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Determination of Luminance Levels of Visual Acuity Charts in Selected Eye Clinics in Owerri and Their Effects on Vision

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Authors' contributions

This work was carried out in collaboration among all authors. Author ECN designed and financed this study, collected data and performed the statistical analysis. Authors NCI and CN wrote the protocol for this study. Author ECE wrote the first draft of the manuscript of this study. Author CN provided the instruments for data collection. Authors GIU, OMN and UCO managed the literature searches. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aim: The study on the determination of the luminance levels of visual acuity charts in selected eye clinics in Owerri and their effects on vision, was carried out in 14 eye clinics in Owerri, Imo State.
Study Design: The study design employed in this study was the quantitative type of design, involving the measurement of variables.
Place and Duration of Study: This study was carried out in Owerri, Imo State, Nigeria, between February, 2019 and November, 2019.
Methodology: A total number of 159 young adult volunteers (60 males and 99 females), which summed up to 318 eyes, between the ages of 18 and 35 years, were used for this study. Using a photometer and internally illuminated visual acuity charts, the visual acuity charts' luminances and visual acuities of the volunteers were measured respectively, under bright ambient examination room illuminations. The t test: two-sample assuming unequal variances statistical method was used to determine if there was a statistical difference in visual acuity, under various visual acuity chart luminance levels.

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Results: Visual acuity chart luminance was found not to differ significantly (since p(t<=t)= 0.44 > *P* = .05)). Fluorescent luminance was found to have no significant effect on right and left eyes' visual acuities (since p(t<=t)= 7.29 > *P* = .05)). Tungsten luminance was found to have no significant effect on right and left eyes' visual acuities (since p(t<=t)= 3.54 > *P* = .05)).
Conclusion: This study showed that visual acuity was not affected by chart luminance, under bright ambient room illuminations.

Keywords: Luminance; visual acuity chart; illumination; fluorescent; tungsten.

ABBREVIATIONS

Candela per Meter's Square	*: This is the unit of luminance.*
Fluorescent Bulb	*: This is a type of energy-saving bulb that consists of a glass tube filled with argon or argon-krypton gas and a small amount of mercury, coated on the inside with phosphors, and equipped with an electrode at both ends.*
Illuminance or Illumination	*: This is a measure of the luminous flux incidences on a given surface.*
Internally Illuminated Visual Acuity Charts	*: These are those charts that have their own internal illumination, supplied by electric light bulbs.*
Luminance	*: This is a photometric measure of the luminous intensity per unit area of light travelling in a given direction.*
Lux	*: This is the unit of illumination.*
Photometer	*: This is a device that is used to measure the strength of electromagnetic radiation, ranging from ultraviolet to visible spectrum.*
Tungsten Bulb	*: This is an example of incandescent lamps which produces light when a current passes through a tungsten filament, heating it up and causing it to glow.*
Visual Acuity	*: This is a measure of the eye's ability to make distinctions between shapes and the details of objects at a given distance.*

1. INTRODUCTION

Vision is said to be the most important of all the five senses. It is mainly through sight that we acquire an understanding of our environment, and gain knowledge which directs our actions and movements [1]. The efficiency and ease with which we see things depends on the level of light present, therefore, necessitating the need to develop a scientific system with which to measure light levels [1]. Achievement of specified lighting levels (luminance) is important in safety and regulation, ensuring that there is the recommended level of lighting in a particular environment such as a laboratory, classroom and an examination room [1].

Light is an effulgent/radiant energy which travels through an invisible medium (known as ether) in form of transverse waves. It can be natural or artificial [2].

Artificial light can be generated by heating a solid body or vapour to the point of incandescence. At this point, the hot body begins to release energy into the surrounding medium, basically as electromagnetic waves of different wavelengths, depending on the temperature of the hot body [2]. Hence, at low temperature, the energy released is in form of heat waves only but at certain higher temperatures. Light waves, in addition to the heat waves, are produced, causing the hot body to glow (i.e. become luminous) [2]. As the temperature increases further, and more of both kinds of radiations are produced, the colour of light changes from bright red to orange, yellow, and finally, white, if the temperature is high enough [2].

