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Determination the Tooth Shade of Patients Attending Out Patient Clinic in Faculty of Dentistry University of Science and Technology (Sudan)

By

Asim Elsir Elmahdi

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Supervisor:

Dr. Magdi Wadie Glada,

MSc

Co-supervisor:

Dr. A. Raouf Alotaibi

MSc, PhD

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Dedication

To

My Beloved family,

To my friends,

AND

To spirits of my beloved;

M.zain & Ghada

Acknowledgment

I would like to express my deepest sense of gratitude to Dr. Magdi Wadie, and to Dr. Nadia Khalifa for their patient guidance, and encouragement.

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Abstract

Introduction: There is limited information about the most dominant tooth colour shade in Sudanese population. The relation between skin tone, age, gender as criteria aiding in selection artificial teeth for completely edentulous Sudanese patients need to be addressed.

Aims: This study aimed to identify the tooth colour shade in a sample of Sudanese population and it's relation to age, gender and skin tones.

Material & method: The study comprised 222 individuals in 4 groups; 15-24 yrs,25-34yrs,35-44yrs and 45 yrs and above. One investigator, calibrated for examining tooth shade, performed all examinations. A Vita 3D master shade guide was used to examine either the maxillary right or left central incisor. A tooth had to be sound for inclusion in the study. Skin tone was divided into three categories (dark, medium and light) after performing a pilot study of 40 photographs and making tone pellet guide using PSPP12-Corel software. Chi-square test was used to analyze the data ($P<0.05$).

Results: Most common tooth colour recorded in the study was 2M2 followed by 2M1, and 2M1.5. Statistically significant association was found between gender and tooth shade where men had darker teeth than female ($P=0.03$), and between tooth shade and age where older people had darker

teeth (p=0.01). Darker skin tone individuals had teeth lighter in colour (p=0.04).

Conclusion: This study concluded that lighter tooth shade was funded in younger age group and female individuals. In appropriate selection of artificial teeth for dark skin tone group it is more relevant to choose light tooth shade Value 1 and Value 2.

مستخلص البحث

المقدمة: هنالك معلومات محدودة عن الوان الاسنان الاكثر شيوعا عند السودانيين، وعلاقتها بلون البشرة والعمر والجنس كمحددات تساعد في اختيار لون الاسنان الصناعية في أطقم الأسنان المتحركة.

الأهداف : هذه الدراسة تهدف لتحديد لون الأسنان عند السودانيين وعلاقتها بألوانهم وأعمارهم وجنسهم.

منهاج البحث : هذه الدراسة ضمت 212شخص ضمن مجموعات عمرية كالتالي:15-24سنة، 25-43سنة،35-44سنة،45سنة فما فوق. باحث واحد قام باجراء كافة الاختبارات لتحديد لون الاسنان ولون البشرة. دليل فيتا للون الاسنان ثلاثي الابعاد استخدم لتحديد لون القاطع العلوي الأيمن أو الأيسر الذي يجب أن يكون سليما ليشمل فى الدراسة. ألوان البشرة قسمت لثلاثة مجموعات: داكنة، متوسطة، وفاتحة اللون بعد القيام بدراسة تجريبية علي 40 صورة فوتوغرافية للوجه استخرج منها ألوان البشرة باستعمال برنامج الكمبيوتر كورل بي اس بي بي 12. استعمل اختبار Chi square لتحليل البيانات(نسبة بيانية< 0.05).

النتائج : ألوان الأسنان الأكثر شيوعا في هذه الدراسة هي 2m2، 2m1، 2m1.5. وهنالك علاقة بيانية مميزة وجدت بين لون الاسنان والجنس حيث ان الرجال لديهم أسنان غامقة الألوان مقارنة بالنساء (نسبة بيانية=0.03)، وأن صغار السن من الجنسين لديهم أسنان فاتحة اللون مما لدي الكبار (نسبة بيانية=0.01). الأشخاص ذوى البشرة الداكنة لديهم أسنان فاتحة اللون (نسبة بيانية=0.04).

الخاتمة: خلصت هذه الدراسة الي أن ألوان الأسنان الفاتحة اللون توجد عند الأعمار الصغيرة وعند النساء مقارنة بالرجال. عند اختيار الأسنان الأصطناعية للأطقم الكاملة لذوي البشرة الداكنة يفضل إختيار الأسنان ذوات قيمة الالوان السنية 1 و 2.

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CHAPTER ONE

Introduction & Literature Review

1. Introduction & Literature reviews

1.1. Introduction

The goals of aesthetic dental restorations are to achieve morphologic, optical, and biologic acceptance. [1] However patient satisfaction of an aesthetic restoration is primarily associated with surface and outline form, translucency and colour of artificial teeth. [2, 3] Whereas meticulous clinical and laboratory work achieve the form of the restoration, the colour of the restoration remain a problem.

The colour of teeth probably constitutes one of the most important parts of our first impression of someone. A smile has been said to be one of the most important interactive communication skills of a person. The ultimate objective of aesthetic in dentistry is to create a beautiful smile, with the teeth of pleasing inherent proportions to one another, and pleasing tooth arrangement in harmony with gingiva, lips and face of the patient. [4] In addition, the aesthetic of any restoration needs to consider the parameters of the surface form, translucency, and colour. [5, 6] Patients nowadays demand not only a healthy mouth but also a perfect smile. Whitening teeth for aesthetic purpose is currently fashionable. These types of situation have raised the need for tooth colour measurement in the field of dentistry in recent years.

Selection of appropriate tooth shade for edentulous patients is an important part of teeth replacement especially with complete edentulous

patients. [7] It has been shown that proper shade selection has a positive impact on the patient's perception of aesthetics and ultimately, the acceptance of their dentures.[7]

Although the dental literature is replete with anecdotal references about denture aesthetics, it is an imprecise area combining both scientific and artistic principles. [8] These principles have been combined to give specific guidelines in teeth shade selection particularly among multiracial communities like ours. Little has been reported about Africa and nothing about our communities.

Various studies have been conducted on the various determinants of colour, i.e., value, hue, and chroma.

Hue is a specific colour resulting from light of specific wavelength acting on the retina. The hue is the indication of a specific colour, e.g. blue, green, reddish yellow. Some authorities suggest that the hue of the teeth should harmonize with the hue of the patient hair (natural hair). Others, however, quote studies that cast doubt on this philosophy. [9] Saturation (chroma) represents the amount of colour per unit area, e.g. a tooth may appear greyer than another tooth. The chroma of both teeth could be equal or one tooth could contain a higher saturation of the grey than the other. Brilliance (value) equates to the lightness or darkness of a tooth. Variations in brilliance are affected by dilution of the colour (i.e. the hue) by black or white.

It is the ratio of white or black on teeth to the natural hue which determines the lightness or darkness of teeth. Translucency enables light to pass through a body without giving any distinguishing image.

