COLOR STANDARDIZATION FOR LAMINATED PLASTIC PROSTHETIC COMPONENTS

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In the past, prosthetics research has been concerned primarily with the mechanical aspects of limb design and construction. We are now capable of making very good, lightweight, durable prostheses of plastic laminate. In our laboratory we have had an occasional experience in which the artificial limb, though technically very adequate, did not quite satisfy the patient. On questioning patients about this reaction, it gradually became evident that the problem was in the mismatch between the color of the prosthesis and that of the patient's skin. We have particularly noted this with our Black patients.

As the Blacks and other minority groups become more conscious of their racial identities, they are rightfully demanding that their individualities be recognized. Those of us in prosthetics must recognize this.

In view of the emerging importance of more adequate esthetic treatment, we developed a system of color comparison and color matching which we hope will aid the prosthetist or orthotist in:

1. Accurate determination of the skin color of the patient.
2. Reproduction of the selected matching color in the laminated plastic prosthesis.
3. Recognizing the importance from the psychological standpoint of matching the color of the prosthesis with that of the patient's skin.

THE RESEARCH STUDY

EARLY METHODS OF SKIN MATCHING

Serious attempts at matching skin colors and tones began early in World War II. The Navy Dental Department at Bethesda made certain original contributions to coloring polyvinyl chloride for their own requirements. Using their experience, the NPRL made several hand molds that made it possible to produce experimentally a limited number of cosmetic gloves. These gloves were used with the Navy articulated artificial hand (Fig. 1).

The Army Prosthetics Research Laboratory (now Army Medical Biomechanical Research Laboratory) were also developing improved devices, including esthetic improvements, for upper-limb amputees. To avoid duplication of effort, NPRL abandoned further research on artificial hands and gloves. The Army has subsequently developed a hand and glove combination which today may be among the best in existence.

Using the experiences of the Navy Dental and Army units, we attempted the cosmetic treatment of artificial legs, concentrating on those

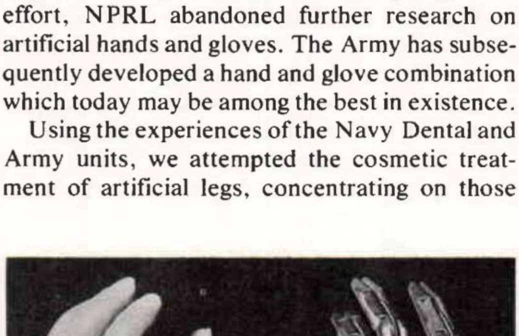

Fig. 1. EXPERIMENTAL POLYVINYL CHLORIDE GLOVE AND ARTICULATED ARTIFICIAL HAND—The NPRL molded polyvinyl cosmetic glove was individually colored at time of fabrication to match the skin tones of the patient.

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for female patients, with some success.

Two types of cosmetic treatment were devised:

1. Sponge Rubber Sections.
   Cut sections of thin, sponge rubber were applied to the external surface of the laminated plastic leg in such a way that the closure line corresponded with the seam line of the nylon hose on the posterior surface of the leg. This presented a smooth, resilient, conforming cover. A paint, mixed to match the skin color and tone of the contralateral leg, was applied. A pledget of cotton gauze was used to gently stipple the wet surface thus providing a life like skin texture. Sheer nylon hose were worn directly over the cover without difficulty. Later work resulted in a method of applying "pancake makeup" to the surface, allowing the patient to change the shade of her prosthetic leg to match the changes due to exposure to the sun. The cover could be cleaned with soap and water.
2. Molded Polyvinyl Chloride
   This consisted of a thin, molded, polyvinyl chloride. The material was formed by a dipping process using a mold made of thin, sheet copper in the shape of the leg. The cover was formed by repeatedly dipping the copper mold until the desired thickness was obtained. Repeated dippings also permitted considerable latitude in achieving proper and pleasing color matches.

Neither of these techniques proved to be practical in making large numbers of limbs and both have been abandoned.

PRESENT COLORING METHODS

Currently we have eight color pigments[3] available to us when we prepare plastic laminated prosthetic components. These are:

1. White	5. 4-A
2. Caucasian	6. 6-A
3. Mexican	7. Burnt Umber in G-62
4. 3-A	8. Black in G-62

Often these do not match very closely the true skin color of the patient. As a consequence the prosthetist mixes two or three colors together until he has a color which looks as though it will be close to the patient's skin color. Sometimes it is. The prosthetist, however, usually does not record how much of each pigment he has used, thus it is impossible to duplicate that specific color later if it becomes necessary.

In many instances limbs consist of several different laminated plastic components which are made at different times by different technicians; for instance, the hip disarticulation prosthesis. Often, the several components come out with slightly differing colors.

With this in mind we decided to attempt to standardize our color system. Our goal was to allow the patient to choose the color that most nearly matched his skin. We had hoped that this procedure would make the patient feel he was a member of the "production team" as well as add to the accuracy of the result. Additionally, we wished to identify the color shadings numerically so that any prosthetist might exactly reproduce a color used earlier.