Luminance is a photometric measure that describes that amount of light that is transmitted, emitted or reflected from a particular area, and falls within a given solid angle [3]. It is sometimes called brightness [2]. Since the human eye sees luminance, it means that the amount of light delivered into the space and the reflectance of the surfaces in the space affects one's ability to see [2,4]. The S.I. unit of luminance is candela

per metres square, (expressed as cd/m^2) [2] and it is measured with a photometer [5].

The tungsten lamp is an example of artificial incandescent light source. Here, light is produced by passing a current through a tungsten filament, heating it up, and causing it to glow [6].

The fluorescent bulb is a type of energy-saving bulb, consisting of a glass tube filled with argon or argon-krypton gas and a small amount of mercury, coated on the inside with phosphors, and equipped with an electrode at both ends [7].

Visual acuity (VA) is defined as a measure of the eye's ability to make distinctions between shapes and the details of objects at a given distance [8]. It is the most important parameter of all visual functions, and it is the centre of all the ophthalmic examinations. Measurement of visual acuity by different eye practitioners and in different clinical settings requires standardization in terms of equality of chart letter sizes, room illumination, testing distance, visual acuity chart luminance, et cetera [9,10].

Visual acuity charts are charts used in measuring the visual acuity of patients [8]. They are made of 3mm translucent, white, cast, acrylic plastic material, a polymer of Polymethyl Methacrylate (PMMA), which is an amorphous thermoplastic material [11,12]. Internally illuminated visual acuity charts are those charts that have their own internal illumination, supplied by electric light bulbs. Ideally, the luminance level of a visual acuity chart should be uniform and not less than 80cd/m^2 or more than 300cd/m^2 [10,13,14].

Most visual functions, including visual acuity and contrast sensitivity, rely on the luminance of the visual stimulus. Ideally, the relationship between vision and luminance may be observed in the effect of luminance on visual acuity [15] and this effect could be affected by the examination room's ambient illumination.

Studies [13,14,16-24] on the effect of VA chart luminance on visual acuity show that visual acuity is significantly affected by variation in luminance. Uncorrected refractive error was cited as the factor responsible for the significant effect of luminance on visual acuity [25]. According to one of the studies, when chart luminance is within the moderate photopic range (40-600cd/m^2), increase in chart luminance by a factor of 2 only alters visual acuity by less than 0.02log unit [13]. In another study, visual acuity was found to decrease uniformly with reduction in chart luminance [17]. In yet another study [15], variation in VA chart luminance was found to have no significant effect on visual acuity.

Results from the studies by [9,26,27] implied that fluorescent bulbs have greater luminance than tungsten bulbs, and that subjects were more comfortable reading with light from fluorescent bulbs, compared to tungsten bulbs.

This paper examined the measurement of the luminance levels of visual acuity charts and ambient examination room illuminations in selected eye clinics in Owerri town. It also involved the determination of visual acuity with various visual charts luminances under bright room illumination, in order to find out if there was any effect on visual acuity under the varying lightening conditions. Visual acuity measurement was taken with tungsten bulb-illuminated charts and fluorescent bulb-illuminated charts to determine the effect of both (if any) on visual acuity. Luminance for this study was defined as the brightness of the visual acuity chart. Ambient room illumination for this study was defined as how bright the examination room was. Maximum visual acuity for this study was taken as 6/6.

2. METHODOLOGY

2.1 Study Location

The study area was Owerri, Imo State, Nigeria (see Fig. 1). Owerri is the capital of Imo State in Nigeria, and also the state's largest city. It is made up of three Local Government Areas which includes Owerri Municipal, Owerri North and Owerri West. Owerri has an estimated population of about 1,401,873 and occupies approximately 100 square kilometers in area [28].