Black's [10] work published in 1908 was the first reference in the dental literature showing the importance of the value in the shade determination

process. He stated that the best aesthetic result was obtained when the proper colour (hue) and translucence (value) were determined. [10]

Black believed that; value was of greater importance than hue. This view was also supported by Clarke [11], Preston and Bergen. [12]

Several shade guides have been invented to match the missing tooth/teeth to neighboring or adjacent teeth, but there is no such guide for completely edentulous patients.

Many criteria have been proposed to aid in selection of artificial teeth like; for example the colour of hair, eyes, and skin, as well as age, and sex of the patient have also been included.

The highest demand for replacement of missed anterior teeth is aesthetic which is playing a positive role in patient acceptance of perceived prosthesis in psychological manner. Tooth colour shade is important to make a denture either removable or fixed.

Most studies in tooth colour shade are done in Caucasian and Asian population, as far as we know, no such study is done in any Sudanese population.

This study will try to determine the most common tooth colour shade among specific population to get a hint or a guide for selection of colour shade of artificial teeth in complete denture construction.

1.2. Objectives:

General:

To study the variations in tooth colour shade in a Sudanese population.

Specific:

- To determine the most common tooth colour shade.
- To correlate the teeth shade to different skin tones.
- To assess the correlation of tooth colour with different variables such as age and gender.

1.3. Literature reviews

1.3.1. Colour phenomenon and perception

Sir Isaac Newton first observed that sunlight separates into bands of bright colours when projected through a prism. The white light was being "refracted" or separated into the colours of the spectrum. Colours originate from light waves that represent different wavelengths or oscillations of electromagnetic energy.

The colour is a phenomenon of light or visual perception that enables one to differentiate otherwise identical objects.

The perceived colour response results from either a reflected or transmitted beam of white light.

The phenomenon of colour is a psychophysical response to the physical interaction of light energy with an object, and the subjective experience of an individual observer.[13]

Three factors can influence the perception of colour, namely, the light source, the object being viewed and the observer viewing the object. The light source can emit radiant energy of a range of wavelengths and this is characterized by the relative amount of energy emitted at each wavelength in the visible spectrum. The light source that illuminates an object affects colour perception, since individual sources contain varying quantities of each of the visible wavelengths of light. The spectral reflectance (or transmittance) of an object characterizes the colour makeup of that object. The spectral reflection or transmission curve of the object represents it graphically, and provides a way of quantifying colour numerically. As objects vary in colour, so do the graphs depicting the energy being absorbed

or reflected. For example, a red object looks red primarily because it reflects red wavelengths more than green and blue.

The observer's Visual system of eye and brain finally affects the overall perception of the colour.[14]

1.3.2. Colour communication

A major problem often arises when attempting to communicate colours to others. To this end a number of colour scales have been developed. The system of colour notation developed by A. H. Munsell in 1905.

Colour can be described according to the Munsell colour space in terms of hue, value and chroma.[15] These coordinates defines how materials modify light by absorption, reflection, refraction, transmission, dispersion, diffraction, and interference.[16 17]

In teeth hue corresponds to the wave length of reflected light. [18] As light pass through the natural teeth, it reflected, refracted, absorbed, or transmitted by a multilayer complex tooth structure that varies according to optical densities of its hydroxyapatite crystal, enamel rods, and dentinal tubules. [19]

Visual stimuli are determined by these reflected or refracted wavelengths, which are transformed in the viewers' cerebral cortex into perception of colour. [20]

Hue is the attribute of a colour that enables one to distinguish between different families of colour, for example, reds, blues and greens.

Value indicates the lightness of a colour ranging from pure black to pure white(In the Vita scale, from the greater to lower value, as with B1, A1, B2,

D1, A2, through D4).[21] Value is the most easily discernable of the three primary optical characteristic, and this aspect is distinguishes light from dark colours.[21 22]

Chroma is the degree of colour saturation and describes the strength, intensity or vividness of a colour. The chromatic component only compares colours of equal hue, [21] and while the same hues are frequently found in the middle and cervical thirds, distinct hues can be identified at the incisal third due to the way the light is refracted, reflected, absorbed, and transmitted.

1.3.3. Nature of tooth colour

The colour of natural tooth is not a same all over the tooth, because the colour is determined by different morphologic structures that absorbed or refract the light to give distinguished colour in different region of the tooth. The colour of the tooth is mainly due to the colour of the underlying dentine[16].

The overlying enamel plays only a minor role. Thin enamel on its own, appears pale blue in reflection and pale yellow in transmission[23].

The colour and appearance of teeth is a complex phenomenon, with many factors such as lighting conditions, translucency, opacity, light scattering, gloss and the human eye and brain influencing the overall perception of tooth colour[24].

1.3.4. Polychromatic phenomenon

In natural, polychromatic teeth, differing colours are distributed, and various optical characteristics are observed through enamel and dentin.[20]

This polychromatic effect resulted from various optical properties that give the colour of the tooth. A broader definition of colour is, therefore, necessary based upon anatomy, optical properties, and polychromacity to appropriately describe tooth colour and aesthetics.

The optical properties of enamel and dentin that affect the perception of colour in addition to hue, value, and chroma: are translucency, opacity, opalescence, iridescence, surface gloss, and fluorescence. These secondary optical properties contribute significantly to the total aesthetic of the tooth.

1.3.5. Optical properties affect tooth colour

Translucency and opacity have been viewed as the most important of these secondary properties, since they are indication of the quality and quantity of light reflection[19] the degree of translucency and opacity is determined by the structure and thickness of enamel and dentin as well as the amount of light that penetrate the tooth or restoration. Although both enamel and dentin are translucent in natural dentition, the enamel layer is virtually transparent and colourless[25]

Opalescence can be defined as the milky, iridescent appearance of a dense, transparent medium of colloidal system when illuminated by visible light. Opalescence occurs in the tooth when visible light is scattered and causes a reflection of short wavelengths of light (bluish tone), transmission

of longer wavelength (yellow orange), and absorption of medium wavelengths (greenish tones). This feature is primarily observed in enamel and in teeth it appears as light scattering effect that is associated with the diameter of enamel rods.

In posterior teeth, these characteristics are exemplified on cusp tips and marginal ridges. In anterior teeth, these effects are observed in the incisal edges and proximal incisal surfaces. Since the colour of dentin is dominated by light absorption and reflection that creates a yellow\orange appearance and mask opalescent effect, opalescent is not readily discernable in this structure.

Iridescence produces a rainbow effect within the object being viewed. While colours change upon alterations of viewing direction, location, and illumination of an object, the manner in which these parameters change dependent upon the wavelength of dispersion, interference, and diffraction of light.

Surface gloss affects the appearance and vitality of teeth and aesthetic dental materials. On the labial surface of anterior teeth, light reflected from tertiary anatomy adds to vitality, whereas less vitality is evident when this anatomy is worn with age.

