the increasing impact of digital device usage, particularly following the global shift toward online learning during the COVID-19 pandemic. Wang *et al.* (2021) observed that children who spent over 6 hours per day on digital screens showed significantly greater myopia progression compared to those with lower screen exposure.

Furthermore, holding reading materials closer than 30 cm and taking fewer visual breaks (less than every 20 minutes) have been associated with faster progression rates.

b. Sleep, Stress, and General Health

Sleep duration and quality have also been linked to myopia progression. Short sleep duration (<7 hours per night) correlates with higher rates of myopia, possibly due to disrupted circadian regulation of ocular growth (Ayaki *et al*., 2016). Chronic academic stress and mental fatigue further exacerbate visual strain, particularly in adolescents subjected to long study hours without adequate visual rest.

Additionally, emerging evidence suggests that dietary habits may influence ocular health. Insufficient intake of vitamin D, which is synthesized during sunlight exposure, has been associated with increased myopia risk (Tideman *et al*., 2016). Diets lacking in omega-3 fatty acids and antioxidants may also impair retinal function and scleral integrity.

c. Socioeconomic and Cultural Influences

Socioeconomic status plays a dual role in myopia progression. Higher socioeconomic backgrounds often correspond with better access to education and technology, increasing exposure to near work and digital screens. Conversely, in lower-income settings, lack of access to refractive correction and eye care services can lead to uncorrected myopia, resulting in sustained retinal defocus that further stimulates axial elongation (Wong *et al*., 2014).

Cultural factors also play a role; in many Asian societies, academic achievement is highly prioritized, leading to early and intense educational activities that promote myopia development.

1.1.8 CONSEQUENCES OF UNCONTROLLED MYOPIA

Uncontrolled progression of myopia, particularly into the high or pathologic range, has profound ocular and systemic implications. The risk of developing sight-threatening complications increases exponentially with each additional diopter of myopia (Ohno-Matsui *et al.*, 2021).

Some of the major clinical consequences include:

High Myopia (≥ −6.00 D):

This is associated with significant axial elongation, typically ≥ 26 mm. It increases the risk of visual impairment by 40-fold compared to emmetropic individuals (Tideman *et al.*, 2016).

Retinal Detachment:

This can occur due to mechanical stretching of the retina and vitreoretinal traction. Highly myopic eyes are up to 10 times more likely to develop rhegmatogenous retinal detachment (Mitry *et al.*, 2010).

Myopic Maculopathy and Degeneration:

This involves progressive chorioretinal thinning, lacquer cracks, and myopic choroidal neovascularization which may lead to irreversible central vision loss (Wong *et al.*, 2014).

Pathologic myopia is now recognized as one of the leading causes of blindness in East Asia and an emerging concern in other regions (Ohno-Matsui *et al.*, 2021).

Open-Angle Glaucoma:

Myopic eyes exhibit elongated optic discs and thinner lamina cribrosa, increasing susceptibility to glaucomatous damage even with normal intraocular pressure (Marcus *et al.*, 2011).

Cataract Formation:

High myopia is linked to earlier development of nuclear and posterior subcapsular cataracts (Luo *et al.*, 2013). These complications highlight the importance of early detection, intervention, and monitoring to prevent irreversible vision loss associated with progressive myopia

1.1.9 PREVALENCE AND PROGRESSION TRENDS IN AFRICA AND NIGERIA

Recent systematic reviews and regionally focused meta-analyses indicate that, historically, myopia prevalence among African children has been substantially lower than reported in East and Southeast Asia, but there is evidence of gradual increases and wide heterogeneity between studies and locations. Ovenseri-Ogbomo *et al.* (2022) reported a pooled prevalence of childhood myopia of approximately 4.7% (SER ≤ −0.50 D) across African studies, with significant variability by country and methodology. This low pooled prevalence contrasts sharply with East Asian data, where prevalence in older children and adolescents exceeds 50–80% (Holden *et al.*, 2016; Morgan *et al.*, 2018). Although prevalence estimates in parts of Africa remain low, longitudinal data describing rates of myopia progression (annual change in spherical equivalent refraction per eye) are relatively scarce across West Africa and Nigeria. Most population and clinic reports from the region are cross-sectional rather than longitudinal, limiting the ability to estimate true progression velocities and risk factors (Naidoo *et al.*, 2016; Kumah *et al.*, 2020). Reviews of the African myopia literature explicitly note this methodological gap which hinders comparison with large prospective cohorts from Asia and Europe (Ovenseri-Ogbomo *et al.*, 2022).

1.1.10 GAPS IN MYOPIA PROGRESSION DATA IN NIGERIA / WEST AFRICA COMPARED TO ASIA AND EUROPE

Two key gaps stand out from the regional literature. First, there is a lack of standardized longitudinal cohorts in West Africa. While East Asian and European countries have multiple large, prospective school-based cohorts that measure spherical equivalent refraction and axial length annually (e.g., the Singapore Cohort Study of the Risk Factors for Myopia and the Northern Ireland Childhood Errors of Refraction Study), West African research remains dominated by cross-sectional designs (Morgan *et al*., 2018; Saw *et al*., 2019). This restricts precise estimation of age-specific progression rates, peak progression periods, and the effectiveness of interventions in local populations (Naidoo *et al*., 2016).

Second, heterogeneity in measurement methods and outcome reporting reduces comparability. A good number of Nigerian studies use non-cycloplegic autorefraction or visual-acuity-based definitions, while global progression studies rely on cycloplegic subjective refraction and axial length measurement, reporting per-eye SER change over time. Owing to the fact that non-cycloplegic refraction can overestimate myopia in young children due to accommodative spasm, the absence of cycloplegia in many community studies reduces certainty about true refractive status (Tideman *et al*., 2018). Reviews have therefore recommended harmonised protocols involving cycloplegia, defined SER thresholds, and per-eye reporting to enable direct comparison with international datasets (Naidoo *et al*., 2016; Ovenseri-Ogbomo *et al*., 2022).

Finally, there is limited published evidence on behavioural and environmental determinants — such as outdoor activity, near work, and screen exposure — from representative Nigerian cohorts. Globally, studies consistently link reduced outdoor time and increased near-work exposure to higher myopia risk and faster progression (Rose *et al*., 2008; Lingham *et al*., 2021). However, few Nigerian studies have quantified these variables in relation to myopia progression, restricting locally relevant recommendations for prevention or control (Ovenseri-Ogbomo *et al.*, 2022).

WHY LOCALIZED DATA ARE NECESSARY (ENVIRONMENTAL AND LIFESTYLE DIFFERENCES)

Myopia development and its progression results from a combination of genetic predisposition and modifiable environmental factors such as educational intensity, outdoor exposure, and near-work behaviour (Morgan *et al.*, 2018; Holden *et al.*, 2016). These factors vary in a considerably significant manner across countries and even within regions. Urbanization, schooling patterns, and digital device use are rapidly evolving in Nigeria, creating unique risk profiles distinct from those observed in Asian populations (Naidoo *et al.*, 2016; Kumah *et al.*, 2020). Consequently, extrapolating progression rates or intervention effects from Asian or European data may misrepresent the Nigerian reality. Localized, longitudinal data capturing annual SER change per eye, axial length (if available), and lifestyle factors are therefore critical for evidence-based recommendations suited to the Nigerian context (Ovenseri-Ogbomo *et al.*, 2022).

1.1.10 SPECIFIC CONTEXT OF BENIN CITY

Benin City, the capital of Edo State, is a rapidly urbanizing metropolis with a dense educational network that includes primary, secondary, and tertiary institutions. The population increasingly engages in academic activities, prolonged near work, and digital device use — all established environmental correlates of myopia onset and progression (Lingham *et al.*, 2021; Rose *et al.*, 2008). Although detailed epidemiological data on daily device use and outdoor exposure in Benin City are scarce, eye clinics and optometric practices report a growing number of patients presenting with distance blur and asthenopic complaints linked to near work (Oduntan *et al.* 2015).

WHY BENIN CITY IS A RELEVANT STUDY SETTING FOR PROGRESSION RESEARCH

First, urbanization and high educational activity make Benin City a prime environment for studying myopia progression among children and adolescents — the demographic most susceptible to refractive change (Rose *et al*., 2008; Lingham *et al*., 2021). Second, there is a clear research gap: no major longitudinal study has quantified annual per-eye changes in spherical equivalent refraction or correlated them with behavioural exposures in this region. Conducting such research will not only bridge this gap but also inform local clinical management and public health strategies for early detection and control of progressive myopia.

Despite the growing global and regional body of evidence on myopia epidemiology, there remains a significant paucity of data on myopia progression within Nigeria, and particularly within Benin City. Most studies conducted in Nigeria have been cross-sectional, focusing on prevalence or distribution of refractive errors rather than longitudinal changes in refractive status. While such studies provide valuable snapshots, they do not capture the rate at which myopia worsens over time, which is essential for understanding its natural history and designing timely interventions. In contrast, well-established longitudinal cohorts in Asia and Europe, such as the Singapore Cohort Study of the Risk Factors for Myopia and the Sydney Myopia Study, have provided robust data on annualized refractive changes and associated risk factors (Saw *et al*., 2006).