2.2 Population of Study

This study was carried out in 14 eye clinics with internally illuminated visual acuity charts, of which 6 are located in Owerri Municipal LGA and 4 in Owerri North and West LGA s respectively. A total number of 159 young adult volunteers (60 males and 99 females), which summed up to 318 eyes (120 eyes for males and 198 eyes for the females), between the ages of 18 and 35 years, were used for this study (Table 1).

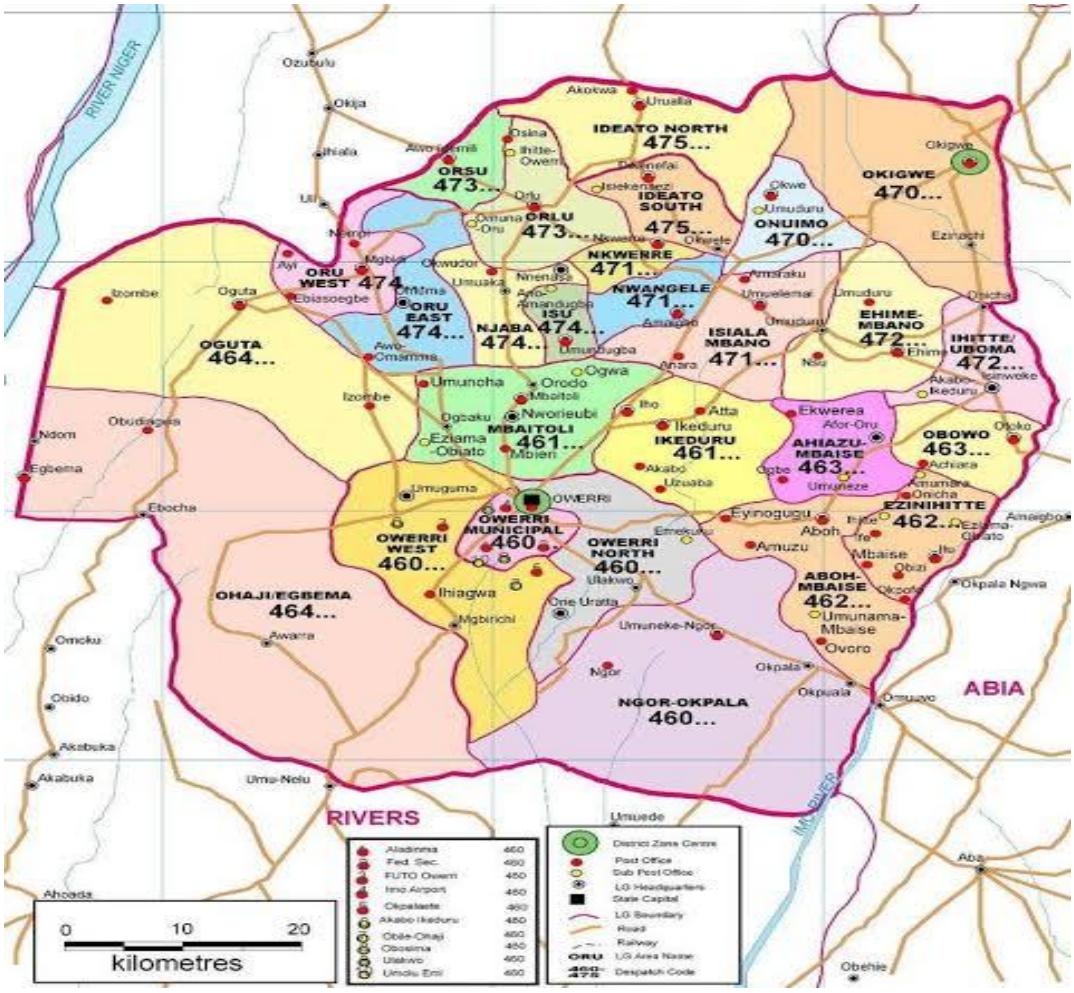

Fig. 1. Map of Imo State showing the location of Owerri
Source: http//:www.LatLong.net/map_of_Imo_State

