CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Knowledge about factors that control and affect human vision is vital for dental practitioners in order to avoid expensive and embarrassing shade matching errors in the rehabilitation of maxillofacial defect patients. It is also important to know the physical properties of the skin and the factors that affect its colour variation (Quevedo et. al, 1975).

Visible light that is reflected identifies the colour of objects. Eyes sense the hue, intensity, and saturation of light, so lighting of proper intensity and colour balance is necessary for consistent and correct shade matching. Although sunlight is the most common standard for good lighting, in everyday practice, it varies with weather conditions, time of day, and season of the year.

In addition to external factors such as lighting, conditions internal to the observer also play a role in accurate colour perception. Colour vision confusion (CVC), often called "colour blindness," is a serious handicap for dental professionals (Carsten, 2003). The popular assumption is that very few people are afflicted; in fact, everyone suffers from some level of colour vision confusion. This distortion of visual information can be permanent or transitory (Deeb, 2005).

The sensitivity of the human eye is also highly observer dependent (Bangston and Goodkind, 1982; Tung et al., 2002), and therefore may respond differently to perceived colours. In contrast, colour measuring instruments like the spectrophotometer and colorimeter use a constant light source, and transfer the measurements into tri-stimulus values on the colour systems, and thus exclude observer subjectivity.

This study evaluated the use of the spectrophotometer, digital camera and flatbed scanner in reproducing skin colour. The aim was to determine if the devices could be used to facilitate the process of matching the colour of facial prosthesis to the adjacent skin colour, and to classify the skin shade of the subjects in the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Colour skin analysis has an important role in the medical, dental and biologic fields. The prosthetic technician faces a challenge when fabricating a maxillofacial prosthesis as it not only has to be functional, but also aesthetic. Besides fulfilling the physical requirements for good mechanical and physical properties, the prosthesis should also be of the appropriate shade, contour and texture relative to the surrounding structures during the time it is in use (Haug et.al, 1999; Polyzois, 1999). These factors affecting aesthetics are conventionally assessed by eye.

In the rehabilitation of maxillofacial defects, a model of the facial prosthesis is carved by hand in wax on the patient's facial moulage. The moulage is made from an irreversible hydrocolloid impression material. Wax is sculpted to restore the lost anatomical structure using the remaining anatomic landmarks as reference. This may be augmented by a preoperative photograph supplied by the patient. Contours of the skin's texture are carved into the wax in the presence of the patient, and details gradually refined using warmed carving instruments. The wax is then flasked and silicone elastomer is packed to match the patient's skin. The final shade of the prosthesis is normally obtained by adding powder pigments to the base colours of the processed silicone. Throughout this time, the patient has to be present at the chair-side (Abdulhadi, 2008).

2.2 MATERIALS USED IN THE REHABILITATION OF MAXILLOFACIAL DEFECT PATIENTS

The main requirements of ideal maxillofacial prosthetic materials are: physical and mechanical properties comparable to the human tissue that they are replacing, the ability to sustain these properties during service, compatibility with the human tissues and the quality of being easy to process (Valauri, 1982). Although the ideal material for restoration of maxillofacial defects has not been found, three main types of materials have been used.

The three main types of materials that are used in maxillofacial prosthetics are:

2.2.1 Polymethyl methacrylate (PMMA, Acrylic resin)

PMMA resin was recommended as a possible temporary material for use in fabricating a maxillofacial prosthesis (Beumer et. al, 1996). The ease of marginal readaptation using chairside denture liner made this a useful material during the period of posthealing scar contracture and wound organization. However, PMMA resin does not result in a prosthesis that feels and looks life-like.

2.2.2 Silicone rubbers

Silicone rubber materials have been used for facial rehabilitation for more than four decades (Kanter, 1970). Silicone elastomers are the materials of choice for maxillofacial prosthesis because of the material's clinical inertness and its life-like appearance (Andres et al., 1992). However, its physical properties are not ideal (Yu et al., 1980; Aziz et al., 2003) and degradation in appearance occurs because of the changes in colour and physical properties (Haug et al., 1999).