Surface gloss has been describes as optical property that produce a lustrous appearance.[26]

Luster is the ratio of light reflected secularly at a material surface or within the body of a restorative material.[27]

The surface morphology of natural teeth influences the surface gloss. While macro or micro morphologically roughened or coarse surface allow

diffuse reflection, flat or smooth surfaces allow specular reflection.[28] This optical scattering has an effect on the colour perception and translucency of the tooth or restorative material, and it should be considered during shade matching between a restorative material and natural tooth structure.[26 29]

Fluorescence occurs when ultraviolet (UV) light rays are absorbed and blue or white visible light is omitted.[28 30] Due the organic composition of the dentin, UV light rays penetrate the enamel and excite the dentin photosensitivity. The emitted light enhances the brilliance and vitality of teeth. Both dentin and enamel fluoresce, and the combination of these structures enhances the whiteness or value of teeth.

1.3.6. Colour systems

The Commission Internationale de l'E´clairage (CIE), an organization devoted to standardization in areas such as colour and appearance, defined in 1931 a standard light source, developed a standard observer and enabled the calculation of tristimulus values, which represent how the human visual system responds to a given colour.[31]

In 1976, the CIE further defined a colour space, CIE Lab, which supports the accepted theory of colour perception based on three separate colour receptors (red, green and blue) in the eye and is currently one of the most popular colour spaces.

The CIE Lab colour space represents a uniform colour space, with equal distances corresponding to equal perceived colour differences. In this three-dimensional colour space the three axes are; L*, a* and b*.

The L* value is a measure of the lightness of an object and is quantified on a scale such that a perfect black has an L* value of zero and a perfect reflecting diffuser an L* value of 100.

The a* value is a measure of redness (positive a*) or greenness (negative a*). The b* value is a measure of yellowness (positive b*) or blueness (negative b*).

The a* and b* co-ordinates approach zero for neutral colours (white, grey) and increase in magnitude for more saturated or intense colours. The advantage of the CIE Lab system is that colour differences can be expressed in units that can be related to visual perception and clinical significance.[32]

1.3.7. Measuring colour of teeth and shade guides

Many methods are currently used to assess tooth colour. These range from visual subjective comparisons using paper, coloured porcelain or acrylic resin shade guides to instrumental objective measurements using spectrophotometers, colorimeters and image analysis techniques.

Both techniques have inherent inaccuracies. Visual examination requires trained and experienced individuals, [33] and shade selection can be affected by illumination and surrounding tissues. Instrumental measurements may be complicated by setup difficulty and heat produced by the instrument in repeated measurements, which could cause discomfort to the subject or failure of the instrument to maintain its calibration. [34]

In 1908 black published his monumental work on operative dentistry. This work was the first reference in the dental literature to the importance of the value in the shade determining process.

Black [10] stated that the best aesthetic obtained when the proper colour (hue) and translucence (value) were found. Of these attributes, he believed that translucence was of greater importance than the true colour. He suggested that translucence be assessed first and that chroma (saturation) should be determined before colour.

Various shade guides existed at this time, but they were designed for the operator to use 1 tab to decide all 3 determinants: value, chroma, and hue.

It was not until the 1930s when Clark[11] published a series on colour science that the current use of shade guides began. In one publication he spoke of brilliance as the most important attribute in the study of tooth colour. Clark[11] incorporated the importance of value into his own design for a guide he called the "Tooth Colour Indicator." It had 60 tabs and only 1 hue (yellow), but provided for the selection and use of 342 gingival colours and 342 incisal colours. In fact, it was never marketed.

A simplified shade guide (the Vita Lumin Vacuum Shade Guide) was developed in the 1960s and was well received by the dental profession. Vita (Vita Zahnfabrik, Bad Sackingen, Germany) changed the name of the Vita Lumin Vacuum Shade Guide to the (Vitapan Classical Shade Guide) in February 1998.

This name change was to differentiate it from Vita's newest guide, the (Vitapan 3-D Master).

The instructions for the Vitapan Classical Shade Guide explain the arrangement according to hue and chroma.

The Vita system is most commonly used in Dentistry. This uses the letters A, B, C and D to notate the hue (colour) of the tooth. The chroma and value are both indicated by a value from 1 to 4. A1 is being lighter than A4, but A4 is being more saturated than A1. If placed in order of value, i.e. brightness, the order from brightest to darkest would be:

A1, B1, B2, A2, A3, D2, C1, B3, D3, D4, A3.5, B4, C2, A4, C3, C4

They also explain how to arrange the guide according to value. The clinician therefore has 16 choices with variability in hue and chroma but no method to assess the most important determinant: value. If the directions were followed completely, the choices would be 16 x 16 or 256 value-chroma-hue combinations.

Another problem with the Vitapan Classical Guide was that the tabs were not dispersed evenly throughout the 3-dimensional colour space .[4]

In the 1970s, Sproull [18 35 36] published a 3-part series on colour. In this series, he suggested that once dentists fully understood the definitions and relative importance of value, chroma, and hue, they would be able to solve the colour-matching problems in a step-by-step manner. He also suggested that dentists were not prepared in dental school to logically analyze colour-matching problems [18]. This perception appears to still be valid today.

In 1980, Preston and Bergen [12] published a workbook that identified value as the most important determinant of colour. The workbook was a teaching aid for training the eye to discern the differences between levels of value, chroma, and hue.

Two hundred ninety-five coloured paper squares were used and sorted onto grids in increments of increasing value, chroma, and hue. The authors'

solution for a shade-determining tool was to use the existing Vitapan Classical Shade Guide in 3 permutations: ordered by hue, incisals and gingivals removed, and glaze removed for custom staining. Preston and Bergen[12] advocated selecting value first.

In 1987 Sorenson and Torres [37] published a 3-part series on improved colour matching of metal ceramic restorations. In the summary, it was stated that there are 5 areas of weakness in shade-matching procedures, one of which was the commercially available shade guides. The authors' solution to this problem, when utilizing Vital Metal Keramik (VMK)-68 porcelain, was to use the shade indicator chart and ring of tabs (52 tabs). These tabs are broken down into opaque, body, and incisal porcelains. This seemed to provide an excellent solution that gave the operator control of all 3 determinants separately. However, it required that the dentist be able to extrapolate the resulting colour from stratification of these porcelain layers.

In 1991 Hall [38] stated that it was possible to minimize the difficulties of colour matching by quantifying the determinants of value, chroma, and hue.

This article was the basis for the design of the Vitapan 3-D Master Shade Guide that the Vita Company introduced to dentists in February 1998.

Hall worked with Vita to design a simple guide that incorporated all of the shade determinants in logical sequence: Value, Chroma, and Hue.

The 3D Master shade guide arranged so that the Value group be determined first out of five Value group tabs at the top of each group. They have the least amount of hue and chroma which allows the rods in the eyes

to more easily determine gradations of value because the rods are more sensitive to gradations of black and white than the cones are sensitive to colour [12].