Table 1. Age and sex frequency distribution of the study population

Age	Male	Percentage	Female	Percentage	Total
18-23	18	5.66%	60	18.87%	78
24-29	24	7.55%	30	9.43%	54
30-35	78	24.53%	108	33.96%	186
Total	120	37.74%	198	62.26%	318

NB: Each eye of the volunteers was counted as an entity, hence the values above

2.3 Selection (Inclusion) Criteria

These include

- Clinics with snellen visual acuity charts internally illuminated with fluorescent or tungsten bulbs.
- Male or female volunteers with corrected visual acuities ≥ 6/6, within the age group of 18-35 years.
- Volunteers within the age group of 18-35 years, who did not have pathological conditions (including but not limited to glaucoma, cataract and ptosis) that could alter visual acuity.

2.4 Procedure for Data Collection

2.4.1 Visual acuity chart luminance

The visual acuity chart luminance measurement was taken by positioning photometer 20 inches from the center of the visual chart with the room

lights on [29]. Readings were taken. This was to measure the chart illumination in the 14 eye clinics The luminance of the visual acuity charts was gotten by converting the chart illumination (in lux) to luminance (in cd/m^2), using the formula below:

$$L = pE$$

Where, L= luminance (cd/m^2),

p= reflection coefficient (which is 0.0400 for acrylic sheets) and
E= illumination in lux [2].

The tungsten bulbs used in this study were the standard incandescent bulbs of 40 watts, with colour temperature of 2700k. Two tungsten bulbs were mounted in each internally illuminated visual acuity chart, to achieve tungsten luminance.

The energy-saving/fluorescent bulbs used in this study were the compact fluorescent bulbs of 25 watts each, with colour temperature of 4000k. Two fluorescent bulbs were mounted in each internally illuminated visual acuity chart, to achieve fluorescent luminance.

2.4.2 Anterior segment examination

The anterior segment examination, with the aid of a slit lamp bio microscope, was done on the volunteers to rule out any pathological condition (such as uvietis, acute angle closure glaucoma, cataract, central corneal scar, ptosis, et cetera), that may affect visual acuity.

2.4.3 Posterior segment examination/ Ophthalmoscopy

Ophthalmoscopy, with the aid of a direct ophthalmoscope, was carried out on the volunteers also, in order to rule out any pathological condition (including, but not limited to, glaucoma, cataract, retinal detachment and dense floaters) that may affect visual acuity.

2.4.4 Tonometry

Intraocular pressure measurement, with the aid of a non-contact tonometer, was carried out on the volunteers, to rule out pathological conditions (such as glaucoma, ocular hypertension, et cetera) that may affect visual acuity.

2.4.5 Visual acuity

Monocular visual acuity was taken for each eye, with the volunteers seated at 6 metres away from snellen visual acuity charts internally illuminated with 2 tungsten bulbs, and then with 2 fluorescent bulbs respectively, in well-lighted examination rooms.

2.5 Data Analysis

The data obtained were presented in tables and figures. The hypotheses were tested at 95% level of significance, using excel computed T test: Two-Sample Assuming Unequal Variances statistical method, since two similar variables, which are not dependent on each other but are of equal number, were being compared.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Luminance levels of visual acuity charts

The luminance levels of visual acuity charts, in the 14 selected eye clinics in Owerri, are shown in Table 2.

Using the T test: Two-Sample Assuming Unequal Variances statistical method of data analysis, it was found that luminance levels of visual acuity charts do not differ significantly in the eye clinics in Owerri (since P(T<=t)= 0.44 > *P* = .05). This is shown in Table 3.

3.1.2 Fluorescent luminance

Mean values of both eyes' visual acuities, measured with a visual acuity chart internally illuminated with a fluorescent bulb, under bright room illumination, are shown in Table 4 and Fig. 2.