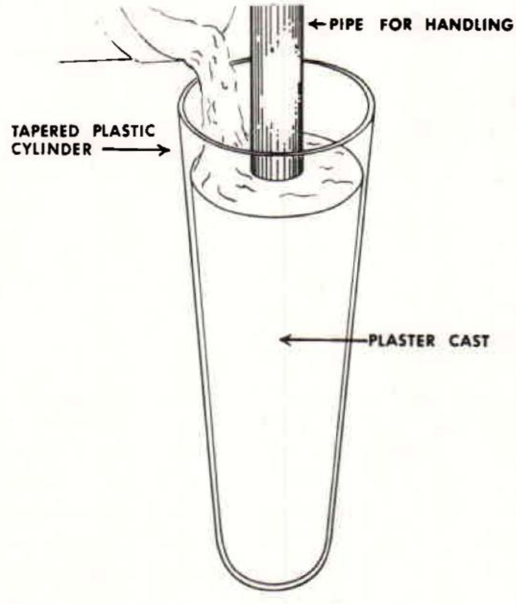

Fig. 2. POURING MOLD—Tapered and rounded mold was used for forming standard plaster models. They were poured with a mandrel in place.

PRODUCTION OF TEST MODELS

The eight basic pigments, listed above, were used to make up a Master Skin Tone Table (Table 1) in which each of the commercial pigments was mixed as indicated, in a total of forty-one combi-

[3]Obtained from Kingsley Manufacturing Company, Costa Mesa, California

(1) White	(1) White	(1) White	(2) Caucasian	(3) Mexican	(4) 3-A	(5) 4-A	(6) 6-A
3% of 1 + 1% of 2	2% of 1 + 1% of 2	1% of 1 + 1% of 2	1% of 2 + 1% of 3	1% of 3 + 1% of 4	1% of 4 + 1% of 5	1% of 5 + 1% of 6	1% of 6 + 1% of 7
3% of 1 + 1% of 3	2% of 1 + 1% of 3	1% of 1 + 1% of 3	1% of 2 + 1% of 4	1% of 3 + 1% of 5	1% of 4 + 1% of 6	1% of 5 + 1% of 7	
3% of 1 + 1% of 4	2% of 1 + 1% of 4	1% of 1 + 1% of 4	1% of 2 + 1% of 5	1% of 3 + 1% of 6	1% of 4 + 1% of 7		
3% of 1 + 1% of 5	2% of 1 + 1% of 5	1% of 1 + 1% of 5	1% of 2 + 1% of 6	1% of 3 + 1% of 7			
3% of 1 + 1% of 6	2% of 1 + 1% of 6	1% of 1 + 1% of 6	1% of 2 + 1% of 7				
3% of 1 + 1% of 7	2% of 1 + 1% of 7	1% of 1 + 1% of 7					

Basic Colors

1—White
2—Caucasian
3—Mexican
4—3-A
5—4-A
6—6-A
7—Burnt Umber in G-62
8—Black in G-62

TABLE 1—Matrix of Mixtures to Obtain Color Swatches. Colors 7 and 8 are deleted because both are jet black.

nations of pigments. We wanted to duplicate, in miniature, exactly the same structure as our laminated limb components, each containing graduated amounts of color pigments. The standard form used to produce identical plaster casts was a tapered, plastic cylinder with a closed, rounded end filled with plaster (Fig. 2). A mandrel is used to facilitate handling and application of suction during polymerization of the laminated plastic. On removal from the mold each test model was dried thoroughly, sanded lightly, and then covered with a thin layer of polyvinyl acetate. The laminating materials (Fig. 3) consisting of a first layer of dacron fleece followed by four layers of nylon stockinet were applied.

Standard quantities of polyester plastic with graduated amounts and kinds of pigments shown in the Master Skin Tone Chart were used to saturate the laminates now in place. Methylethylketone peroxide was used as the catalyst and each unit was polymerized under suction.

When completely polymerized the top brim was cut away (Fig. 4) and the conical cup removed from the plaster. The cups were then cut into four longitudinal fourths and the elements shaped into "paddles" to provide four sets of color samples for use in the production shop. Each paddle was coded to show the color and percentages of each component—the numerical identification referred to earlier—to allow accurate color duplication. Apothecary scales were used in all weighings, because considerable accuracy is required in this procedure. When completed, each of the four sets of paddles were strung together on a nylon cord, ready for use in directly matching the skin color (Fig. 5).

The actual matching (Fig. 6) should take place in ordinary daylight, and not under artificial light. However, special lights are available which are color corrected and permit inside color matching. These are used inside a special light booth which masks out other kinds of artificial light.

