COLOURATION TECHNIQUES FOR INTRINSIC STAINING OF MAXILLOFACIAL SILICONE PROSTHESIS: A NARRATIVE REVIEW

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Abstract

Several congenital and acquired defects require alloplastic restorations. These kinds of prosthesis may be retained and supported by osseointegrated implants, the remaining skin with or without adhesive and body cavities. Extraoral maxillofacial prosthesis are primarily fabricated using silicone. Obtaining a reliable and reproducible coloration technique is important in the process of fabrication. The present study is to study the development of and advancements in intrinsic staining techniques of silicone prosthesis. The authors reviewed literature and summarized the different colouration techniques for intrinsic staining previously and presently used for maxillofacial silicone prosthesis from published research available in the Dental Library of the University of Malaya and different databases: Science Direct, PubMed and Web of Science. There are diverse methods to intrinsically match the colour of facial skin in maxillofacial prosthetics. Newer methods used in coloration have produced more accurate colour matching and have proven to be less time-consuming.

Keywords: Colour, Facial Skin, Maxillofacial Prosthesis, Silicone, Staining

Introduction

Facial deformities are often distressing and can negatively affect patients' physical and mental health, indirectly leading to serious social and psychiatric problems (1). In general, plastic surgery is usually preferred over prosthetic reconstruction (2). However, some acquired and congenital defects still require alloplastic restorations. These alloplastic restorations can also be referred to as extraoral prosthesis, which is used to restore the lost structures, shape, and appearance. They are often held or supported by osseointegrated implants (3), body cavities, and remaining skin with or without adhesive (4).

Extraoral prosthesis significantly impacts the patient's quality of life and self-esteem. Currently, postoperative defects can be acceptably restored. These restorations often have a lifelike appearance and improve the patient's aesthetic appearance. In addition, patients can participate more confidently in social life and blend into the community without their facial defects being noticeable. To achieve a better prognosis, it is necessary to offer the patient a multidisciplinary treatment that involves various health professionals such as speech therapists, physical therapists, psychologists, nurses, physicians and orthodontists for the prosthetic rehabilitation process.

Extraoral maxillofacial prosthesis are predominantly made of silicone. Silicones, also known as polydimethylsiloxane, are the most effective material to date. This material has proven to be more popular than other materials due to its good physical properties, such as excellent tensile and tear strength (over a range of temperatures), ease of handling, chemical inertness, low toxicity, good thermal properties, and oxidative stability. When cured sufficiently, silicone elastomers resist absorption of organic matter that leads to bacterial growth. Therefore, cleaning this material is important and can be accomplished with normal soap solutions. In addition, they can be dyed intrinsically and/or extrinsically to achieve a more natural appearance (5).

Mimicking natural skin colour is routinely done by trial-and-error, as there are no exact colour recommendations. Matching colour to human skin in the fabrication of prosthesis is a major challenge. Since Malaysians are a multiracial community, skin colour is considered to be a mixture of light and dark skin colours. The actual skin colour is influenced by many substances, but melanin is considered the most important colour-producing element. A person has a dark complexion when the melanin content is high. People with light skin colour have lower melanin content. Their skin colour is determined more by

the hemoglobin circulating in the veins and the bluish-white connective tissue under the dermis. A reliable and reproducible customized colour key for self-colouring silicone in the Malaysian population would be a worthwhile endeavor to achieve an ideal skin colour match. Skin is composed of multiple layers, and this structure places limitations on the reproduction of colour (6).

The purpose of this study is to present the development, rationale, and advances in intrinsic colouring techniques. In the following sections, the authors discuss the importance of intrinsic staining in the fabrication of silicone prosthesis, the concepts, and techniques. Some of the methods described in the literature are still viable, while others are not.

Materials and Methods

The authors summarised several different staining techniques for intrinsic staining that have been used for maxillofacial silicone prosthesis. They based this on all published research on this topic available in the Dental Library, University of Malaya and in databases such as Science Direct, PubMed and Web of Science.

Results and Discussion

1: How important is intrinsic staining when fabricating silicone facial prosthesis?

Knowledge of factors that control human vision is crucial to evade expensive and embarrassing shade matching errors in the rehabilitation of maxillofacial defects in patients. Adding on, it is essential to distinguish the physical properties of the skin and the multiple key factors that affect its variations (7). The colour of what we see is identified as the visible light is reflected. The three components of light are hue, intensity, and saturation. Correct and consistent shade matching requires good lighting of proper intensity. Sunlight may have some benefits to mankind, but it varies with different rays or intensity, during the day.