The vita 3D master colour shade guide improves consistency of tooth colour selection, addresses the critical elements of tooth shade measurement (which have previously been unexplored by other shade systems, such as a systematic arrangement of shades within the natural tooth colour space and an objective, numerical measure of colour). This shade guide has been shown to significantly improve repeatability of measuring tooth shade compared to a traditional shade guide for a group of general practitioners but not for prosthodontists.[39]

Visual colour determination, by comparison of the tooth with standard colour tooth shade guides, is the most frequently applied method in dentistry. It is a subjective process whereby the tooth and the shade guide are observed simultaneously under the same lighting conditions. General variables such as external light conditions, experience, age, and fatigue of the human eye and physiological variables such as colour blindness may lead to inconsistencies and bias. [14, 40] In addition, standardized verbal means for communication of visually assessed colour characteristics are limited.[41] Despite these limitations, the human eye is very efficient in detecting even small differences of colour between two objects.[42]

3.1.7. Range and distribution of tooth colour

The range of colour and distribution of colour in different region of the tooth have been described by a numbers of investigators. In general the maxillary anterior teeth are slightly more yellow than the mandibular anterior teeth[33], and the maxillary central incisors are higher in value than the lateral incisors and canines. [33,34,43,44]

The middle site of the tooth has been described as the site that best represents the colour of the tooth material. [33] This is because the incisal site is most often translucent and is affected by its background and because the cervical colour is modified by the scattered light from the gingiva. [31, 45]

Allowing teeth to dry out has been shown to make the teeth appear whiter. [5, 2] For example; Russell et al.[2] applied a rubber dam to the anterior teeth of seven subjects and allowed the teeth to dry out for 15 min.

The colour of the teeth were measured before and after with a spectrophotometer and it was shown that L* significantly increased, a* significantly increased towards zero whilst b* showed no significant change. Thus, the colour of the teeth had become lighter and less saturated. The colour of the teeth returned to their baseline values after 20 min from the removal of the rubber dam. In addition, polyvinylsiloxane impressions had a similar effect on tooth colour, but required at least 30 min in order for them to regain their original baseline colour.

3.1.8. Selection of tooth colour for complete edentulous patients

Several Tooth shade guides have been developed throughout the last century [46], but these guides have been essentially useful in patients with healthy natural teeth that could be used for comparison with the guide.

However, in the edentulous patients the uses of a shade guide, photocolormetric analysis, and digital shade analysis guides are limited. Hence the prosthodontist has to look elsewhere for other guidelines for the selection of the proper shade of artificial teeth in completely edentulous patients.

This is particularly true in African population where complete edentulism occurs at an early age due to widespread periodontal diseases and the inadequacy of oral health care. [47]

3.1.9. Factors affecting teeth colour for edentulous patients

Several factors such as age, sex, and skin colour have been proposed as aids for artificial teeth selection, and numerous methods have been devised for the evaluation of reliable aesthetic factors in determining artificial tooth selection for edentulous patients in predominantly white populations.[48] To date no universally reliable method of determining tooth shade has been found.[48, 49] In addition, there is limited reported scientific information on the relationship between the colour shade and these criteria in Sudanese population.

Depending in hair colour as guide is unreliable because the hair colour can change as the colour of tooth, and it can be changed at will. [50]

The colour of eyes is proposed as guide but the size of iris is so small in comparison to the face, and also its colour can be changed. [49]

Most authors favored colour of the skin as guide to the tooth selection. [49] Some authors stated that people with the fair complexions have teeth with less colour range and colour saturation thus the teeth are lighter and in harmony with colour of the faces. Also, it has been said people with the dark complexions generally have darker teeth that are in harmony with colour of the face. [49]

It is often noted that people of African descent have very white teeth. This could be an optical illusion, due to the contrast of teeth with darker skin making the teeth appear lighter and teeth looking darker when compared with lighter skin. A region looks much darker when the surrounding region is more illuminated.

In general, studies have shown that tooth colour is not related to ethnicity.[50] However there has been some conflicting research which has found otherwise. In one study it was found that tooth shade has an inverse relationship with skin colour, i.e., the lighter the skin tone the darker the tooth shade. [51] These results are similar to pervious results performed among multiracial populations in which dark skin people required a lighter tooth shade. [52]Similar finding reported by Azad *et al*[53] in Pakistanian population.

On the other hand some studies found that there was no relationship between the tooth shade and colour of the skin. [54, 55]

Primary teeth have been shown to have lighter value than permanent teeth. With respect to permanent teeth, tooth shade has been shown to have a direct relationship to age. As the age increases, there is an increase in dentin deposition which ultimately leads to darkening of the teeth. [50 51 52]

Natural tooth colour has a significant tendency to increase with the age of the subject, generally becoming darker and more yellow.[34, 45, 46, 47, 48, 50, 56, 57] With advancing age, it has been reported that the colour can increase in redness at the incisal site because of the long term occlusal wear loss in the incisor region.[51]

The impact of age on tooth colour is due to a number of factors. As the dental pulp ages it shrinks, leaving secondary dentine in its wake.[58] The surrounding dentine becomes harder and less permeable.

At the same time, it has been hypothesized that pigments and ions of an amorphous organic and inorganic nature permeate through the enamel, depositing at the dentine– enamel junction and within the dentine structure.[58] The dentine chroma becomes more saturated and the overall value of the tooth becomes lower.

Combined with an ever-decreasing enamel thickness as a result of normal wear, the dentine colour begins to dominate anterior tooth shade. Indeed, such thinning has been shown in vitro to contribute to increase in yellow when tooth colour is measured using a spectrophotometer.[23] The net result is a progressive darkening of the teeth associated with age. In the midst of a

vast array of genetically determined tooth colours, all teeth darken over the course of time.[58]

Study conducted by Zhou et al.[59], it was found that teeth colouration fluctuates within the period spanning the initial and final stages of puberty. This is characterized by a decrease in hue and value and an increase in chroma.

In addition, gender influence on tooth shade has been subject of controversy. While some authors believe there is no significant relationship between gender and tooth shade [34 59], others believe there is relationship between gender and tooth shade. [33, 49, 50,52,53,54]

3.1.10. Tooth colour perception and appearance:

In contemporary dentistry, the needs of patients are considered in terms of function and dental appearance. The appearance of the teeth is related to both cultural factors and individual preferences, i.e. the viewer's perception of a visual experience can be pleasant or unpleasant, and what is considered 'beautiful' in one culture may be 'ugly' in another [60]. The most common associations with facial attraction are the eyes and mouth.[61].

The oral region plays an important role when an individual speaks or approaches another person and, for example, poor oral hygiene and ugly teeth are noticed by others.[60] In addition, the subjects' perception of tooth whiteness, health and attractiveness is greatly influenced by the colour of the adjacent lips and gums.[62]

In a dental aesthetics attitudes survey[60] of 254 subjects, it was found that the appearance of the teeth was found to be more important to women than men and significantly more important to younger people than older. In addition, the perception that very white teeth are beautiful significantly decreased with increasing age of the subject, and younger subjects expressed a greater preference for white teeth than older subjects.