Statistical analysis showed that energy-saving (fluorescent) bulbs' luminances have no significant effect on visual acuity, under bright room illumination (since P(T<=t) = 7.27 > *P* = .05). This is shown in Table 5.

3.1.3 Tungsten luminance

Mean values of both eyes' visual acuities, measured with a visual acuity chart internally illuminated with a tungsten bulb, under bright room illumination, are shown in Table 6 and Fig. 3.

Statistical analysis showed that tungsten bulbs' luminances have no significant effect on visual acuity, under bright room illumination (since P(T<=t) = 3.54 > *P* = .05), as shown in Table 7.

Table 2. Luminance levels of visual acuity charts in 14 selected eye clinics in Owerri

Clinics	LGA	Number of volunteers	Type of illuminating bulb	Luminance levels of Visual Acuity charts
A	Owerri municipal	12	Fluorescent	14.40cd/m^2
B	Owerri north	11	Fluorescent	13.28cd/m^2
C	Owerri west	11	Fluorescent	14.48cd/m^2
D	Owerri north	11	Fluorescent	14.64cd/m^2
E	Owerri municipal	12	Fluorescent	14.60cd/m^2
F	Owerri municipal	12	Fluorescent	14.56cd/m^2
G	Owerri west	11	Tungsten	14.72cd/m^2
H	Owerri west	11	Tungsten	15.76cd/m^2
I	Owerri north	11	Fluorescent	14.64cd/m^2
J	Owerri north	11	Fluorescent	14.44cd/m^2
K	Owerri municipal	12	Tungsten	14.68cd/m^2
L	Owerri west	11	Fluorescent	14.52cd/m^2
M	Owerri municipal	11	Tungsten	15.20cd/m^2
N	Owerri municipal	12	Tungsten	15.64cd/m^2

Table 3. Analysis using T-test statistical tool

Mean	**450.25**
Variance	26662.79
Observations	14
Hypothesized Mean Difference	0
Df	10
t Stat	0.801745
P(T<=t) one-tail	0.220668
t Critical one-tail	1.812461
P(T<=t) two-tail	0.441336
t Critical two-tail	2.228139

Table 4. Mean values of right and left eyes' visual acuities, measured with a visual acuity chart internally illuminated with a fluorescent bulb, under bright room illumination

Visual acuity chart luminances (cd/m^2)	Mean visual acuities (decimal)
14.40	0.35
13.28	0.48
14.48	0.48
14.68	0.40
14.60	0.48
14.56	0.41
14.64	0.39
14.44	0.28
14.52	0.27

3.2 Discussion

Luminance is sometimes called brightness. Since the human eye sees luminance, it means that the amount of light delivered into the space and the reflectance of the surfaces in the space may affect one's ability to see [2].

The results obtained from this study showed that visual acuity chart luminances do not significantly vary in the eye clinics in Owerri (Table 3) (since, P(T<=t)= 0.44 > *P* = .05). These results gave VA chart luminance window of 13.28 cd/m^2 to 17.76 cd/m^2, for the eye clinics in Owerri (Table 2). Considering the fact that similar electrical companies manufacture and distribute electrical bulbs, and similar plastic companies manufacture and/or import acrylic plastic sheets in Nigeria, it is safe to assume that the luminance level of the VA charts used in other eye clinics in Nigeria will fall into the same luminance range/window as the

ones obtained in this study. This luminance window is in line with the recommendation made by Jackson and Bailey [13], where they suggested that VA chart luminance should be in the range of 80-320cd/m^2 within any clinic environment. They also agree with the recommendation made by Cole [10], who suggested that chart luminance level should be within the range of 40-600cd/m^2, after he pointed out that the standard chart luminance in Britain is 120 cd/m^2, while the recommended levels differs from 85-300 cd/m^2, in other countries.

Mean values of right and left eyes' visual acuities, measured with a visual acuity chart, internally illuminated with a fluorescent bulb, under bright ambient room illumination.