Apart from the prosthesis having good physical and mechanical properties, it should also be of the ideal and acceptable shade, contour, and texture relative to the surrounding structures for better aesthetic outcomes (8). When rehabilitating facial defects, the wax-up is carved by hand in wax on the patient's facial mould. The wax is moulded to replicate the lost anatomical structure using the remaining landmarks as references. This may be done by using preoperative photographs provided by the patient as a guide. The patient's skin is matched using contoured wax which is flasked and later after dewaxing, the silicone elastomer is packed for processing. The final intrinsic shades are attained by adding from the base colours and later enhancement with extrinsic stains on processed silicone is usually performed. In the end, this process will result in a finished facial prosthesis that hopefully is functional and aesthetically pleasing (9).

Intrinsic pigments are those that are added and mixed into the silicone before the curing process. Translucency and the depth of the shade can be better obtained with intrinsic staining. Intrinsic colour is also less vulnerable to environmental changes and handling. Once the material is cured or processed, the colour cannot be rubbed off as it is the basic shade of the prosthesis.

Extrinsic colouration may be more predictable but is more susceptible to deterioration. This method of colouration easily degrades when subjected to repeated direct exposure to sunlight and the environment, cleaning, and handling. Due to this, patients may need to visit the maxillofacial prosthodontist for frequent colour touch-ups of the prosthesis. The basic shade has to be achieved by the intrinsic colour, later the extrinsic staining can be done over it to further enhance the look by detailing and more paintings. Flocking materials should not be added in abundance when obtaining the intrinsic colour as it will significantly influence the mechanical properties negatively.

2: Concept of intrinsic staining

The base shade selected should be slightly lighter than the lightest skin tone of the patient because the prosthesis will darken further when extrinsically coloured. The desired skin shade is acquired by adding the primary colours drop by drop into the mixed silicone before curing. Once the intended shade is mixed, the curing process is completed. The resultant silicone is tested against patients' skin colour. More adjustments and details of the silicone prosthesis can be added with extrinsic colours.

Knowledge of primary, secondary and complementary colours is helpful in the selection of chroma (Table 1) (Figure 1). Chroma refers to the degree of vividness of a colour. It can also be termed saturation or colour intensity.

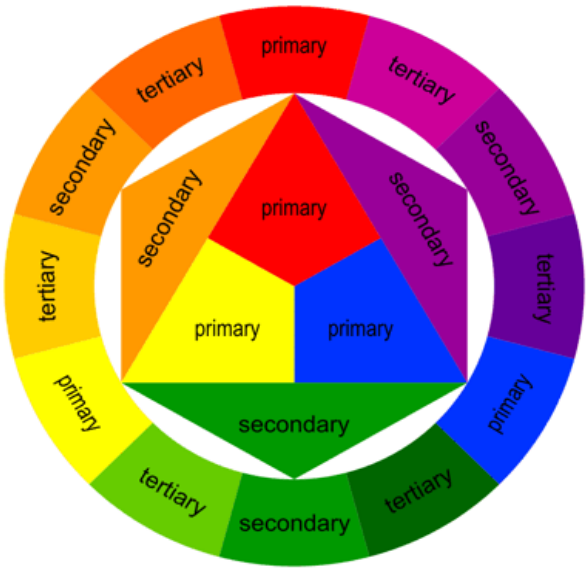

Figure 1: Primary, secondary, tertiary, and complementary colours

*Complementary colours lay exactly opposite each other on the colour wheel (10).

Table 1: Primary colours, secondary colours, and complementary colours

Primary Colour	Secondary Colour	Complementary Colour
Red	Red + Yellow = Orange	Red - Green
Yellow	Yellow + Blue = Green	Yellow - Violet
Blue	Blue + Red = Violet	Blue - Orange

Kaolin powder (white) is used to create opacity within the silicone. Dry colours or basic skin pigments are used for intrinsic staining. Flocking fibers and veins can also be used to enhance the appearance of the prosthesis. Curing the silicone prosthesis is done either on a metal mould or a stone mould. There are reported colour changes in the prosthesis depending on the colour of the moulding stone used. Among the investing materials studied, die stone produced the maximum colour change in the silicone with dental stone (green) showing the least change and dental stone (white) showing intermediate results (10).

The degree of colour change may also be affected by the moulding-stone colour and increase in vulcanization temperature. The L*, a*, and b* values for the maxillofacial silicone elastomers are influenced by the direction of the increase or decrease according to the selected colour (11).