Understanding the rate of myopia progression among patients in Benin City would therefore play a crucial role in improving early detection, individualized management, and prevention of vision-threatening complications. Rapidly progressing myopia is a known risk factor for the development of pathological myopia, retinal detachment, glaucoma, and myopic maculopathy — all of which carry a substantial burden of irreversible visual impairment (Tideman *et al*., 2018). Establishing progression benchmarks would allow eye care practitioners to identify high-risk individuals early and implement targeted interventions such as myopia control lenses, orthokeratology, or low-dose atropine where appropriate(Lingham *et al*., 2021).

From a public health standpoint, localized data on myopia progression would assist in policy formulation and resource allocation. Accurate progression data can inform school vision screening intervals, guide public health campaigns on safe screen usage and outdoor time, and shape training curricula for optometrists and ophthalmic technicians to prioritize preventive eye care (Naidoo *et al*., 2016). Furthermore, the evidence generated from Benin City could serve as a reference model for other urban areas in Nigeria and West Africa, enabling regional comparison and contributing to a more comprehensive understanding of myopia dynamics across diverse African settings.

Ultimately, the findings of this study will have multilevel benefits — advancing local clinical practice, informing evidence-based policy, and improving patient quality of life through early and effective management of progressive myopia. By bridging the gap between global evidence and local context, this research aims to support a shift from reactive correction of myopia to proactive prevention and control within the Nigerian eye care landscape.

1.2 STATEMENT OF THE PROBLEM

Most existing data on myopia progression have been provided by controlled myopia intervention studies, which have a short follow up period, limited numbers or are based on imputed data. This limits adequate insights into the association between age of onset and final refractive error (Polling *et al.,* 2021).

In addition, the array of studies that investigate the progression of myopia, its extent, and related demographic characteristics across different age groups in Nigeria and Africa as a whole are not as robust or as substantial as that of othe r populations (especially the Asian and Caucasian population). Without longitudinal data, it will be challenging to understand risk factors, the natural course of the condition, or gaps in eye healthcare delivery in Nigeria and Africa.

1.3 AIM AND OBJECTIVES OF THE STUDY

1.3.1 AIM

To determine the change in myopia of patients aged 6 - 25 years of age in selected eye clinics in Benin City over a period of 10 years.

1.3.2 OBJECTIVES OF THE STUDY

Primary Objective: To determine the annual progression rate of myopia among patients 6-25 years of age.

Secondary Objectives:

To describe the age-wise pattern of myopia progression (e.g. comparing children, adolescents, and adults) using these age brackets: 6-10, 11-15, 16-20, and 21-25.

To examine differences in progression by baseline myopia severity:

- Mild myopia: -0.50 to -3.00 Spherical equivalent (SE)
- Moderate myopia: -3.00 to -6.00
- High/severe myopia: <-6.00 (more negative)

1.4 RESEARCH QUESTIONS

What is the average annual rate of myopia progression in the cohort over the 10-year period?

How does myopia progression vary by age group? (e.g. Are younger patients progressing faster than older ones?

What proportion of patients exhibit significant progression (e.g. ≥–0.50 D change per year) and does this relate to their baseline refraction?

Are there gender differences associated with faster or slower myopia progression in this population?

How do the observed progression trends compare with global/regional estimates reported in the literature?

1.5 HYPOTHESES OF THE STUDY

H_1: Younger patients experience significantly faster progression in Spherical Equivalent (SE) compared to older counterparts.

H_2: Higher baseline myopia (e.g., ≤ –3 D) predicts greater annual progression.

H_3: Gender has an effect on myopia progression rate.

H_3: Patients with faster progression and higher baseline refractive errors are more likely to develop high myopia (≤ –6 D), increasing risk of ocular complications.

1.6 SIGNIFICANCE OF THE STUDY

Public health impact

Myopia, especially moderate to high degrees, is a leading cause of visual impairment worldwide and is linked to serious ocular complications later in life. Understanding myopia progression is essential for mitigating its long-term health and economic consequences thus improving the quality of life of affected persons.

Fills knowledge gap in Nigeria

Most existing studies in Nigeria are cross-sectional, offering only prevalence snapshots in isolated regions. Absence of longitudinal data limits the formulation of myopia control programs and effective public policies. This study can provide a longitudinal analysis of myopia progression in Nigeria.

Local context / environmental insights

Environmental factors—like increased indoor time, near work, and reduced sunlight exposure—are strongly linked with the development and progression of myopia. By focusing on a defined LGA, this study can explore how local behaviors, place of residence, education patterns, and urbanization influence myopia trends among the population.

Improving eye care services

Low spectacle uptake and poor awareness compound the burden of uncorrected refractive error in Nigeria. A 10-year retrospective study can uncover patterns in healthcare access and barriers to refractive correction, guiding interventions like school vision screening and affordable spectacles.

Global and regional relevance

Longitudinal data from Africa are sparse compared to robust cohorts in Asia. This study will provide critical comparative data, enhancing global myopia control discussions and promoting equity in eye health research.

Contributing to the body of literature

This research can provide baseline data for future studies and help develop effective management strategies and guidelines for myopia thus contributing ultimately to better control of this condition and its complications in Nigeria and Africa as a whole.

1.6 DEFINITION OF TERMS

Myopia: Also known as nearsightedness or short-sightedness, myopia is a common vision condition where light entering the eye focuses in front of the retina instead of directly on it. This usually results from the eyeball being too long or the cornea having an excessive curvature. Individuals with myopia can see nearby objects clearly, but distant objects appear blurry. It is quantitatively defined in research as a spherical equivalent refractive error of ≤ -0.50 diopters (D).

Myopia Progression: This refers to the worsening or increase in the degree of myopia over time, typically measured by an increase in the negative dioptric power needed for correction or an increase in the axial length (front-to-back measurement) of the eye. Progression is most common in childhood and adolescence, often stabilizing in the late teens or early twenties. The primary goal of myopia control treatments is to slow this progression, as higher levels of myopia increase the lifetime risk of serious eye diseases like retinal detachment and glaucoma.

Patient: A person who is receiving or registered to receive medical care or treatment from a doctor, hospital, or other healthcare professional. It applies to any individual interacting with a clinician for reasons ranging from perceived illness to health promotion and disease prevention.

Spherical Equivalent (SE): In optometry, the spherical equivalent is a single value that represents the overall refractive power of the eye, taking into account both sphere and cylinder (astigmatism) power. It is calculated using the formula: SE = Sphere + (Cylinder / 2). This measurement is particularly useful for comparing refractive errors across different studies and for prescribing certain types of contact lenses or assessing suitability for refractive surgery.

Annual Myopia Progression Rate: This is a quantitative measure of how much a person's myopia has worsened over a one-year period, expressed in diopters per year (D/year).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 GLOBAL EVIDENCE ON MYOPIA PROGRESSION

Numerous retrospective cohort and clinical studies have quantified how rapidly myopia progresses by age and by baseline refractive error. Donovan *et al*. (2012) in a meta analysis searched the National Library of Medicine's PubMed literature database for articles on myopia progression. The estimated myopia progression at a mean age of 9.3 years after 1 year of follow-up was -0.55 D for populations of predominantly European extraction and -0.82 D (95% CI) for Asians. The estimated progression rates were dependent on baseline age, with decreasing progression as age increased. The rates also varied with gender (Donovan *et al*., 2012)

Polling *et al*. in the Drentse Refractive Error and Myopia (DREAM) Study (2012) assessed data from a branch of opticians in the Netherlands from 1985 onwards in a retrospective study. Subjects with prescriptions at an interval of at least 1 year were included in the analysis. A total of 2555 persons (57.3% female) met the inclusion criteria. Those with first prescription before the age of 10 years showed the strongest progression and a significantly ($p<0.001$) more negative median final spherical equivalent refraction (SER) (-4.48 D; IQR: -5.37 to -3.42). All children who developed SER=-3 D at 10 years were highly myopic (SER =-6D) as adults, children who had SER between -1.5 D and -3 D at 10 years had 46.0% risk of high myopia, and children with SER between -0.5 D and -1.5 D had 32.6% risk of high myopia. Myopia progression reduced with age; all refractive categories stabilized after age 15 years except for SER = -5 D who progressed up to -0.25 D annually until age 21 years. The authors believe that SER at 10 years is an important prognostic indicator and will help determine treatment intensity (Polling *et al*., 2012].