This was in agreement with a study where photographs of four maxillary dentures, identical except for shade, were rank ordered for preference by 150 subjects, where it was found that older subjects preferred darker colours than younger subjects.[63]

Current concepts on tooth shade selection consider the patient's perception of his or her tooth shade and colour when selecting the appropriate tooth shade, especially in edentulous patients[8, 64 65]. No scientific support to this hypothesis exists at this time because many factors may influence the patients' choice of shade and colour, especially in black African populations where white teeth are regarded as an element of beauty.

No literature was found on the influence of country or area on perception of tooth colour.

CHAPTER TWO

Materials & Methods

2. Materials and methods

2.1. Study design:

Cross sectional study (hospital based).

2.2. Study population:

Sudanese patients attended the outpatient clinic at the Faculty of Dentistry of University of Science and Technology during the study period.

2.3. Sampling:

Census study; all male and female patients attended the outpatient clinic at the Dental Hospital of the University of Sciences and Technology Omdurman, aged 15 to 45 years old who had just undergone scaling and polishing had been included.

The sample divided into four age groups with 10 years interval, and the shade of either left or right maxillary central incisor determined which should be free of internal pigmentation, restoration, endodontic treatment, bleaching, or orthodontic appliances.

2.4. Data collection:

2.4.1 Tooth shade:

One investigator calibrated for determining tooth shade (pretest and post test-test was done in regard to tooth shade determination), performed all examinations. A Vita lumin 3D shade (Vita Zahnfabric H. Rauter Gmb H&

Co. KG. Bad Sakingen, Germany) used to measure the colour shade after informing the patient about the purpose of the study, Picture 1.

Shade guide selected to examine either the maxillary left or right central incisor, which had to be free of restorations and dental caries. An individual shade tab positioned directly next to the tooth under examination and compared to the middle third of the crown.

Due to fact that dehydration affects the colour of the teeth and that several hours are required for the teeth to return to their original shade, patients examined prior to dental treatment. To overcome the effects of fatigue and tiring of the operator, following measures are also adopted: all shade readings made preferably between 10:00 am and 12:00 noon; and the shades established within 1 to 2 minutes.

All shade readings made swiftly, from an arm's length distance. Shade tabs moistened before placing them in the correct position on the inside of the upper lip next to the tooth being matched.

First of all, the value (1, 2, 3, 4 or 5) selected, starting from the darkest group. Next, chroma selected from the same value group in the middle (M) column. Lastly, hue selected by determining whether the natural tooth was more reddish (R-column) or more yellowish (L-column) than the shade sample.

Picture 1; Vita 3D Master tooth shade guide

2.4.2 Skin complexion

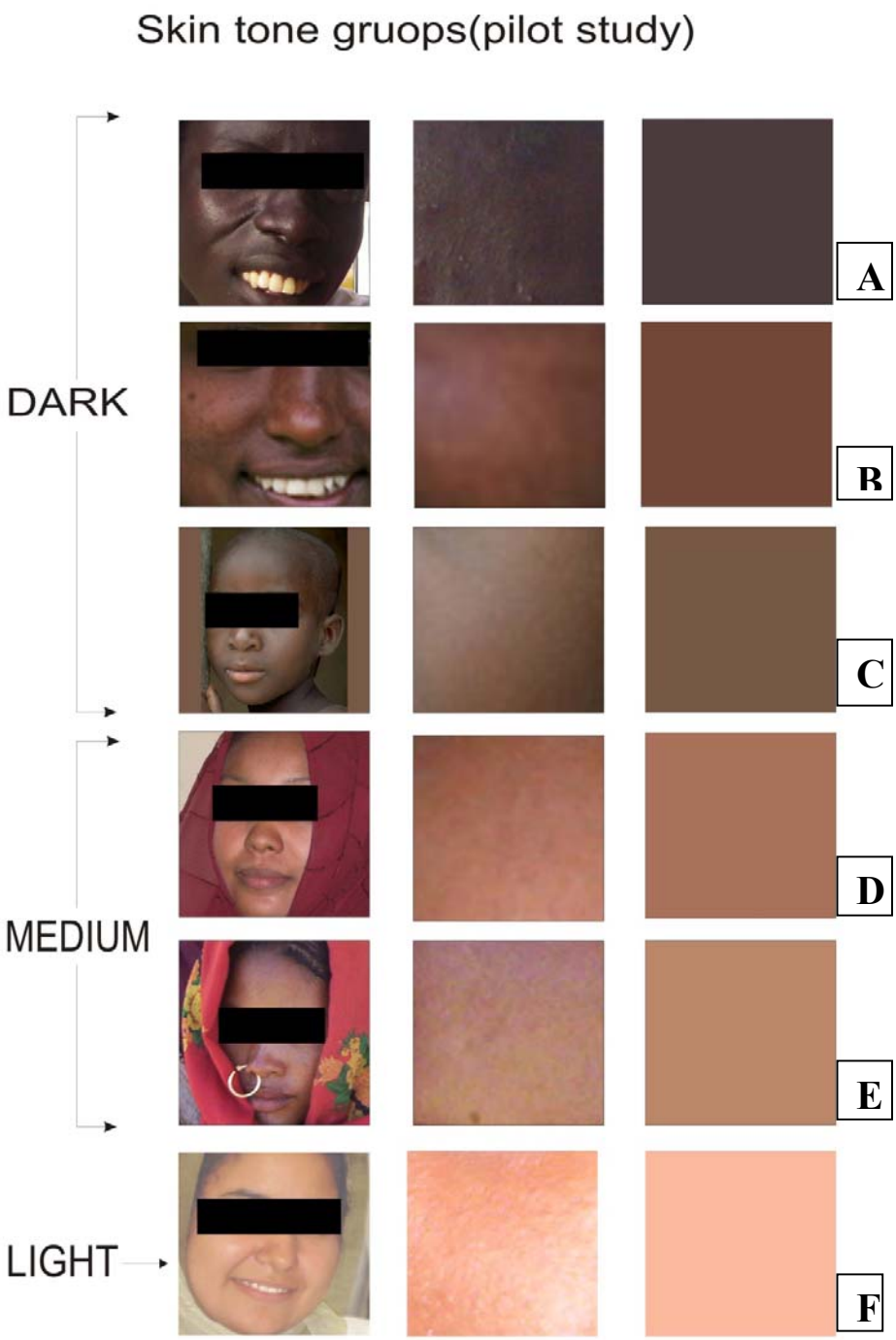
For determination of skin complexion in the study population a pilot study had been held out using digital camera (Sony Cyber-shot 10.1 Mega Pixels).

A photograph of the face had been taken using the lateral and frontal view at a distance of about 25 cm. the photos was taken in the day light after stopping the flash of the camera.