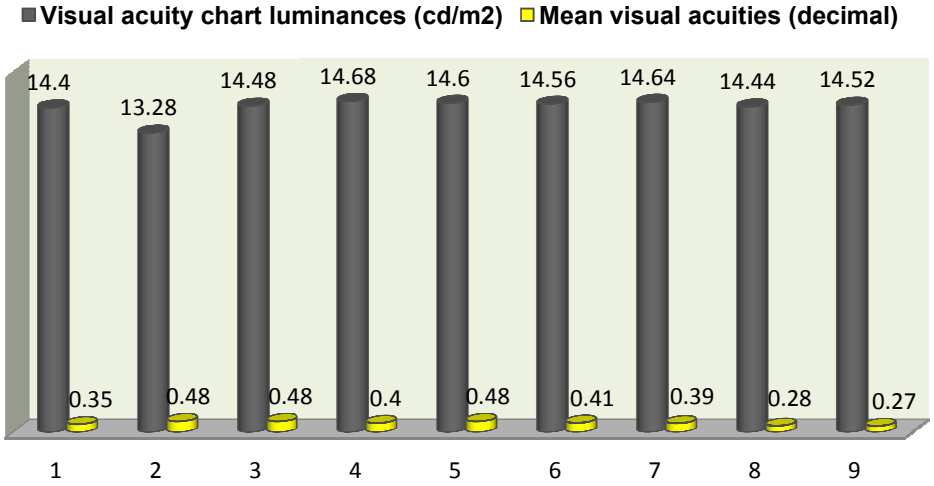

Fig. 2. Mean values of right and left eyes' visual acuities, measured with a visual acuity chart internally illuminated with a fluorescent bulb, under bright room illumination

Table 5. Analysis using T-test statistical tool

	Visual acuity chart luminances (cd/m^2)	Mean visual acuities (decimal)
Mean	14.4	0.393333333
Variance	0.1848	0.0066
Observations	9	9
Hypothesized Mean Difference	0	
Df	9	
t Stat	96.047282	
P(T<=t) one-tail	3.645E-15	
t Critical one-tail	1.8331129	
P(T<=t) two-tail	7.291E-15	
t Critical two-tail	2.2621572	

Table 6. Mean values of right and left eyes' visual acuities, measured with a visual acuity chart internally illuminated with a tungsten bulb, under bright room illumination

Visual acuity chart luminances (cd/m^2)	Mean visual acuities (decimal)
14.72	0.48
15.76	0.28
14.68	0.27
15.20	0.54
15.64	0.34

Table 7. Analysis using T-test statistical tool

	Visual acuity chart luminances (cd/m^2)	Mean visual acuities (decimal)
Mean	15.2	0.382
Variance	0.252	0.01482
Observations	5	5
Hypothesized Mean Difference	0	
Df	4	
t Stat	64.14538302	
P(T<=t) one-tail	1.76912E-07	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	3.53823E-07	
t Critical two-tail	2.776445105	