Verkicharla *et al*. (2020) investigated annual myopia progression in individuals from South Indian states across different age groups, and its association with age of onset and severity of myopia. This retrospective study included the data of 6984 myopes (range: 1–30 years), who visited at least twice to LV Prasad Eye Institute and on whom a standard retinoscopy technique was performed to determine refractive error. Based on spherical equivalent (SE) refractive error, individuals were classified into mild, moderate, high and severe myopic groups. Myopia progression was calculated as difference between SE at 1-year follow-up visit and at baseline. To determine the age-specific myopia progression, individuals were further categorized as myopes who are at least 15 years or younger and those who are older than 15 years. The mean annual progression of myopia was influenced by both the age group and severity type of myopia. The overall mean myopia progression ranged from -0.07 ± 0.02 D (standard error) to -0.51 ± 0.02 D across different age groups with maximum change in refractive error noted in children aged 6–10 years and the least in adults aged 26–30 years. Myopia progression was greater in severe myopes, followed by high, moderate, mild myopes and in individuals aged ≤ 15 years compared to those aged >15 years. Severe myopes alone had similar annual myopia progression rate irrespective of age. Early onset of myopia was associated with high myopia in adulthood. This study showed that the magnitude of myopia progression in children from South Indian states is comparable to that of Caucasians and Chinese (Verkicharla *et al*., 2020)

2.2 FACTORS INFLUENCING MYOPIA PROGRESSION (GENDER, LIFESTYLE, PARENTAL MYOPIA, AND OTHERS)

Wong & Dahlmann-Noor (2020) analyzed 23,593 urban UK children (0–17 years) over a decade. They found that the proportion of spectacle prescription for myopia rose from 24% to 32% (2008–2017) and that median progression among those who progressed was –0.40 D/year. Girls progressed slightly faster than boys (–0.42 vs –0.38 D/yr). As expected, children with moderate myopia at baseline progressed more rapidly than those with mild myopia (–0.54 vs –0.37 D/yr). Notably, Wong *et al.* found no significant ethnic differences in progression in this multicultural London cohort, suggesting that in a common urban environment genetic differences may play a limited role. They concluded that urban lifestyles might equalize progression rates across ethnicities, yielding higher rates than traditionally seen in European contexts (Wong and Dahlmann-Noor, 2020)

Manoharan *et al.* (2023) developed the Myopia Progression Risk Assessment Score (MPRAS) using longitudinal data from children aged 6–17 years. The model incorporated SER, age, parental myopia, and sex as predictors of annual myopia progression. The mean SER progression across the sample was −0.44 D per year, and the inclusion of sex improved the model's predictive accuracy by about 6%. Although the difference between boys and girls was small (−0.03 D per year), it remained consistent across datasets. The study demonstrated that sex is an independent, albeit modest, predictor of refractive change and should be considered in both research analyses and risk communication to patients (Manoharan *et al.*, 2023).

Jones-Jordan *et al.* (2021) conducted a large longitudinal study to explore how myopia progression varies with sex, age, and ethnicity in children. The researchers collected annual cycloplegic refraction data and calculated changes in spherical equivalent refraction (SER) for each eye. They found that girls showed slightly faster myopia progression than boys, averaging −0.35 D per year compared to −0.31 D in boys, after adjusting for age and baseline myopia. Although the difference was small, it was statistically significant, suggesting a potential biological or behavioural influence on progression. The study also highlighted that progression tended to slow with increasing age, particularly after age 14. The findings underline the need to include sex as a variable in myopia studies since even modest differences could affect long-term refractive outcomes (Jones-Jordan *et al.*, 2021)

In a prospective cohort study, Wang *et al.* (2021) assessed changes in SER among Chinese schoolchildren aged 6–8 years following one year of home confinement during the COVID-19 pandemic. Cycloplegic refraction revealed a mean myopic shift of −0.34 D per year overall, which was more pronounced in girls (−0.37 D) than in boys (−0.30 D). The authors attributed this to increased near work and reduced outdoor time, particularly among female participants. Importantly, they adjusted for parental myopia and environmental factors, confirming that the observed sex difference remained significant. The study demonstrated that lifestyle patterns influenced by gender roles could accelerate refractive change, highlighting how environmental pressures interact with biological predisposition to influence progression (Wang *et al.*, 2021).

Varošanec *et al.* (2024) conducted the CroMyop Study, a prospective investigation into myopia progression among Croatian children aged 7–15 years. The researchers assessed SER changes using standard subjective refraction and analysed sex-specific trends across two years. They reported a mean annual progression of −0.39 D in girls and −0.33 D in boys, indicating a modest but consistent gender difference. Environmental factors, such as outdoor time and reading duration, significantly influenced progression, with girls reporting lower outdoor exposure. The study concluded that lifestyle differences, combined with earlier onset of puberty in females, may partly explain faster myopia progression. Importantly, this research highlights how both biological and environmental variables interact to influence refractive change (Varošanec *et al.*, 2024)

The Anyang Childhood Eye Study (ACES) examined the longitudinal relationship between outdoor activity, near work, and myopia progression among Chinese adolescents aged 10.9–15.6 years over two years. Involving 1,997 participants (mean age 12.7 ± 0.5 years), the study assessed changes in spherical equivalent refraction (SER) and axial length (AL) through annual cycloplegic measurements and standardized questionnaires on lifestyle patterns (Li *et* *al*., 2022). Results demonstrated a weak but suggestive association between increased outdoor time and slower axial elongation, with a difference of −0.016 mm/year between high and low outdoor-time tertiles (P = 0.053). This effect was more pronounced in children who were non-myopic at baseline, showing a reduction of −0.036 mm/year (P = 0.009), while no significant association was observed among existing myopes (P = 0.595). Changes in SER followed a similar but statistically nonsignificant pattern (P > 0.05). The findings suggest that greater exposure to outdoor light may help delay the onset of myopia rather than substantially slow progression once myopia has developed. Other activities, including near work and screen use, showed no significant correlation with AL or SER change (P > 0.11). The ACES results reinforce that while outdoor exposure exerts a modest protective effect, its influence is likely preventive rather than therapeutic in established myopia cases (Li *et al*., 2015).

A hospital-based cross-sectional study by Chen *et al*. (2021) investigated the relationship between axial length (AL) and spherical equivalent refraction (SER) in 1,208 eyes of Chinese children aged 2–12 years. The study demonstrated a strong negative correlation between AL and SER, showing that a 1 mm increase in AL corresponded to approximately a −1.23 D shift towards myopia after adjusting for age and sex. Mean AL increased progressively with age—from 22.24 mm in the 2–6 year group to 24.33 mm in the 10–12 year group—while SER concurrently decreased from +0.73 D to −1.72 D. Boys exhibited longer ALs than girls (23.66 mm vs 23.05 mm), but girls demonstrated greater myopic shifts per millimetre of AL elongation (−1.68 D vs −0.94 D). These findings highlight an early-onset trend of axial elongation and myopic refractive change, reinforcing that myopia development is closely linked to ocular growth patterns in childhood. The results underscore the need for early monitoring of AL and SER in paediatric populations for timely myopia control interventions (Chen *et al*., 2021).

Using national survey data from South Korea, Kim *et al*. (2024) analysed secular trends in myopia progression among 6–18-year-olds over a ten-year period. The results showed that myopia prevalence increased from 65.4% to 76.8%, with a greater rise among girls. The annual SER change was also faster for females (−0.40 D) compared with males (−0.33 D). The researchers attributed this difference to both environmental and hormonal influences, including longer study hours and earlier puberty in girls. Their findings demonstrate that gender disparities in myopia are consistent not only across cohorts but also across time, underscoring the importance of monitoring sex-based risk patterns in both research and clinical practice (Kim *et al*., 2024).

The International Myopia Institute (IMI) 2025 Digest by Tahhan *et al*. (2025) reviewed global trends and determinants of myopia, integrating evidence from longitudinal and interventional studies. The report noted that although the sex differences in myopia progression are generally small, girls tend to exhibit a slightly higher annual SER change of approximately −0.05 to −0.10 D compared with boys. It emphasised the need for researchers to include sex as a covariate when modelling myopia progression and to report outcomes separately for males and females. The IMI also highlighted the importance of early detection and preventive measures, especially in populations with strong environmental risk factors. This consensus underscores the global relevance of investigating gender-based differences in myopia progression (Tahhan *et al*., 2025).

2.3 PROGRESSION OF MYOPIA IN AFRICA AND NIGERIA

Kyei *et al*. (2024) investigated the pattern of progression of myopia among a Ghanaian clinical cohort through a retrospective analysis of a clinical data set of all healthy myopic participants attending a tertiary eye care center. Participants' biennial refraction examinations were tracked for refractive changes 4 years after the date of the first visit. Myopia progression was defined as a difference in spherical equivalent between consecutive biennial visits equal to, or greater than −0.50 D of myopia. The medical records of 169 myopic participants were reviewed, with the majority (53.8%) being female. Univariate regression revealed that the 36–59-year-old age range is associated with a 60% reduced likelihood compared to those belonging to the 0–17-year-old age group, and the Mole-Dagbon ethnicity is associated with an almost fourfold increased likelihood of experiencing myopia progression compared to those of Ga-Adangbe ethnicity.