Skin tones divided into 3 categories: light, medium and dark, according to observation of skin tones of 40 individuals, and with the help of computer soft ware (PSPP12- Corel). The skin tones pellets in the right side of the picture 2 were taken from the side of the face, the area from which the colour was taken should be not reflected light or it was shadowed. Then by Corel soft ware the pellet is magnified to represent the colour of the correspondent group.

The most dominant colours of the group were selected and finally arranged in six colours from dark to light tone. The skin pellets A, B and C considered as dark skin group, while skin pellets D and E as medium and F as the light skin group.

In data collection, the examiner selected one group for every individual after comparing skin complexion with skin tone chart. Various shades arranged into corresponding skin tone groups devised. Female patients will be asked to remove lipstick prior to examination.



Picture 2; Pilot study in skin tones

Examinations accomplished with natural light and neutral back ground. A light blue colour viewed between examinations for calibration of the eyes.

The data collection form included the personnel data, tooth shade, and skin tone group.

2.5. Data management

Colour shade took with reference to the factors of hue, value, and chroma. Colour shade compared with the variables such as age, gender and skin tones from the data collection form to see whether there were any statistically significant relations.

The results statistically analyzed using SPSS to manage the data and Chi square test used to see if there was association between tooth colour shade, gender, age and skin tone (P value<0.05).

The study determined the most common colour among the study population which can then be used as the reference for subsequent studies on this item.

2.6. Ethical consideration:

Clearance letters from the administrators of the University and the Teaching Hospital obtained. The confidentiality of the volunteers was assured.

Consent letters had completed by the patients to make sure that they knew and agreed with the purpose of the study.

CHAPTER THREE

Results

3. Results:

3.1. Gender and age distribution:

The study comprised of 222 individuals, eighty eight (39.6%) males and one hundred thirty four (60.4%) females.

Most of the population in this study fell in the range of first and second age groups (Table 1).

The first age group (15-24 yrs) and the second age group (25-34 yrs) comprised of seventy two individuals (32.4%) each, the third age group (35-45 yrs) and the fourth group (45 years and above) both had thirty nine subjects (17.6%).

Gender	Age				Total
	15-24 yrs	25-34 yrs	35-44 yrs	45yrs and above	
Male	31 (35.2%)	26 (29.5%)	15 (17.1%)	16 (18.2%)	88 (100%)
Female	41 (30.6%)	46 (34.3%)	24 (17.9%)	23 (17.2%)	134 (100%)
Total	72	72	39	39	222

Table.1; Age distribution among different gender

3. 2. Association between skin tone and gender:

The majority of the study population fell within the medium (42.3%) and dark skin groups (41%) (Figure 1).

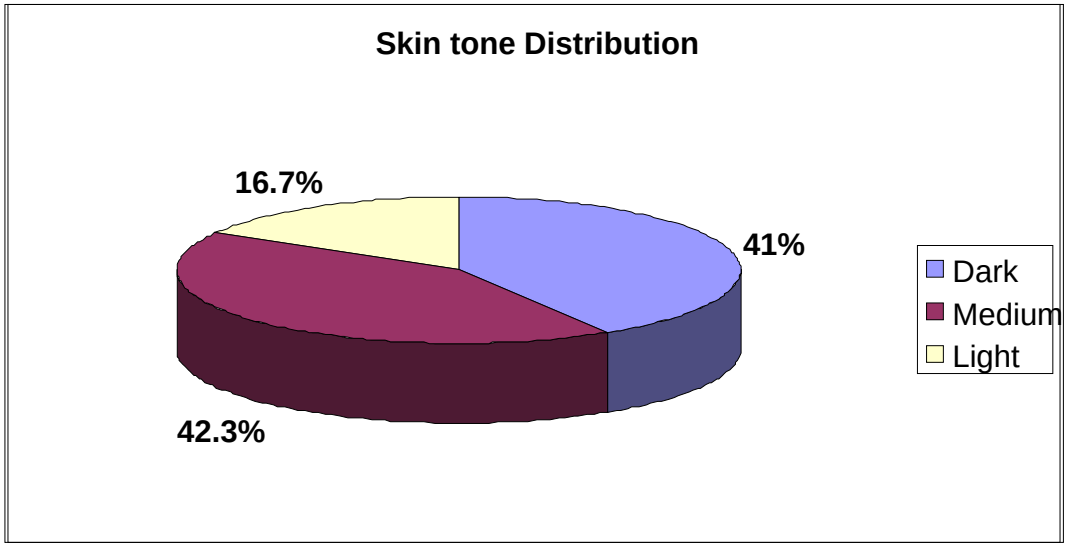


Figure (1)**; Skin tone distribution among the study population.**

Females tended to have lighter skin tone (78.4%) when compared to males (21.6%) (Table 2).

Skin tone	Male	Female	Total
Dark	45	46	91
	(49.5%)	(51.5%)	(100%)
Medium	35	59	94
	(37.2%)	(62.8%)	(100%)
Light	8	29	37
	(21.6%)	(78.4%)	(100%)
Total	88	134	222

Table (2); Distribution of skin tone groups among different gender

3. 3. Association between skin tone and age group:

The distribution of Dark skin tone in first and second age group was 35.2% and 31.9%; respectively.

Medium skin tone was observed in 31.9% of both the first and second age groups.

Light skin tone was recorded in 35.1% in the second age group (Table 3).

Age group	Skin tone			Total
	dark	medium	light	
15-24 years	32 (35.2%)	30 (31.9%)	10 (27.1%)	72
25-34 years	29 (31%)	30 (32%)	13 (35.1%)	72
35-44 years	16 (17.6%)	16 (17.6%)	7 (18.9%)	39
45years & above	14 (15.4%)	18 (19.1%)	7 (18.9%)	39
Total	91 (100%)	94 (100%)	37 (100%)	222

Table (3); Distribution of skin tone according to different age groups

3. 4. Tooth shade distribution:

The Vita 3D master tooth shade has 26 tooth shades in total, out of which only 19 were recorded in this study sample. The most common tooth shade recorded was 2M2 (16.7%), followed by 2M1 (15.8%), 2M1.5 (12.6%), and 1M2 (9%) (Table 4).

	SHADE	NO.	PERCENTAGE
	2M2	37	16.7%
	2M1	35	15.8%
	2M1.5	28	12.6
	1M2	20	9%
	2L1.5	13	5.9%
	2R1.5	12	5.4%
	3M2	12	5.4%
	1M1.5	11	5%
	2M3	11	5%
	3M1.5	11	5%
	2M2.5	10	4.5%
	1M1	9	4.1%
	2R2.5	3	1.4%
	3M1	3	1.4%
	2L2.5	2	0.9%
	3M3	2	0.9%
	3L1.5	1	0.5%
	3R1.5	1	0.5%
	3R2.5	1	0.5%
Total	19 shades	222	100%

Table (4); Distribution of tooth shades among study population

3. 5. Tooth shade distribution in different gender

Most of the study population fell within the Value 2 tooth shade. The results indicated that males had a higher percentage (18.2%) in Value 3, than females (11.2%), whilst females had a higher percentage (23.1%) in Value 1 than males (10.2%) (P = 0.03), (Figure 2).