3: Colour matching techniques in facial prosthetics

Multiple colouration techniques and methods have been used to obtain precise matching when fabricating facial prosthesis (12). Ouellette (1969) (13) developed a spraying technique that was a feasible method for realistically tinting silicone prostheses. The most common is the chairside visual trial and error method (14). Later other methods such as tattooing, using a milling machine (15) and commercial cosmetics evolved. Comparing the chairside visual trial-and-error, the photometric techniques or instrumental colorimetric were able to provide a more reliable, quantitative, and consistent outcome of an object's colour (16). Some clinicians use intrinsic stains, while other uses extrinsic stains to obtain the final resultant appearance of the prosthesis. The various colouration techniques being employed in the past is a worth insight (Table 2).

Table 2: Studies on colouration techniques

Study	Staining technique	Purpose	Colouring technique	Outcome/ Advantages (Adv) or Disadvantages (Disadv)
Ouellette (1969) (13)	Extraoral staining	To develop a spraying technique for colouring facial prosthesis	External spraying was done after the basic shade has been casted	Adv: This technique provides a feasible method for realistically (colour distribution) tinting silicone prosthesis
Firtell and Bartlett (1969) (17)	Extraoral staining	To describe a method for tinting external facial prosthesis	Preparation of stock colour and blending of base shade	Adv: Reproducible surface tinting of the external maxillofacial prosthesis
Schaaf (1970) (14)	Extraoral staining	Developing a tattooing method for colour-characterizing silicone rubber facial prosthesis	Painting a colouring material on the prosthesis surface, then penetrating the paint with a needle to a depth of 1–2 mm, thus carrying some of the pigments below the surface	Tattooing method for colour-characterizing facial prosthesis. Adv: The colour lasts long enough as they have penetrated to the depth of the prosthesis surface
Chalian et al. (1974) (15)	Intraoral staining	To develop a milling machine primarily to simulate skin colour and texture in the final prosthesis	When the milling machine is switched on, intrinsic colours are incorporated into the silicone material by adding small chunks of silicone material that have just a dab of the colour or colours that are needed to match the patient's skin	A portable milling machine designed for intrinsic colouring of heat-vulcanizing silicone materials for the extraoral prosthesis. Adv: Only a small quantity of colour is needed to reproduce the skin shade. Disadv: A milling machine that is heavy needs to be carried to places to use this technique
Fine et al. (1978) (18)	Intrinsic staining	To overcome the deterioration of the initial colour stability after fabrication of the silicone prosthesis	The technique involved the usage of different colours, named "Different- coloured Rayon Flock Fibers", & the eradication of the silicone fluid used previously as a thinner	Shade simulation is obtained on a "trial and error" visual basis or by the utilization of instruments and computed methods. Disadv: Very time consuming as multiple trials are needed to obtain the accurate colour

Table 2: Studies on colouration techniques (continued)

Study	Staining technique	Purpose	Colouring technique	Outcome/ Advantages (Adv) or Disadvantages (Disadv)
Hanson et al. (1983) (19)	Intrinsic staining	To study the role of commercial cosmetics in colouring maxillofacial prosthesis	Two cosmetic manufacturers were consulted: Mary Kay Cosmetics and Elizabeth Arden. The former manufacturer supplied liquid samples of its cosmetics, which were incorporated directly into the clear, uncured Dow Corning MDX4-4210 silicone polymers	The use of combinations of premixed cosmetic earth pigments in facial prosthesis colouring techniques provides an efficient and predictable method of fabricating skin-coloured prostheses. Disadv: Premix combinations may not be able to reproduce the skin colour accurately
Ma et al. (1988) (20)	Intrinsic staining	To have a reliable method for colour verification of facial prosthesis before final processing	Used for colour verification of facial prosthesis before the final processing. Fabrication of a rectangular wedge-shaped medical-grade silicone specimen for matching colour for the maxillofacial prosthesis	A colour shade tab could be made
Over et al. (1998) (21)	Intrinsic staining	To see if a correlation in colour measurements could be achieved between the silicone shade samples and duplicated silicone samples made using a shade-guide colour formula	A Minolta colourimeter was used to make facial skin measurements on 15 white adults. The readings were compared with the previous L*a*b* readings from the corresponding patient's skin measurements, and the relative colour difference was then calculated	There was a good correlation between the patient's colourimeter measurements and the silicone samples, with the b* colour dimension the most reproducible, followed by the L* and the a*
Gozalo-Diaz et al. (2007) (22)	Intrinsic staining	The purpose of this study was to determine the colour of vital craniofacial structures and evaluate the validity and test-retest reliability of a non-contacting 45°/0° optical configuration	A spectroradiometer and an external light source were configured in a non-contacting 45°/0° (45° illumination and 0° observer) optical configuration to measure the colour of patients' vital craniofacial structures (central and lateral incisor and canine, attached gingiva, lips, and facial skin)	Given its acceptable validity and reliability, the use of a non-contacting 45°/0° optical configuration is recommended as a viable alternative to obtain CIE L*a*b values for shade replication in craniofacial prosthetic rehabilitation. Disadv: There may be an error when the degree of optical evaluation is done from operator to operator
Guttal et al. (2008) (23)	Intrinsic staining	To develop a shade guide for Indian skin colour	Four-step wedges of silicone 1, 2, 4, and 6 mm were made and powder pigments were added, measured by a digital analyser, tested in the malar region	Silicone shade guide of three basic skin tones: light, medium, and dark complexion
Hu X et al. (2010) (24)	Intrinsic staining	To compare the accuracy of contact and non-contact measuring systems	Twenty-four thick MFE specimens approximately 23 mm in diameter and differing in translucency were made with -2000, a platinum silicone elastomer (factor II) mixed with five pigments, i.e., tan, black, red, yellow, and titanium dioxide powder. Five instruments were utilized, and the colour of each elastomer was measured three times by each instrument studied	Disadv: the non-contacting measuring system performs differently with inaccuracy but is comparable in precision when compared with contact measuring systems