The burden of myopia in Africa is increasingly recognised, but evidence from longitudinal and clinic-based studies remains limited compared with Asia and Europe. Systematic reviews of African data emphasise a paucity of longitudinal cohorts and recommend clinic-record analyses as an accessible source of progression data for the region (Ovenseri-Ogbomo *et al.*, 2022). This literature gap justifies clinic-based retrospective investigations that extract repeated subjective refractions from patient files, because such studies can quickly provide context-specific estimates of spherical equivalent (SER) change, identify high-risk subgroups, and inform local myopia management strategies.

2.4 MYOPIA INTERVENTION AND CONTROL STUDIES

The Atropine for the Treatment of Myopia (ATOM 2) study conducted in Singapore was a randomized, double-masked trial involving 400 children aged 6–12 years, designed to evaluate the dose-dependent efficacy of 0.5%, 0.1%, and 0.01% atropine in controlling myopia progression. Over two years, mean myopia progression measured in spherical equivalent refraction (SER) was −0.30 ± 0.60 D, −0.38 ± 0.60 D, and −0.49 ± 0.63 D respectively, compared to about −1.20 D/year commonly observed in untreated Asian cohorts (Chia *et al.*, 2012). Axial elongation was minimal in the 0.01% group (0.41 mm) compared with 0.27 mm and 0.37 mm in the higher-dose groups, demonstrating clinically significant efficacy despite lower concentration. After treatment cessation, the rebound effect was mildest in the 0.01% group, suggesting that low-dose atropine offers optimal long-term control with fewer adverse effects such as photophobia and near blur. This trial remains a cornerstone in pharmacologic myopia management, establishing low-dose atropine as a safe, effective, and sustainable intervention for reducing SER progression in children.

The Defocus Incorporated Multiple Segments (DIMS) spectacle-lens trial evaluated the effect of specially designed spectacle lenses that incorporate multiple small segments creating myopic peripheral defocus on childhood myopia progression. In a double-masked randomized controlled trial of 183 Chinese children (aged 8–13 years) over two years, DIMS wearers experienced significantly less spherical equivalent refraction (SER) progression and axial elongation than those wearing single-vision lenses. Specifically, the DIMS group showed about 0.44 D less SER progression and 0.34 mm less axial elongation across two years, and subsequent three-year follow-up data demonstrated that the protective effect persisted with continued wear (Lam *et al*., 2020; Lam *et al*., 2022). The trial used cycloplegic autorefraction as its primary refractive endpoint, reporting both absolute SER changes and age-adjusted differences between groups; wearing time and adherence correlated with magnitude of benefit. Clinically, DIMS spectacles provided a non-contact, non-pharmacologic option with minimal visual side-effects, making them attractive for clinic settings where contact lenses or pharmacotherapy may be less acceptable. The study established DIMS as an evidence-based spectacle intervention that meaningfully reduces SER progression in children and supplied a practical benchmark (≈0.2–0.3 D/year benefit) for comparing optical strategies in other populations (Lam *et al*., 2020; Lam *et al*., 2022).

Spectacle lenses incorporating arrays of aspherical lenslets — i.e., highly aspherical lenslets (HAL) and slightly aspherical lenslets (SAL) — have been evaluated in randomized trials for myopia control. A two-year randomized clinical trial reported that HAL and SAL spectacles significantly slowed SER progression and axial elongation compared with single-vision lenses, with greater efficacy for HAL. Across the trial, HAL wearers exhibited marked reductions in progression (reported reductions ranging from ≈0.3–0.8 D over 1–2 years and AL differences of ~0.1–0.35 mm depending on analysis and follow-up) compared with controls (Bao *et al.*, 2022; Li *et al.*, 2023). One-year subanalyses showed incremental benefits related to daily wearing hours, while longer follow-up suggested sustained protection and lower conversion to high myopia in HAL groups. Importantly, visual performance and adaptation were generally acceptable, and adverse visual symptoms were minimal. HAL/SAL lenses offer a spectacle-based, low-risk optical alternative for SER-based myopia control, suitable for populations or age groups where contact lens wear or pharmacotherapy is less feasible (Bao *et al.*, 2022; Li *et al.*, 2023).

Cao and colleagues conducted a randomized clinical trial of daily 650-nm low-level red-light (LLRL) therapy in 336 myopic children to evaluate effects on spherical equivalent refraction (SER) and axial length (AL). Over one year, children allocated to LLRL experienced substantially less myopic progression than controls; the trial report summarised that the control group became nearly 1.0 D more myopic and had about 0.3 mm greater axial elongation than the LLRL group (Cao *et al.*, 2024). The treatment was delivered with a handheld, clinic-prescribed device used daily for short sessions, and investigators reported no retinal safety signals during the study period. Effect sizes were clinically meaningful — equivalent to slowing of SER by roughly 0.8–1.0 D/year compared with usual care in this cohort — and the AL differences were consistent with the refractive findings. The authors highlighted that LLRL acts rapidly (measurable within months) and may be particularly useful for children with fast progression, but they emphasised the need for replication at independent centres and longer follow-up to characterise durability and safety. For clinics considering non-pharmacologic tools, the trial shows LLRL is a promising new option that produces large SER gains compared with no active treatment (Cao *et al.*, 2024).

CHAPTER THREE

3.0 METHODOLOGY

3.1 STUDY DESIGN

This was a retrospective observational study.

3.2 STUDY LOCATION

This study was carried out in the following Eye Clinics in Benin City, Edo state, Nigeria:

1. Glovera Eye Clinic.
2. Sight and Vision Eye Hospital.
3. Echos Hospital Limited
4. GIM Medical Center.

3.3 STUDY POPULATION

Patients of 6-25 years of age who visited the selected Eye clinics in Benin City between 2014-2025.

3.4 SAMPLING TECHNIQUE/SAMPLE SIZE DETERMINATION

3.4.1 SAMPLING TECHNIQUE

Convenience sampling technique.

3.4.2 SAMPLE SIZE DETERMINATION

Sample size (n)$=\frac{(Z_{1-\propto/2})^{2}\times \mathrm{SD}^2}{\mathrm{d}^2}$ formula, (Charan and Biswas, 2013)

n = Desired sample size

$Z_{1-\alpha/2}$=Critical value and a standard value for the corresponding level of confidence. (At 95% CI or 5% level of significance (type-I error) = 1.96)

SD = standard deviation of variable

d = Margin of error or precision

From the study, Saw *et al*. (2005): -1.71D/yr (-1.98 to -1.44D)

- Estimated Standard Deviation (SD) from IQR.

The IQR = Q2 – Q1 = −1.44− (−1.98) = **-0.54D**

Estimating SD from IQR using the formula:

$$SD = \frac{IQR}{1.35}$$

SD = 0.40

$$n = \frac{1.96^2 \times 0.40^2}{0.05^2} = 245.8 \approx 246$$

Attrition factor of 10% gives approximately 25

Final calculated sample size = **271**

300 subjects' eyes were used for this study.

3.5 MATERIALS AND METHOD

MATERIALS USED

-Data extraction sheets

- Writing materials

- Mobile Devices

METHOD

Data from patients' hospital case files and health records were extracted and imputed into a standardized database. Collected variables included:

1. Gender of patient
2. Age of patient at first visit
3. Age of patient at last visit
4. Refractive measurements obtained during non-cycloplegic subjective refraction (spherical equivalent, SER) from first and last visit.
5. Annual myopia progression rate was calculated for each eye.

3.6 INCLUSION & EXCLUSION CRITERIA

3.6.1 INCLUSION CRITERIA

1. Patients with at least two documented subjective refraction results (separated by greater than 1 year) between 2014–2024.
2. Patients with −0.50D or more negative spherical equivalent (SE) of myopia in either eye.
3. Patients between 6-25 years of age on their first visit.

3.6.2 EXCLUSION CRITERIA

1. Patients with histories of ocular surgery (e.g. refractive or cataract surgery) or conditions affecting refraction (e.g. keratoconus, significant cataract) that could confound natural myopia progression or ocular or systemic diseases that may impact refractive parameters e.g diabetes.
2. Patient’s record of only one visit to the eye clinic.
3. Patients greater than 25 years of age at their first visit.
4. Patients diagnosed with pathological myopia.

5. Records within complete or unreliable data(e.g.missing dates)

3.7 DESCRIPTION OF THE STUDY

Consent/Permission

Permission was requested and granted from all the selected eye clinics to carry out this study at their respective locations.

Data Collection

The data extraction sheet created was used to collect data relevant to this research from the patients' files and records. This data included gender, refractive findings, age of patients at first and last visits.

Conversion of Refractive findings to Spherical Equivalent Refraction (SER)

The refractive findings from the patients' first and last visits were all converted to SER using the formula, SER = Sphere + 1/2 Cylinder (Enaholo *et al.*, 2023).

Calculation of Annual Myopia Progression rate

The Annual Myopia Progression rate for each of the patients' eyes was calculated and inputed into the data extraction sheet.