2.2.3 Polyurethanes

Polyurethanes have great possible use as maxillofacial materials. They have good environmental stability, high tear resistance and elongation and accept intrinsic colouring (Goldberg et al., 1978). However, there are problems in their properties which are affected by aging. This leads to colour and characteristics changes (Gonzalez, 1978). The maximum life of this material is between 6-12 months (Goldberg et al., 1978).

2.3 SHADE MATCHING OF THE PROSTHESIS TO THE SURROUNDING FACIAL STRUCTURES

Colour matching of facial prostheses to human skin is a challenge to the clinician. The ultimate aim of colour matching in maxillofacial prosthesis is that the shade of the prosthesis should be as close as possible to the shade of the facial structure. Colouring of the prosthesis may be achieved by the following methods:

2.3.1. Extrinsic contouring and colouring techniques of the facial prosthesis

Extrinsic colouring is done on the base colours of the processed prosthesis to achieve a desired skin tone. A method for colouring extra oral maxillofacial prostheses prepared from silicone elastomers was described by Ouellette et. al. (1968). In this method, the silicone elastomer prosthesis was sprayed using an artist's airbrush with pigment dispersions diluted with xylene to a spraying consistency. After tinting, a clear overlay of silicone elastomer was sprayed over the tinted prosthesis to give the illusion of depth and a realistic surface. The results were however, not satisfactory because it was affected by external conditions.

Another method of surface colouration was tattooing oil colours into the surface of the prostheses (Schaff, 1970). This technique afforded great versatility in tinting while resulting in a permanent colouring that did not obliterate the surface texture. However, it was still not useful because it also depended on external pigments that were affected by external conditions like light, heat, and water.

2.3.2. Intrinsic colouring techniques of the facial prosthesis

Intrinsic colouring was incorporated into the base colours to match the skin tones. The most commonly used intrinsic colouring agents are dry earth pigments, such as rayon fibre flocking, artist's oil paints and kaolin, and liquid facial cosmetic. However, the physical properties of maxillofacial elastomers were changed by the incorporation of these colouring agents. Dry earth pigments, kaolin, and rayon flocking acted as solid filler without bonding to the silicone, and artists' oils and liquid cosmetics acted as a liquid phase without bonding to the silicone matrix (Over et al., 1998; Haug et al., 1999).

2.3.3. Factors affecting the colour stability of silicone elastomers used in maxillofacial prosthetics

One factor that limits the service of facial prostheses is the result of degradation of the elastomer and colour instability. Deterioration may be caused by many factors, which include environmental exposure, changes in humidity, degradation of certain ultraviolet light susceptible pigments and colour changes within the elastomers (Lemon et al., 1995; Beatty et al., 1995; Tran et al., 2004). Early colour changes in prosthesis may be the result of degradation of certain ultraviolet light-susceptible pigments, whereas longer term colour shifts may be caused by colour changes within the elastomer (Beatty et al., 1995).

2.4 COLOUR AND COLOUR MODES

Colour is a subjective sensation that is derived from the stimulation of nerve centres, and the perception of it has three fundamental elements:

1. The light.

2. The eye.

3. The reflectance properties of the object (Yukosawa and Era, 2006).

2.4.1. Colour Modes

A colour mode determines the colour model used to display and print images. Spectrophotometers, colorimeters, cameras, scanners, television monitors and printers base their colour modes on established models for describing and reproducing colour. Common modes include RGB (red, green, blue); CMYK (cyan, magenta, yellow, black); and CIE L*a*b* (Commission Internationale de l`Eclairage) (Cowlishaw, 1985).

Unlike the RGB and CMYK colour models, the LAB colour is designed to approximate human vision. The RGB or CMYK spaces model the output of physical devices rather than human visual perception (Margulis, 2006). However, transformations among the colour modes may be done with the help of appropriate editing applications or colour management software which convert colour data to different colour standards (RGB, CMYK, L*a*b* etc.) (Obermeier, 2007).