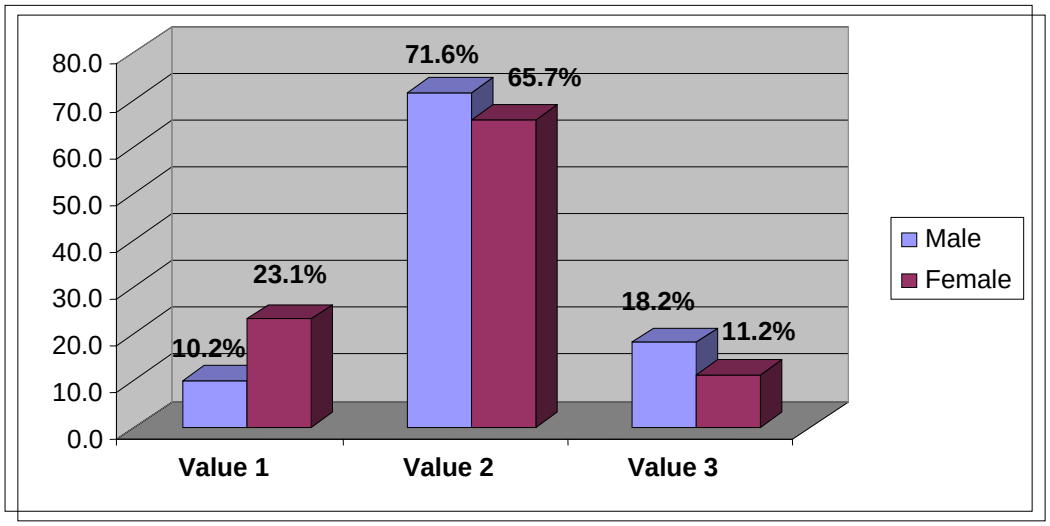


Figure (2); distribution of tooth shade values among gender groups

A high number of the study population fell within Chroma 1.5 and Chroma 2 tooth shade, (Figure 3).

Saturation of Chroma showed a high association with different genders (P = 0.04); males tended to have teeth that were more saturated.

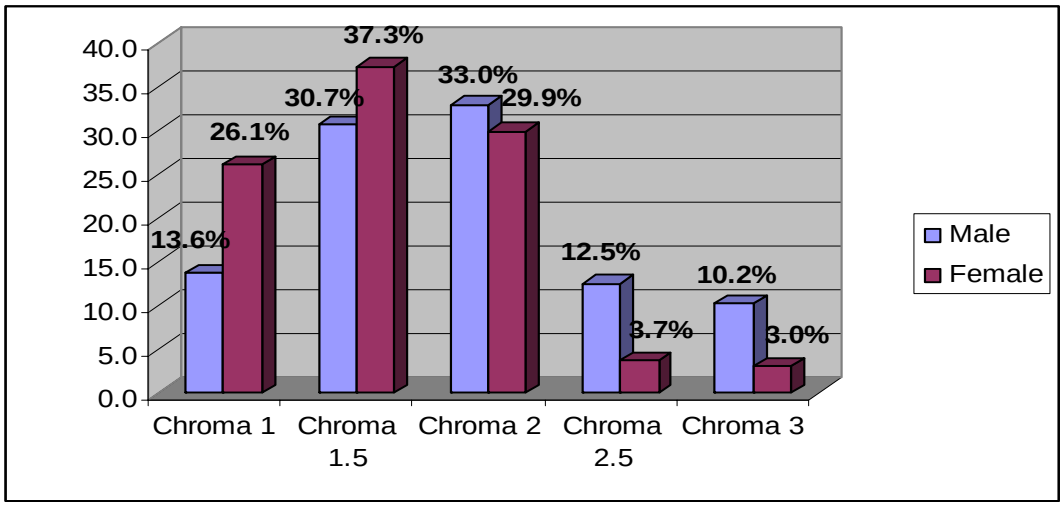


Figure (3); Distribution of Chroma according to gender

3. 6. Tooth shade value distribution in the different age groups:

There was significant association between age and tooth shade Value in the population studied. Young patients (15-24 yrs) showed a higher percentage (30%) in Value 1 and were completely absent in Value 3. The older age group (45 yrs and above) were absent in Value 1 and had a higher percentage (61.5%) in Value 3 (P = 0. 01), (Table 5).

Age group	**Value**			**Total**
	1	2	3	
15-24 years	22 (55%)	50 (33.1%)	0 (0%)	72
25-34 years	15 (37.5%)	55 (36.4%)	2 (6.4%)	72
35-44 years	3 (7.5%)	31 (20.5%)	5 (16.1%)	39
45years & above	0 (0%)	15 (10%)	24 (77.5%)	39
Total	40(100%)	151(100%)	31(100%)	222

Table (5); Distribution of tooth shade Value according to age groups

The same relation was found between the age and tooth shade Chroma; as the age of individuals increased, the saturation of their teeth increased (P = 0.01) (Table 6).

Age group	**Chroma**					**Total**
	1	1.5	2	2.5	3	
15-24 years	23 (48.9%)	23 (29.9%)	23 (34.4%)	2 (12.4%)	1 (7.6%)	72
25-34 years	16 (43.1%)	23 (29.9%)	28 (40.6%)	4 (25.0%)	1 (7.6%)	72
35-44 years	4 (8.5%)	15 (19.5)	9 (13.0%)	5 (31.3%)	6 (42.6%)	39
45years and above	4 (8.5%)	16 (20.7%)	9 (13.0%)	5 (31.1%)	5 (38.6%)	39
Total	47(100%)	77(100%)	69(100%)	16(100%)	13(100%)	222

Table (6); Distribution of tooth shade Chroma according to age groups

3. 7: Tooth shade value distribution in different Skin tone Groups:

According to the results obtained in (table 7), the majority of the study population fell within the Value 2 tooth shade. Value 2 tooth shade was recorded in (65.9%) of the dark and (69.1%) of medium skin tone; respectively.

Value 1 tooth shade was found in (57.5%) of the dark skin and in (7.5%) of the light skin group.

Darker people had lighter teeth than the light skin tone group (P = 0.04) (Table7).

Skin tone	Value			Total
	1	2	3	
Dark	23 (57.5%)	60 (39.7%)	8 (25.8%)	91
Medium	14 (35.0%)	65 (43.0%)	15 (48.8%)	94
Light	3 (7.5%)	26 (18.5%)	8 (25.8%)	37
Total	40(100%)	151(100%)	31(100%)	222

Table (7): Distribution of tooth shade Value in different skin tone groups

Most of the study population fell in the medium Hue (89.2%). No statistically significant relation was found between different skin tones and the Hue of tooth shade (Table 8).