3.8 DATA ANALYSIS

DESCRIPTIVE STATISTICS

- The primary outcome is annual myopia progression, defined as the change in spherical equivalent (in diopters) per year between visits. For each patient, mean progression will be computed by dividing total diopter change by years of follow-up. Overall mean (±SD) progression rates and by subgroups (age band, gender, baseline myopia level) was calculated**.**

INFERENTIAL STATISTICS

- Statistical comparisons (ANOVA or t-tests) tested for differences between groups.
- Regression models (linear or mixed-effects if appropriate) assessed the association of age, initial refractive error, and other factors with progression rate was produced.
- Proportions of “fast progressors” (e.g. >–0.75 D/year) was determined and compared to benchmarks from the literature.
- All analyses was performed in statistical software (e.g. SPSS or R), with significance set at $p<0.05$. Graphical plots illustrate progression trajectories by age.

3.9 ETHICAL CONSIDERATION

Ethical clearance was obtained from the Department of Research and Ethics Committee of the Faculty of Optometry, University of Benin, Benin City in accordance with the tenets of the Declaration of Helinski. The REC approval number is EC/UBEN/LSC.OPT/25/152. This was to ensure that the study was not against public interest. To maintain anonymity, personal information such as name was not collected. Permission to access records from selected clinics was requested and granted before procession.

3.10 LIMITATIONS OF THE STUDY

1. Limited resources and human personnel.
2. Low availability of myopia progression data.
3. Due to the low availability of myopia progression data, a convenience sampling method was implemented in place of a stratified sampling method which would have more adequately represented each age group from the study population.
4. Analysis of one eye per subject would have mitigated confounding factors that may affect the progression of myopia per person.

CHAPTER FOUR

4.0 RESULTS

A total of 300 eyes were examined for myopia progression from different eye clinics in Benin City with age ranging from 6 years and above. Of the 300 eyes examined, 214 (71.3%) of them belonged to females and 86 (28.7%) belonged to males. 52 (17.33%) of them were aged between 6 and 10 years, 70 (23.33%) were aged between 11 and 15 years, 132 (44.0%) of them were aged between 16 and 20 years and 46 (15.33%) were aged between 21 and 25 years. The mean age was 15.87±4.75 years (Table 4.1).

Table 4.1: Demographic variables of the patients

Demographic variable	Group	Frequency (%)	χ^2	p-value
Gender	Female	214 (71.3)	54.613	0.000*
	Male	86 (28.7)		
Age	6-10 years	52 (17.33)	61.920	0.000*
	11-15 years	70 (23.33)		
	16-20 years	132 (44.0)		
	21-25 years	46 (15.33)		
Mean age: 15.87±4.75 years				

The average annual rate of myopia progression amongst the participants was calculated as -0.15D/year.

Age-wise pattern of myopia progression at first visit were -0.30 for participants aged 6 – 10 years, -0.25 for participants aged 11 – 15 years, 0.00 for participants aged 16 – 20 years and -0.28 for participants aged between 21 – 25 years (Table 4.2). Myopia progression varied significantly ($p<0.05$) amongst the age groups. This indicates that myopia progression was faster among younger patients than older patients. Thus, hypothesis one is accepted.

Table 4.2: Age-wise pattern of myopia progression

Age Group	Count	M±SD	p-value
6-10 years	44	-0.38±0.1	0.000*
11-15 years	28	-0.13±0.0	
16-20 years	156	-0.03±0.14	
21-25 years	58	-0.33±0.08	

M – Mean; SD – Standard deviation; * significant difference

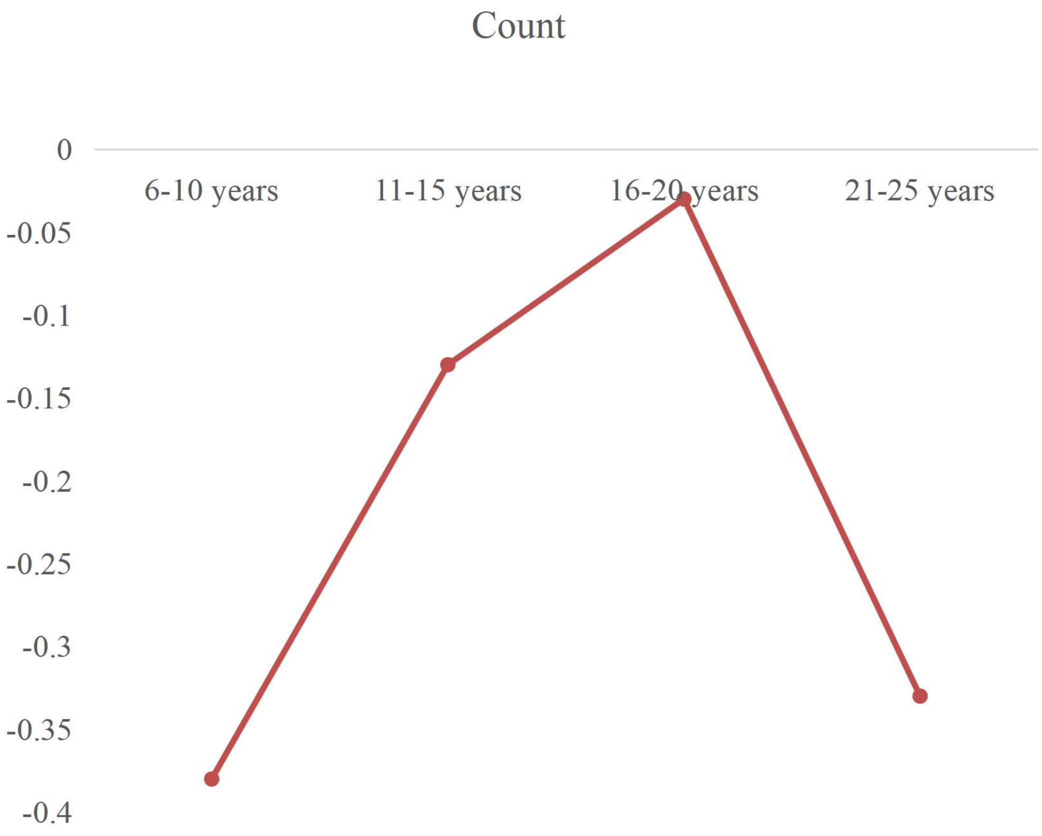

Figure 4.1: Age-wise myopia progression

Only 13.0% of the participants exhibited significant myopia progression (defined as an annual progression rate of at least -0.50 D/year). The proportion of significant progression varies by baseline refraction (spherical equivalent at first visit):

High myopia (SE <-6.0): 20%

Moderate myopia (SE -3.0 to 6.0): 9.0%

Mild myopia (SE -0.50 to -3.00): 39%

Patients with mild myopia showed greater average annual myopia progression rate (-0.17 D/year). Moderate myopia progresses more slowly on average (-0.11 D/year). Thus, the hypothesis two is rejected.

Mean progression by severity based on gender and age indicated that progression rates were slightly faster (more negative) in patients with higher baseline myopia. Thus, hypothesis four is accepted. Females mostly populated the mild myopia group, while males populated the moderate myopia group. Younger ages (6-10 years) showed more high severity cases with greater negative progression. Smaller none myopia group, which were only 7, showed a mean of -1.00.

Females showed faster progression in younger age groups (6-10: -0.44; 21-25: -0.42), less so in 16-20 years (-0.07). Males in 16-20 years had no progression (0.00).

Progression varied with moderate myopia, with females aged 16-20 years showing a small positive change (0.04), while male aged 21-25 years and female aged 6-10 years showed more negative progression (-0.25).

Across all severities, progression rates tend to be more negative (greater progression) in younger ages, and mild myopes generally progress faster than moderate (Table 4.3).

Table 4.3: Age/gender-wise pattern of myopia progression

Severity	Gender	Age Group	Count	M±SD
Mild	Female	11-15 years	28	-0.13±0.0
Mild	Female	16-20 years	86	-0.07±0.1
Mild	Female	21-25 years	28	-0.42±0.0
Mild	Female	6-10 years	30	-0.44±0.06
Mild	Male	16-20 years	28	0±0.0
Moderate	Female	16-20 years	42	0.04±0.21
Moderate	Female	6-10 years	14	-0.25±0.0
Moderate	Male	21-25 years	30	-0.25±0.0

M – Mean; SD – Standard deviation

Figure 4.2: Age/gender-wise pattern of myopia progression

The average annual myopia progression rate for females was -0.16±0.21 D/year. For males, the average annual myopia progression rate was -0.13±0.13 D/year (Table 4.4). T-test indicated that there was no significant difference between the females and the males (p=0.33). Thus, gender did not have significant effect on myopia progression in this population (p>0.05). Thus, hypothesis three is rejected.