Table 2: Studies on colouration techniques (continued)

Study	Staining technique	Purpose	Colouring technique	Outcome/ Advantages (Adv) or Disadvantages (Disadv)
Wee et al. (2013) (25)	Intrinsic staining	To develop a skin shade guide for the human skin of different racial groups	One hundred and nineteen participants were screened and asked to remove any facial makeup, seated with lower jaw and forehead resting lightly on the head frame, and the spectrophotometric scan was done	Five distinct skin shade tabs' clustering analysis
Nemli et al. (2018) (26)	Intrinsic staining	To evaluate the accuracy in colour and translucency matching of the computerized colour matching system across different skin colours	Using a spectrofluorometer (e-skin, Spectromatch Ltd., Bath, UK), 28 different specimens were measured and the colour code displayed on the screen was noted down. Later the code was used to replicate with silicone. This replicated skin colour on silicone is compared with the original skin colour using a spectrophotometer and a digital camera. Delta-E, the colour difference unit, was employed for the determination of the degree of colour match. (Smaller Delta-E means a closer match between two colours)	Adv: The computerized colour measuring and matching system specific to human skin colour resulted in low colour differences (CIELAB Delta-E) between target and replicate colour silicone specimens

4: Intrinsic staining over extrinsic staining techniques

In intrinsic staining, the pigments are directly added to the silicone before curing, and this produces better colour and texture outcomes that may last longer. While in extrinsic staining, the pigments in the form of dyes or paints are applied directly on the surface of the completed prosthesis (27). The difference between Intrinsic Staining and Extrinsic Staining is discussed in Table 3.

Table 3: Differences between intrinsic staining and extrinsic staining

Intrinsic Staining	Extrinsic Staining
Pigments are added and mixed into the silicone before curing. It is applied within the mould during the casting procedure	Externally added pigments after the curing process is over
Depth of the colour translucency can be better achieved accurately	The prosthesis can only be modified on the exterior surface
Less predictable as the outcome can be evaluated only after the curing process	A more predictable method and the outcome can be evaluated directly on patients' skin at chairside
Stimulates the laminar structure of the skin	Stimulates the superficial layer of skin
3-dimensional finishing can be achieved by in-cooperating subsurface details such as blood vessels, freckles, and moles to enhance aesthetics	Finishing is obtained by using a paintbrush and different colours
This type of staining is less vulnerable to environmental conditions and material handling	Should be used sparingly as it is more vulnerable to environmental conditions and material handling

Recommendation

The selection of the colouration technique is dependent on the clinician. Currently, the most advocated method is trial and error. This method is the most economical and convenient as it can be performed at the chairside, but exact matching is not easy. The development of a more predictable method to obtain patients' lightest skin tone is very important. The intrinsic colour must be as close to the patients' skin colour to produce a life-like prosthesis for the patient. The development of a shade guide with exact proportions formulation of colour mixtures will be a good solution to this issue.

Conclusion

In the fabrication of maxillofacial prostheses, intrinsic colour matching is a pivotal step. The procedure of colouration has been more accurate and less time consuming with the newer approaches and methods available.

This narrative review revealed that the most common technique utilized in clinical practice for intrinsic colour matching of the facial prosthesis is the trial-and-error method. There have been digitalized colour matching techniques available in recent times. These techniques need to be further studied for ease of use by clinicians. Following intrinsic staining, further characterization of the prosthesis can be done using extrinsic stains. There is no current evidence indicating the superiority of one technique over the other.

Competing interests

The authors declare that they have no competing interests. Facts and opinions in this submitted articles is/ are solely the personal search from respective authors. All the authors are responsible for all contents in this article(s) including accuracy of the facts, statements, citing resources, and so on.

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