2.4.1.1 RGB Mode

The RGB mode uses the RGB model, assigning an intensity value to each pixel ranging from 0 (black) to 255 (white), for each of the RGB components in a colour image. For example, a bright red colour might have an R value of 246, a G value of 20, and a B value of 50. When the values of all three components are equal, the result is a shade of neutral grey. When the value of all components is 255, the result is pure white; and when the value is 0, the result is pure black.

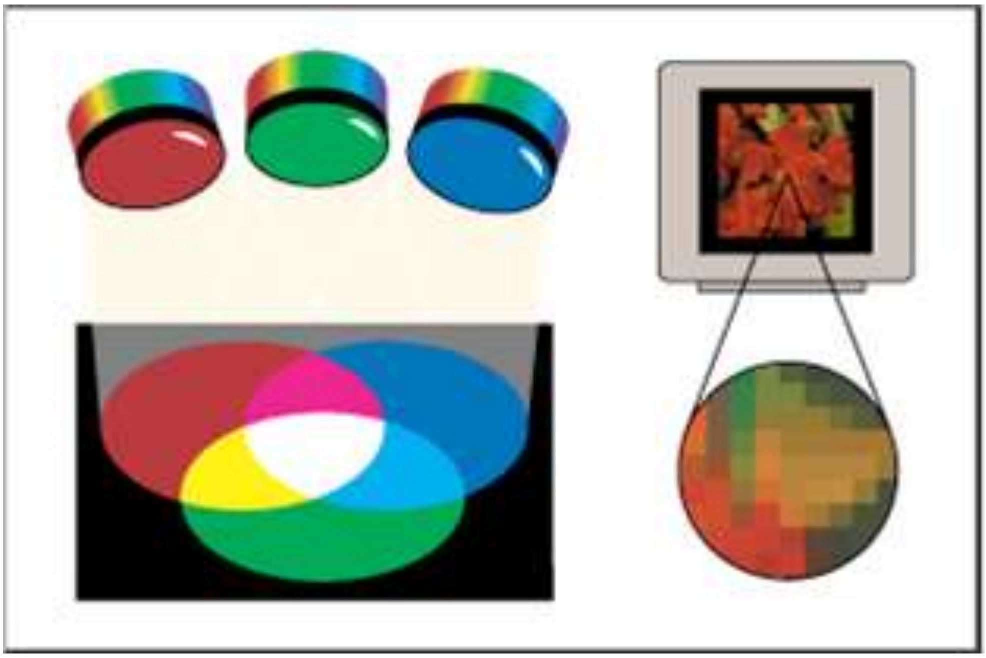


Figure 2.1 The RGB Mode.

2.4.1.2 CMYK Mode

In the CMYK mode, each pixel is assigned a percentage value for each of the process inks. The lightest colours are assigned small percentages of process ink colours, while the darker colours higher percentages. For example, a bright red might contain 2% cyan, 93% magenta, 90% yellow, and 0% black. In CMYK images, pure white is generated when all four components have values of 0%.

Figure 2.2 The CMYK Mode.

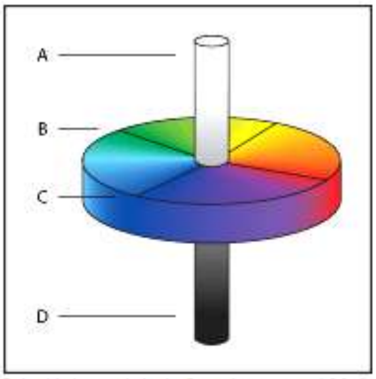
2.4.1.3 Lab Mode

The Lab system defines any colour into tri-stimulus values (L), (a), and (b). (L) stands for lightness (the black-white factor), (a) for the red-green factor and (b) for the yellow blue factor. The lightness component (L) can range from 0 to 100. The (a) component (green-red axis) and the (b) component (blue-yellow axis) can range from+128 to -128.