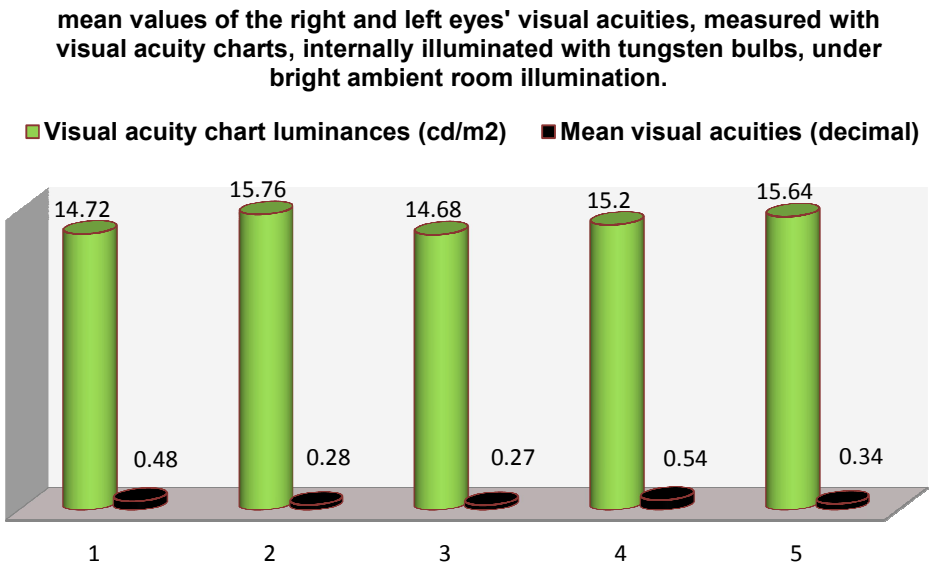

Fig. 3. Mean values of right and left eyes' visual acuities, measured with a visual acuity chart internally illuminated with a tungsten bulb, under bright room illumination

From the result obtained in this study also, we observed from Table 2, that the luminance levels of the visual acuity charts illuminated with tungsten bulbs were high compared with those illuminated with fluorescent bulbs. This may be attributed to the fact that tungsten bulbs achieve full brightness faster than fluorescent bulbs. The luminance/brightness of electrical bulbs gradually increases from the time they are switched on till they achieve full brightness, and then stabilizes [2]. The luminance of the visual acuity charts, illuminated with these bulbs, was measured immediately the charts were switched on at the light sources. This disagrees with several authors [9,20,21] who are of the opinion that a fluorescent bulb has greater luminance compared with a tungsten bulb of equal wattage.

Comparing the right and left eyes' visual acuities, measured with visual acuity charts internally illuminated with a fluorescent (Table 4) under bright room illumination, the result showed that VA chart luminance had no significant effect on right and left eyes' visual acuities measured with VA charts, internally illuminated with a fluorescent bulb, under bright room illumination (Table 5) (since, P (T<=t)= 7.29 > *P* = 0.05). This disagrees with the findings of several authors [13,16-18] who are of the opinion that visual acuity values are affected by changes in VA chart luminance and ambient illumination of the examination room.

Comparing the right and left eyes' visual acuities, measured with visual acuity charts internally illuminated with tungsten bulbs (Table 6), under bright room illumination, the result showed that VA chart luminance had no significant effect on the right and left eyes' visual acuities measured with a VA charts, internally illuminated with

tungsten bulbs, under bright room illumination (Table 7) (since, P(T<=t)= 3.54 > *P* = 0.05).

This result also disagrees with results of the studies carried out by several authors [25,19,20-24] which states that change in VA chart luminance significantly affected visual acuity.

The reason behind these results (Tables 3 and 5) may be because the corrected visual acuities of the volunteers were used in this study. The results obtained from similar studies, especially those carried out by several authors [16,25,30] revealed significant effect on visual acuities of patients with uncorrected refractive errors.

4. CONCLUSION

The results of this study showed that the luminance levels of visual acuity charts did not differ significantly in the various selected eye clinics in Owerri. It was found also that under bright ambient room illumination, with constant chart luminance, visual acuity chart luminance (fluorescent and tungsten) had no significant effect on the right and left eyes' visual acuities of the subjects. Visual acuity was found to be better under tungsten luminance than fluorescent luminance.

It is recommended that further studies be carried out on volunteers with uncorrected refractive errors. It is also recommended that further studies be done to find out why visual acuity readings were better under the tungsten luminance, compared with the fluorescent luminance.

CONSENT

All authors declare that an informed consent was obtained from each of the volunteers, for publication of this case report and accompanying images.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the ethics committee of the School of Health Sciences and Technology, Federal University of Technology, Owerri, Imo State, Nigeria.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

VISUAL ACUITY CHART INTERNALLY ILLUMINATED WITH FLUORESCENT BULBS

VISUAL ACUITY CHART INTERNALLY ILLUMINATED WITH TUNGSTEN BULBS

Peer-review history:
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