Table 4.4: Annual myopia progression rate based on gender

Gender	M±SD	t-value	p-value
Male	-0.13±0.13	-0.97	0.33
Female	-0.16±0.21		

M – Mean; SD – Standard deviation

CHAPTER FIVE

5.0 DISCUSSION

This study provides critical insights into the progression patterns of myopia in a West African urban environment. The sample was predominantly female (71.3%), and the mean age was approximately 16 years. The proportion of patients in various age groups and the gender distribution in this Benin City population are in line with regional patterns of clinic attendance and reflect broader demographic shifts in urban Nigerian society.

The average annual myopia progression in this cohort was –0.15 D/year, a rate consistent with recent studies in similar African urban settings and notably lower than rates typically observed in East Asian populations, where annual progression may exceed –0.4 D/year in school-aged children (Lam *et al.*, 2020; Wang and Zhou, 2025). Age-wise analysis highlighted the highest progression among children aged 6–10 years (–0.38 D/year), with slower progression as age increased, mirroring the natural history of myopia documented globally (Bao *et al.*, 2022; Kyei *et al.*, 2024). Only 13% of participants exhibited significant myopic progression (≥–0.50 D/year), and this group was distributed unevenly across baseline refraction levels, with higher rates among those with high myopia (20%) and those who were not myopic at baseline (33%).

These findings align with robust meta-analytic evidence from across Africa, which consistently reports lower overall myopia prevalence (4–5%) compared to Asia, but a similarly increasing trend as urbanization, near-work, and reduced outdoor activities become more common (Ovenseri-Ogbomo *et al.*, 2022). Major surveys from Nigeria, Ghana, and South Africa report that prevalence tends to be higher in urban schoolchildren and in females, although, as in this Benin City cohort, gender does not significantly influence annual progression rates (Ebri *et al.*, 2019).

Younger patients experienced more rapid progression than older individuals, a finding in agreement with both African and international data (Bao *et al*., 2022; Wang and Zhou, 2025). The relationship between baseline severity and progression observed in this population, where mild myopia at baseline tended to progress more rapidly than moderate myopia, has also been reported in Asia and Europe and suggests a window of opportunity for intervention in early-onset cases (WHO Report, 2017; Lam *et al*., 2020; Bao *et al*., 2022).

Females composed the majority of the mild myopia group, while males were more prevalent among moderate cases, but annual progression rates did not differ significantly between genders (–0.16 D/year in females, –0.13 D/year in males). Global literature offers mixed conclusions on gender's independent effect, but most large-scale studies, including systematic reviews in African schoolchildren, support the present finding of no significant gender difference in progression (Ovenseri-Ogbomo *et al*., 2022; Wang *et al*., 2021).

The lower myopia progression in this West African population, compared to East Asian countries, is likely related to later school entry, more time spent outdoors, and possibly less intensive near-work in early childhood (Holden *et al*., 2016). However, rapid urbanization across sub-Saharan Africa is associated with behavioral shifts (higher near-work, reduced outdoor activity, increased use of digital devices), which are established risk factors for both onset and progression of myopia (Morgan *et al*., 2016; Kyei *et al*., 2024; Wang and Zhou, 2025;).

Studies report a clear urban-rural gradient: children in urban centers like Benin City are at greater risk of myopia onset and progression, due both to lifestyle changes and to socioeconomic factors influencing health-seeking behavior and access to eye care (Ovenseri-Ogbomo *et al*., 2022). Socioeconomic status, ethnicity, and educational level further moderate risk in both African and global cohorts (Wang and Zhou, 2025).

Current evidence-based approaches to myopia control include spectacle and contact lens designs (e.g., DIMS lenses, multifocal contacts), pharmacological options (low-dose atropine), and environmental modifications (increasing outdoor activity, reducing near-work/screen time) (WHO Report, 2017; Lam *et al*., 2020; Bao *et al*., 2022; Wang and Zhou, 2025). While such interventions have shown promise in clinical trials and urban settings in Asia and Europe, accessibility, cost, and cultural suitability are ongoing challenges in African contexts.

Clinical surveys in Africa highlight the importance of routine refraction, early detection, and health education for parents and children, with additional emphasis on increased time outdoors and the regulation of screen time as practical and effective population-level measures (WHO, 2017; Ovenseri-Ogbomo *et al*., 2022).

Myopia's growing prevalence in African children and adolescents presents significant public health implications, including the risk of vision-threatening complications in the future (Bao *et al*., 2022). Although rates remain lower than in Asia, African countries should prioritize myopia surveillance, accessible corrective services, and tailored health promotion efforts as urbanization intensifies (Wang and Zhou, 2025).

Ultimately, the results from this study reinforce the broader evidence: myopia progression is most pronounced in younger children and those with mild myopia at initial diagnosis, with minimal gender influence. Socio-environmental changes, such as urbanization, are poised to accelerate these trends unless preventive and interventional strategies are widely implemented.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

This study investigated changes in myopia among patients attending selected eye clinics in Benin City, Nigeria, over the past decade. The study addressed the rate and pattern of myopia progression, its association with age, gender, and baseline severity, and contextualized these findings within African and global trends. With a retrospective cohort design, data were extracted from 300 patient records aged 6–25 years who met inclusion criteria (minimum two visits, reliable refractive records).

Myopia progression was analysed using spherical equivalent refraction (SER) changes between visits. The average annual progression rate was –0.15 D/year. Younger age groups showed faster progression (–0.38 D/year among 6–10 year olds), while progression slowed with increasing age. Most patients had mild or moderate myopia at baseline; those with mild myopia progressed faster (–0.17 D/year) than moderate cases (–0.11 D/year). Only 13% of patients exhibited significant progression (≥–0.50 D/year), and this was more common in those with high myopia or not myopic at baseline.

Gender was not a significant factor, females predominated, especially among mild cases, but average progression for females (–0.16 D/year) and males (–0.13 D/year) was not statistically different. These results are consistent with evidence from Africa and globally, confirming that early onset and younger age are greater risks for myopia progression, while gender is a less important factor. The study also highlighted the role of urbanization, increased near-work, limited outdoor activity, and digital device use as contributors to rising myopia rates.

The research fills a major gap by providing local longitudinal data on myopia progression, supporting effective clinical and public health planning. It offers baseline rates for comparison with global studies, and identifies key risk periods for intervention.

6.1 CONCLUSION

Myopia is a growing public health concern in Benin City, reflecting global trends. The study demonstrated that younger patients and those with mild myopia at baseline are at greater risk of progression, emphasizing the need for early detection and regular monitoring. Despite the predominance of females among clinic attendees, gender was not associated with higher progression rates. These findings highlight the importance of targeted interventions for children and adolescents, as well as population-level strategies to mitigate future risks.

Urbanisation, changes in education, and increased screen time are poised to accelerate myopia rates and progression in this urban Nigerian setting. The significance of this research lies in its provision of local progression rates and demographic risk profiles, which can guide optometric care and inform policy.

6.2 RECOMMENDATIONS

Following findings from this study, the following are recommended:

1. Patients and parents of patients should be encourages to have one primary eye care provider, if possible, so that progression can be easily tracked and monitored.
2. Parents of younger patients should ensure that they take their children for routine and follow up eye examination.
3. Government at all levels should implement routine myopia screening and progression monitoring in schools and clinics.
4. Schools should encourage routine eye examination in their pupils and should be open to free eye screenings by charitable persons or organizations.

5. Government and stakeholders of eye health should promote public health campaigns to encourage outdoor activity and regulate screen time, especially for school-aged children.

6. Parents, teachers, and children should be educated about modifiable risk factors which include: near-work habits, reading posture, and taking regular breaks during intense visual tasks.

7. Government should ensure access to affordable refractive correction and advanced interventions when needed.

8. Patients with moderate and high myopia should be monitored more closely and should be given myopia control interventions such as bifocal lenses.

By acting on these recommendations, clinicians, educators, and policymakers can mitigate the growing burden of myopia and its complications, improving visual outcomes for Nigeria’s youth.