There are two major Lab systems:

1. CIE L*a*b* (French system): 1931, 1976, 1986, 1994, and 2000. (1976 commonly used in related applications).

2. Hunter Lab (US system): 1948, 1966. (1966 commonly used in related applications).



L*a*b* model: **A.** Luminance =100 (white) **B.** Green to red component **C.** Blue to yellow component **D.** Luminance = 0 (black)

Figure 2.3 The Lab Mode.

2.5 EVALUATION OF COLOUR

The subjectivity of the visual perception of the human eye in assessing colours has led to the use of colour measuring devices that evaluate colours based on colour modes. The measuring instrument collects and quantifies the amount of light reflected from an illuminated object. It does not however tell us anything about how that information is translated into human colour perception (Hunter and Harold, 1987).

Colour is a 3 dimensional quantity uniquely specified by the three properties of hue, lightness and saturation. The human eye can distinguish between more than 1 million chromaticity values. Each impression of colour for a human being arises from the superposition of the illumination, the reflectivity/ transmittance of the object and the how the human eye detects colours with red, green and blue sensitivity. Therefore, a colour-measuring instrument has to recognize the spectral characteristics of the illumination and of the eye. Basically, measuring colour involves finding the amounts of red, green and blue light which need to be mixed together to give the same colour as the object being measured. This can be done using colour measuring instruments. Two types of instruments are commonly used to measure colour, the colorimeter and the spectrophotometer. Both colorimeters and spectrophotometers can give the same tristimulus values, though the spectral method is usually more accurate.

Although colour measurement instruments may be used to facilitate colour matching, and human vision may be less sensitive to perceived colour differences, visual perception is still valuable in a clinical setting involving multi-ethnic patient population (Leow et al., 2006).

2.5.1 Colorimeter

The colorimeter is a device that determines the quality of a substance from the absorbed light of the substance colour. It uses three or more filters to produce a response similar to that of the eye. It normally uses the CIE L*a*b* and Hunter Lab values to measure the colours. Using the colorimeter to develop an intrinsic silicone shade guide for facial prostheses, it was shown that the CIE L*a*b* colour measurements of the white facial skin may be correlated to the values of the silicone shade samples (Over et al., 1998).

2.5.2 Spectrophotometer

The spectrophotometer measures the amount of light reflected or transmitted by a sample at discrete wavelengths. The recipient light is considered as a colour of that substance, and generally measured using the CIE L*a*b* or Hunter Lab values.

When the spectrophotometer was used to study the reproduction of skin shade of prosthetic materials for the purpose of introducing them into the production cycle of the silicone prostheses, it was found that because of the intrinsic factors of the materials, automatic colour detection for prosthesis production was a complex procedure (Gozalo-Diaz et al., 2007). Therefore, the system was deemed inappropriate to be used, and further development was essential before it could be used to fulfil the needs of prostheses manufacturers (Bicchierini et al., 2005). This is because computerized colour formulations provided by this system offers objectivity to an otherwise subjective task in the colour matching procedure for facial prostheses (Cowerd et al., 2008; Johnston, 2009).

2.5.3 Digital cameras and similar recording devices

These are devices that take video or still photographs, or both, via an electronic image sensor. The system uses the RGB mode, as the RGB is the most commonly used colour space for storing and representing digital images. The digital camera was assessed to be more useful in the clinical setting for shade matching procedures, compared to the spectrophotometer (Jarad et al., 2005).

2.5.4 Scanner

The scanner is a device that captures images from photographic prints, posters, magazine pages, and similar sources for computer editing and display. Scanners are available as hand-held, feed-in and flatbed types. They use the RGB system of measuring colour. There is no mention of the use of scanners for shade matching procedures in the dental literature.

2.6 VARIATIONS OF SKIN COLOUR IN DIFFERENT ETHNIC GROUPS

Skin characteristics vary according to ethnic origin, and a range of factors such as geographical or cultural environment may influence skin properties (Richards et al., 2003; Caisey et al., 2006). According to Johann Friedrich Blumenbach (1752 - 1840), one of the founders of scientific racism theories, there are five colour typology for the human race. He divided the human race according to the following skin tone terminology:

- White People: These belonged to the Caucasian or white race
- Black People: These belonged to the Ethiopian or black race
- Yellow People: These people belonged to the Mongolian or yellow race
- Cinnamon Brown or Flame Coloured People: They belonged to the Malay or brown race (Bernasconi and Lott., 2000).