Skin tone	Hue			Total
	Yellow	Medium	Red	
Dark	4 (25%)	83 (43.9%)	4 (23.5%)	91
Medium	10 (62.5%)	73 (38.6%)	11 (64.7%)	94
Light	2 (12.5%)	33 (17.5%)	2 (11.8%)	37
Total	16(100%)	189(100%)	17(100%)	222

Table (8); Association between Hue and skin tones

Chroma 1.5 recorded in 77 individuals and Chroma 2 in 69 individuals. No significant relationship was found between skin tone and tooth shade Chroma (Table 9).

Skin tone	**Chroma**					**Total**
	1	1.5	2	2.5	3	
Dark	19 (40.4%)	31 (40.3%)	27 (39.1%)	9 (56.3%)	5 (38.5%)	91
Medium	19 (40.4%)	36 (46.8%)	28 (40.5%)	6 (37.5%)	5 (38.5%)	94
Light	9 (19.2%)	10 (12.9%)	14 (20.4%)	1 (6.2%)	3 (23%)	37
Total	47(100%)	77(100%)	69(100%)	16(100%)	13(100%)	222

Table (9); Association between tooth shade Chroma and skin tones

CHAPTER THREE

Discussion, Conclusion & Recommendation

4.1Discussion

The most dominant tooth shade in population studied was the light colour shade and was limited to Value 1, Value 2, and Value 3. The dark tooth colours Value 4 and Value 5 were not registered in the sample.

This study aimed to determine the relationship between tooth colour shade and different variables such as skin tone, age and gender in a sample of the Sudanese population. These variables represent some of the factors that serve as guidance in selection of artificial tooth colour in edentulous patients.

The Vita 3D Master tooth shade guide was chosen because of its simplicity and cost effectiveness[24], even though the spectrophotometer is known to have better tooth shade determining properties. Although, Vita Lumin Classical shade guide has been used in previous studies to determine tooth colour, it has not been used in this study due to its inability to systemically distribute shade in the colour space relevant for human teeth.[66]

The skin tone was taken from the face, because of its close perimeter to the teeth, and it is the natural contrast to teeth colour.

Previous studies, such as those of Jahangiri *et al* [52] and Azad *et al* [53] who used make-up guides; for foundation base cream and lip stick, respectively, to determine the skin colour from the dorsum of the hand, both studies concluded that it was questionable if such guides represented the full spectrum of dark skin.

It has been suggested that in the edentulous patients the colour of the face could serve as a basic guide for tooth colour. [49] It has been highlighted that brilliance (value) of teeth, should correspond to darkness or lightness of the facial skin tone, while hue should harmonize with facial colour and colour saturation of teeth should correspond to saturation of facial colour. [49, 52]

Before starting data collection on the present study, pilot study was performed, in which 100 photographs from the face were taken and according to which skin tone was divided into dark, medium and light.

For tooth shade determination, the middle third of the tooth was used because of the colour gradation in natural teeth from the incisal to the cervical areas. The middle third of the teeth is said to be the best representative of its colour because the incisal site is most often translucent and is affected by its background while the cervical colour is modified by scattered light from the gingiva, and

the colour of underlying dentine due to the enamel being thinnest toward the cervical area of the tooth.[5, 45]

The hypothesis that age and gender can be used in selection of colour of artificial teeth is supported by this study where both age and gender were found to have statistically significant associations with tooth colour. It was noted that with increasing age, there was a tendency for the teeth to be of darker shade Value (P = 0.01), which is in accordance to other studies. [34, 45, 46, 47, 48, 50, 56, 57] In addition, teeth tended to became more saturated (P =0.01) with age.

In the present study men had teeth with darker Value (P = 0.03) and more saturation (P = 0.04) when compared to women. These results are supported by studies of Goodkind *et al*[33], Odioso *et al*[50], Azad *et al* [53], and Esan *et al* [54]. These studies established significant associations between gender and tooth shades, where men presented with darker tooth shades than women. However, other studies conducted by Hasegawa *et al* [34] and Zhu *et al* [59], concluded that men and women did not present any difference in colour of anterior teeth.

When considering tooth colour shade in relation to skin complexion; the results showed that in Value 1 and Value 2 tooth shades, there was a tendency for darker skinned individuals to have lighter teeth (P = 0.04).

This relation between tooth colour and skin complexion has been established by previous studies of Jahangiri *et al* [52] and Azad *et al*[53] found that the darker skin individuals tended to have teeth which were lighter in colour when compared to lighter skin groups who tended to have teeth which were darker in colour.

However, a few studies disagree with the possibility of a relationship between tooth colour and skin tone. Esan *et al* [54] as well as Dummett and his colleagues[55], concluded that there was no correlation between colour of the skin and teeth colour. Azad *et al* [53] argued that Esan *et al*[54] and Dummit and his colleagues[55] used the Vita Lumin Classical Shade Guide which could have led to inaccurate results.

Variations of the results concerning associations of gender, tooth colour and skin tone, could be explained by the variations in the populations studied as well as methods used to assess skin tone and colour of the teeth.

4.2: Conclusions

Within the limitations of this study, the results showed agreement with the selection criteria for artificial tooth colour for the completely edentulous patient, and the following conclusions can be drawn:

1. Most common tooth colour recorded in study was 2M2 followed by 2M1, and 2M1.5.
2. Males had darker teeth (Value 3) and more saturated in colour, when compared to females (Value 1) and.
3. Older individuals had teeth darker (Value 3) and more saturated than younger who had teeth lighter (Value 1) and less saturated in colour.
4. There was tendency that darker people had lighter teeth.

4.3: Recommendations

1. Artificial teeth for complete denture could be of Value 1, Value 2, and Value 3; with saturation of 1.5 and 2.
2. More advanced researches to invent tooth shade guide for artificial teeth using skin tone chart to aid in selection of denture's teeth well received by prosthodontists and edentulous patients regarding aesthetic and convenience.
3. In older age group edentulous patients we can select teeth with Value 2 and Value 3, and for younger edentulous patients we can select teeth with Value 1 colour shade.

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Appendix 1

Data collection form

1 **Gender** ☐
1. Male 2. Female

2 **Age group**

1. (15 – 24)
2. (25- 34) ☐
3. (35 – 44)
4. (45 and above)

3 **Skin tone**
1. dark (A)
2. medium (B) ☐
3. light (C)

4 **Tooth shade**
1.Value ☐

2.Hue
1. yellow (L)
2. medium (M) ☐
3. red (R)

3.Chroma ☐

Appendix.2

إستمارة موافقة

أنا المريض \ المريضة:

أوافق علي المشاركة في البحث العلمي عن ألوان الأسنان عند السودانيين .

توقيع المريض\ المريضة:----------

التاريخ:----------