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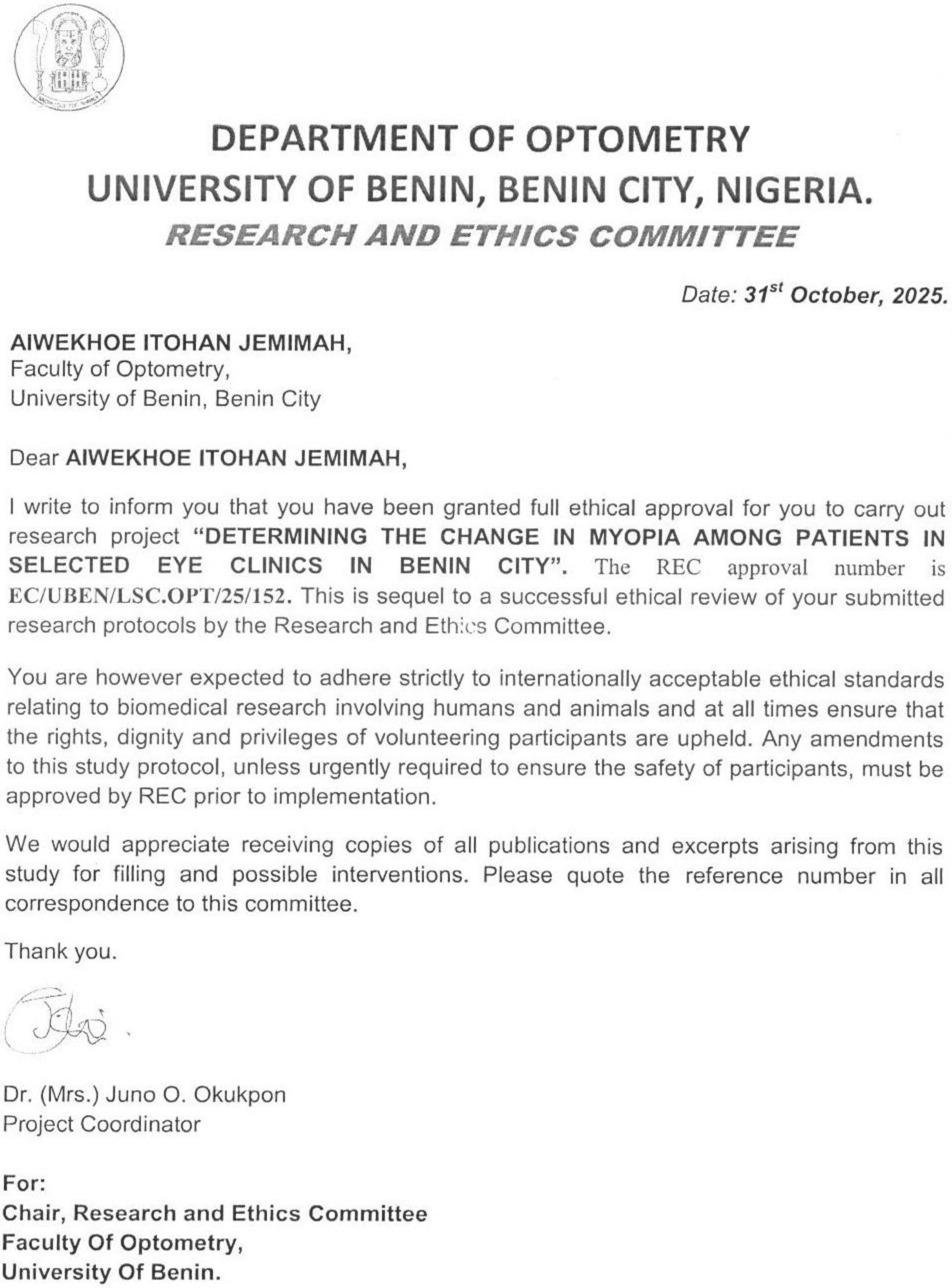
APPENDICES

APPENDIX I

ETHICAL APPROVAL AND PLAGIARISM CLEARANCE



DEPARTMENT OF OPTOMETRY
UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.
RESEARCH AND ETHICS COMMITTEE

Date: ***31st October, 2025.***

AIWEKHOE ITOHAN JEMIMAH,
Faculty of Optometry,
University of Benin, Benin City

Dear **AIWEKHOE ITOHAN JEMIMAH,**

I write to inform you that you have been granted full ethical approval for you to carry out research project **"DETERMINING THE CHANGE IN MYOPIA AMONG PATIENTS IN SELECTED EYE CLINICS IN BENIN CITY".** The REC approval number is **EC/UBEN/LSC.OPT/25/152.** This is sequel to a successful ethical review of your submitted research protocols by the Research and Ethics Committee.

You are however expected to adhere strictly to internationally acceptable ethical standards relating to biomedical research involving humans and animals and at all times ensure that the rights, dignity and privileges of volunteering participants are upheld. Any amendments to this study protocol, unless urgently required to ensure the safety of participants, must be approved by REC prior to implementation.

We would appreciate receiving copies of all publications and excerpts arising from this study for filling and possible interventions. Please quote the reference number in all correspondence to this committee.

Thank you.

Dr. (Mrs.) Juno O. Okukpon
Project Coordinator

For:
Chair, Research and Ethics Committee
Faculty Of Optometry,
University Of Benin.

152

Faculty of Optometry,
University of Benin,
29th October, 2025

The Chairperson
Research Ethics Committee (REC)
Faculty of Optometry,
University of Benin.

Through;
The Project Coordinator,
Faculty of Optometry.
University of Benin,
P.M.B 1154
Ugbowo, Benin City.

Dear Ma,

RE: APPLICATION FOR ETHICAL REVIEW AND CLEARANCE

I hereby apply for ethical clearance to conduct a research study titled:

"DETERMINING THE CHANGE IN MYOPIA AMONG PATIENTS IN SELECTED EYE CLINICS IN BENIN CITY".

This study aims to assess the change in myopia of patients in selected eye clinics in Benin City over a 10-year period.

Principal investigator (PI):	**Investigator:**
Dr. (Mrs.) UWAGBOE PRECIOUS NGOZI	AIWEKHOE ITOHAN JEMIMAH
	LSC1900007

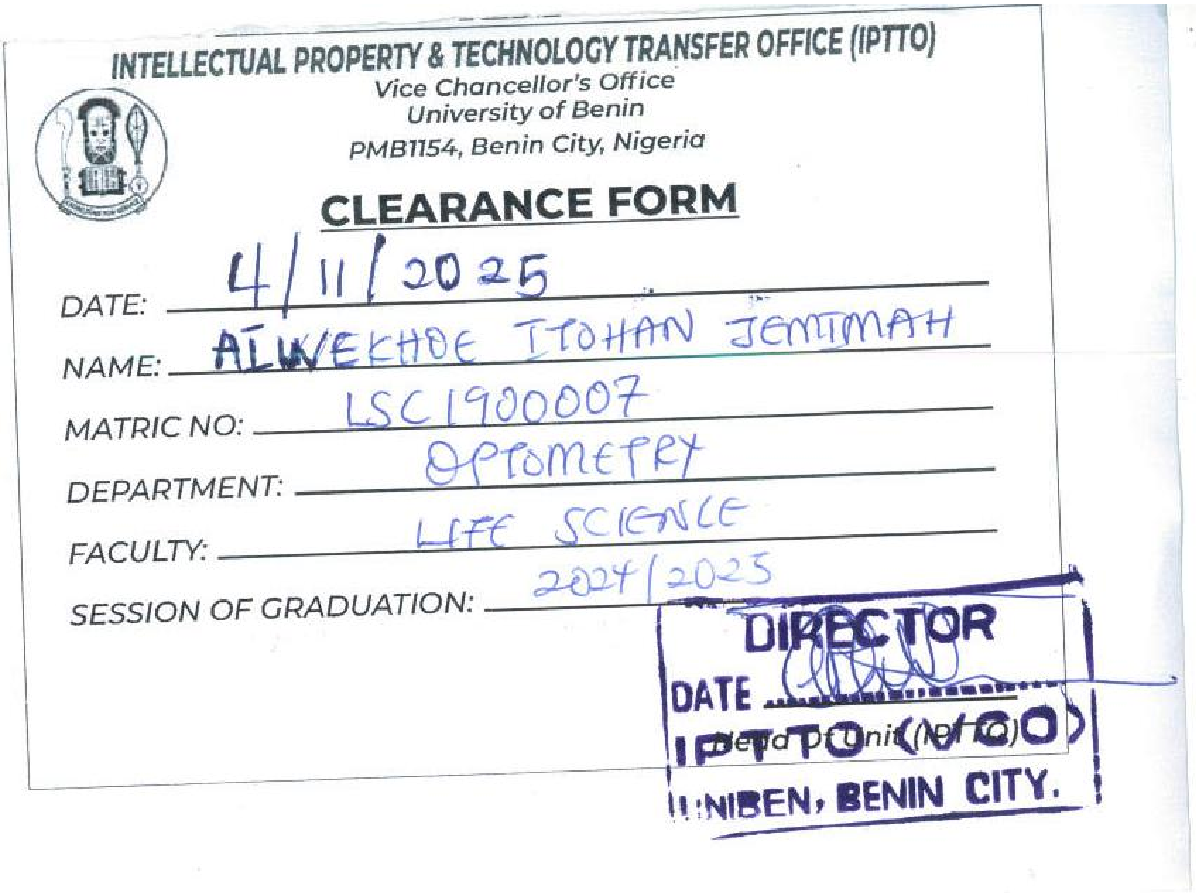
I kindly request the Research Ethics Committee to provide the required application documents for completion and submission as part of the ethical review process.

Thank you for your consideration. I look forward to your favorable response.