The colour of the human skin depends on three main factors: melanin pigmentation, the quantity of blood, and the oxygenation of blood. The skin components are responsible for the natural appearance of the skin tone. When the light reflects from the skin surface, the reflected light tone is dependent on the basic colours of the skin which are the melanin, haemoglobin, and carotene pigments. These pigments when measured are represented by the L*a*b* values. The melanin pigment represents the brown colour, haemoglobin represents the red colour and the carotene pigment represents the yellow colour. The composition of these pigments will give approximately the true colour of the skin (Quevedo et. al, 1975).

Cosmetic companies produce skin colour and makeup shades for women of different ethnic groups. Three types of complexion – dark, medium, or light – are generally distinguished. Variations of these shades were classified to suit different ethnic groups (Caisey et al., 2006; Wei et al., 2007). Consequently, it is necessary to produce a shade guide for silicones used in the rehabilitation of maxillofacial defect patients from different ethnic groups (Aina et al., 1978; Cowerd et al., 2008; Guttal et al., 2008). However, no standard set of colour classification of the human skin was found in the literature.

2.6.1 Using the Lab values in the analysis of skin tones of different ethnic groups

The Lab values separate lightness values of a colour from its hue and saturation. Ignoring the variations in different parts of the body, the values of a* and b* of the human skin generally remain constant. In this case the dark side of a face may have different L* values but near identical a* and b* values to the lighter side.

The concentration of melanin governs the "tan" of a skin colour by changes to the a* shade value and the L* value, and the types of melanin (red or yellow) determines the skin shade. Although there may not be a standard for skin colour of different ethnic groups, under normal conditions, most Caucasian skin tones lie within this range of values: (L*:62-72, a*:2-10, and b*:11–22) (http://www.swpp.co.uk/professional_imagemaker/accurate_reproduction_skin_tones.html).

2.6.2 Silicone shade guide for maxillofacial prostheses

Studies had been carried out to find acceptable shade guides for intrinsic and extrinsic colouring of silicone materials (Schaff, 1970; Haug et al., 1999). However, these shade guides may be limited due to the wide spectrum of skin tone that is influenced by many factors, including ethnicity, age, degree of exposure to sunlight and location of the structure to be replaced. The shade guide may be useless if the real skin tone differs significantly from the shades present on the shade guide (Barnhart, 1960).

2.7 STATEMENT OF THE PROBLEM

It is difficult to obtain the exact reproduction of skin colour when rehabilitating maxillofacial defect patients due to the limited base colours in the maxillofacial prosthetic kits. Generally, the patient has to be present when the process of tinting the prosthesis is carried out in the clinic to get the proper shade for the prosthesis. The problem of getting the proper shade by directly comparing to the patient's skin may be facilitated if a reliable reproduction of the colour of the skin can be made easily and conveniently. This would enable the process of getting the shade of the prosthesis as close to the patient's skin to be done in the absence of the patient. The patient need only be present when the facial shade is assessed just before delivery of the prosthesis.

2.7.1 Aims and Objectives

The aim of this study was to determine and compare the ability of 3 devices (the spectrophotometer, digital camera and flatbed scanner) in reproducing colour that is closest to the skin shade.

The specific objectives of the study were:

a. To find an inexpensive and simple technique of reproducing the skin shade to facilitate the shade matching procedure in the rehabilitation of maxillofacial defect patients.
b. To compare visually the reproduction of skin colour by the colour measuring device (spectrophotometer) and image producing devices (digital camera and scanner).
c. To classify the skin colour of the Malaysian population.

2.8 HYPOTHESIS

There are no differences in the reproduction of skin colour in a sample of the Malaysian population by the spectrophotometer, digital camera and flatbed scanner when compared visually.