Yours faithfully,

AIWEKHOE ITOHAN JEMIMAH

Investigator



INTELLECTUAL PROPERTY & TECHNOLOGY TRANSFER OFFICE (IPTTO)
Vice Chancellor's Office
University of Benin
PMB1154, Benin City, Nigeria

CLEARANCE FORM

DATE: 4/11/2025

NAME: AIWEKHOE ITOHAN JEMIMAH

MATRIC NO: LSC1900007

DEPARTMENT: OPTOMETRY

FACULTY: LIFE SCIENCE

SESSION OF GRADUATION: 2024/2025

DIRECTOR
DATE
IPTTO (VCO)
UNIBEN, BENIN CITY.

Head of Unit (IPTTO)

APPENDIX II

DESCRIPTIVE TABLES OF DATA ANALYSIS

FREQUENCIES

Statistics

		Gender	Age at first visit	Se at first visit	Age at last visit	Se at last visit
N	Valid	300	300	300	300	300
	Missing	0	0	0	0	0
Mean				-2.9908		-3.3483
Std. Deviation				2.54880		2.76496

STATISTICS

		Total change	Annual myopia progression rate
N	Valid	300	300
	Missing	0	0
Mean		-.3636	-.1108
Std. Deviation		.76645	.29800

FREQUENCY TABLE

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	212	70.7	70.7	70.7
	Male	88	29.3	29.3	100.0
	Total	300	100.0	100.0	

AGE AT FIRST VISIT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	11-15.0	106	35.3	35.3	35.3
	16-20	102	34.0	34.0	69.3
	21-25	43	14.3	14.3	83.7
	6-10.0	49	16.3	16.3	100.0
	Total	300	100.0	100.0	

SE AT FIRST VISIT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-14.00	2	.7	.7	.7
	-12.00	1	.3	.3	1.0
	-11.50	1	.3	.3	1.3
	-11.00	3	1.0	1.0	2.3
	-10.00	6	2.0	2.0	4.3
	-8.50	1	.3	.3	4.7
	-8.00	6	2.0	2.0	6.7
	-7.00	5	1.7	1.7	8.3
	-6.50	2	.7	.7	9.0
	-6.00	5	1.7	1.7	10.7
	-5.75	1	.3	.3	11.0
	-5.50	5	1.7	1.7	12.7
	-5.25	3	1.0	1.0	13.7
	-5.00	15	5.0	5.0	18.7
	-4.75	3	1.0	1.0	19.7
	-4.50	15	5.0	5.0	24.7
	-4.00	8	2.7	2.7	27.3
	-3.75	1	.3	.3	27.7
	-3.50	18	6.0	6.0	33.7
	-3.25	4	1.3	1.3	35.0
	-3.00	17	5.7	5.7	40.7
	-2.75	10	3.3	3.3	44.0
	-2.50	13	4.3	4.3	48.3
	-2.25	17	5.7	5.7	54.0
	-2.00	24	8.0	8.0	62.0
	-1.75	18	6.0	6.0	68.0
	-1.50	7	2.3	2.3	70.3
	-1.25	4	1.3	1.3	71.7
	-1.00	20	6.7	6.7	78.3
	-.75	19	6.3	6.3	84.7
	-.50	43	14.3	14.3	99.0
	-.25	3	1.0	1.0	100.0
	Total	300	100.0	100.0	

AGE AT LAST VISIT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	>25	17	5.7	5.7	5.7
	11-15.0	13	4.3	4.3	10.0
	11.15.0	57	19.0	19.0	29.0
	16-20	112	37.3	37.3	66.3
	21-25	89	29.7	29.7	96.0
	6-10.0	12	4.0	4.0	100.0
	Total	300	100.0	100.0	

SE AT LAST VIST

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-14.00	2	.7	.7	.7
	-13.00	1	.3	.3	1.0
	-12.00	4	1.3	1.3	2.3
	-11.00	3	1.0	1.0	3.3
	-10.75	1	.3	.3	3.7
	-10.00	2	.7	.7	4.3
	-9.50	1	.3	.3	4.7
	-9.00	1	.3	.3	5.0
	-8.00	6	2.0	2.0	7.0
	-7.50	2	.7	.7	7.7
	-7.00	4	1.3	1.3	9.0
	-6.50	7	2.3	2.3	11.3
	-6.25	5	1.7	1.7	13.0
	-6.00	5	1.7	1.7	14.7
	-5.75	1	.3	.3	15.0
	-5.50	12	4.0	4.0	19.0
	-5.25	2	.7	.7	19.7
	-5.00	20	6.7	6.7	26.3
	-4.75	3	1.0	1.0	27.3
	-4.50	12	4.0	4.0	31.3
	-4.25	3	1.0	1.0	32.3
	-4.00	5	1.7	1.7	34.0
	-3.75	10	3.3	3.3	37.3
	-3.50	14	4.7	4.7	42.0
	-3.25	8	2.7	2.7	44.7
	-3.00	21	7.0	7.0	51.7
	-2.75	5	1.7	1.7	53.3
	-2.50	11	3.7	3.7	57.0
	-2.25	7	2.3	2.3	59.3
	-2.00	21	7.0	7.0	66.3
	-1.75	10	3.3	3.3	69.7
	-1.50	9	3.0	3.0	72.7
	-1.25	4	1.3	1.3	74.0
	-1.00	16	5.3	5.3	79.3
	-.75	23	7.7	7.7	87.0
	-.50	17	5.7	5.7	92.7
	-.25	7	2.3	2.3	95.0
	.00	8	2.7	2.7	97.7
	.25	7	2.3	2.3	100.0
	Total	300	100.0	100.0	

TOTAL CHANGE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.75	2	.7	.7	.7
	-2.50	8	2.7	2.7	3.3
	-2.25	3	1.0	1.0	4.3
	-2.00	4	1.3	1.3	5.7
	-1.75	3	1.0	1.0	6.7
	-1.50	14	4.7	4.7	11.3
	-1.25	6	2.0	2.0	13.3
	-1.09	1	.3	.3	13.7
	-1.00	20	6.7	6.7	20.3
	-.75	14	4.7	4.7	25.0
	-.50	49	16.3	16.3	41.3
	-.25	38	12.7	12.7	54.0
	.00	83	27.7	27.7	81.7
	.25	25	8.3	8.3	90.0
	.50	11	3.7	3.7	93.7
	.75	10	3.3	3.3	97.0
	1.00	6	2.0	2.0	99.0
	1.50	1	.3	.3	99.3
	1.75	1	.3	.3	99.7
	2.00	1	.3	.3	100.0
	Total	300	100.0	100.0	

ANNUAL MYOPIA PROGRESSION RATE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.50	2	.7	.7	.7
	-1.25	1	.3	.3	1.0
	-1.13	1	.3	.3	1.3
	-1.00	1	.3	.3	1.7
	-.88	1	.3	.3	2.0
	-.75	4	1.3	1.3	3.3
	-.67	1	.3	.3	3.7
	-.63	6	2.0	2.0	5.7
	-.58	1	.3	.3	6.0
	-.55	2	.7	.7	6.7
	-.50	12	4.0	4.0	10.7
	-.42	4	1.3	1.3	12.0
	-.38	4	1.3	1.3	13.3
	-.36	3	1.0	1.0	14.3
	-.33	2	.7	.7	15.0
	-.33	1	.3	.3	15.3
	-.30	4	1.3	1.3	16.7
	-.29	1	.3	.3	17.0
	-.26	1	.3	.3	17.3
	-.25	38	12.7	12.7	30.0
	-.21	2	.7	.7	30.7
	-.20	5	1.7	1.7	32.3
	-.19	5	1.7	1.7	34.0
	-.17	5	1.7	1.7	35.7
	-.14	2	.7	.7	36.3
	-.13	21	7.0	7.0	43.3
	-.10	7	2.3	2.3	45.7
	-.08	1	.3	.3	46.0
	-.08	14	4.7	4.7	50.7
	-.07	3	1.0	1.0	51.7
	-.06	1	.3	.3	52.0
	-.06	1	.3	.3	52.3
	-.04	1	.3	.3	52.7
	-.04	2	.7	.7	53.3
	.00	82	27.3	27.3	80.7
	.04	1	.3	.3	81.0
	.04	1	.3	.3	81.3
	.05	2	.7	.7	82.0
	.06	1	.3	.3	82.3
	.08	4	1.3	1.3	83.7
	.08	1	.3	.3	84.0

.10	3	1.0	1.0	85.0
.12	1	.3	.3	85.3
.13	12	4.0	4.0	89.3
.14	1	.3	.3	89.7
.15	1	.3	.3	90.0
.17	1	.3	.3	90.3
.17	1	.3	.3	90.7
.17	2	.7	.7	91.3
.20	1	.3	.3	91.7
.25	12	4.0	4.0	95.7
.33	2	.7	.7	96.3
.35	1	.3	.3	96.7
.38	1	.3	.3	97.0
.40	1	.3	.3	97.3
.50	4	1.3	1.3	98.7
.75	1	.3	.3	99.0
.83	1	.3	.3	99.3
1.00	2	.7	.7	100.0
Total	300	100.0	100.0	