MATCHING SKIN COLORS

In use, the paddle most nearly matching the

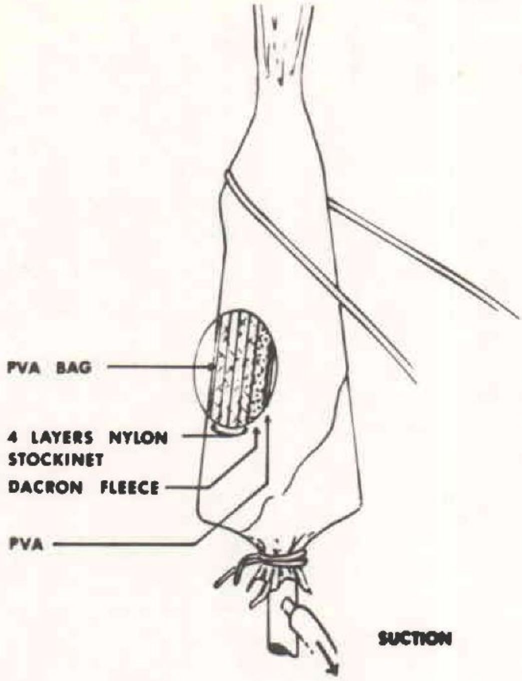

Fig. 3. LAMINATE OVER MODEL—The standard laminated structure was duplicated over models similar to a laminated shin. Suction was used during polymerization.

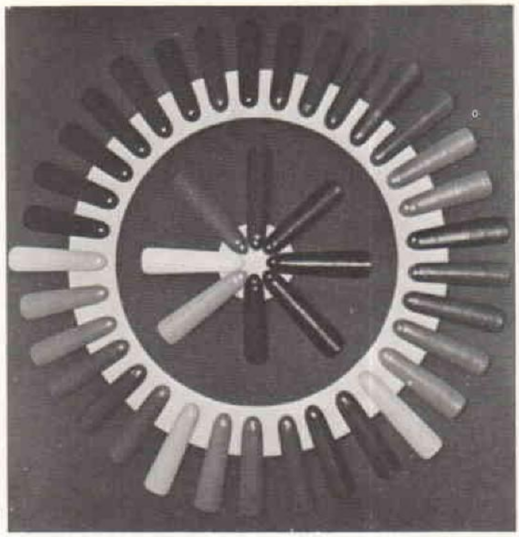

Fig. 5. SKIN TONE COLORS—Paddles in array show the eight basic colors in the center plus the remaining thirty-three skin tones arranged around the periphery.

skin color of the subject is selected, using daylight only. Referring to the Master Skin Tone Chart, the formula on the back of the paddle

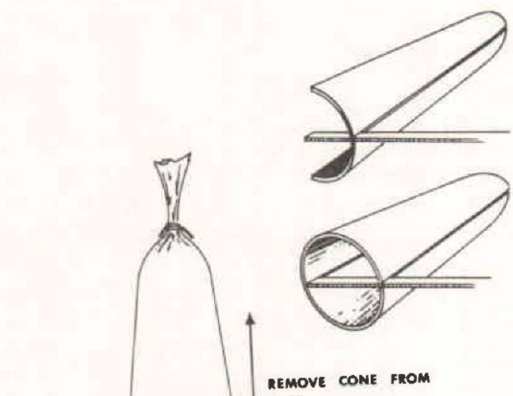

Fig. 4. REMOVAL & QUARTERING—The cone is shown being removed and quartered.

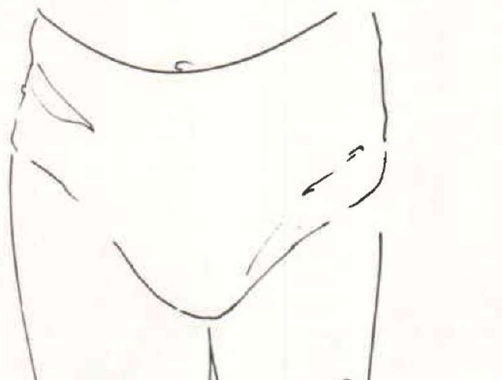

Fig. 6. MATCHING SKIN COLORS—Appropriate paddle is selected by comparing with skin.

selected is located. For example, suppose the formula is—"1% of 3 + 1% of 8". This means that when the amount of plastic is determined which will be required for lamination of the component at hand—for instance, 600 grams—then the calculation will be as follows:

600 grams of polyester
6 grams of #3 (1% of Mexican)
6 grams of #8 (1% of Black in G-62)
___ plus catalyst
612 grams—total

When mixed, applied and polymerized under suction, the resulting lamination will accurately match the skin tone paddle selected and, if the original matching was properly accomplished, it will accurately match the skin of the patient.

DISCUSSION

This color-matching system requires some care and a few precautions. The quantities noted are exact. Materials used must not become contaminated by careless use and storage. The scales must be accurate enough to weigh the small quantities involved. We have found that the plastic laminate color is affected somewhat by the underlying material. The same color will appear darker over wood. It will appear lighter over white foam.

One problem which still is unsolved is that there is some variation in the pigments as they come from the supplier. It is hoped that better quality control can be instituted, and we hope to make recommendations in the future to the prosthetic-orthotic profession relating to standards. We feel that patient participation is very important. The patient is given the samples and is encouraged to try them out in various lighting conditions. It is left up to him to choose the proper color. When he does this he feels he has become part of the clinic team, because he has some say in how his artificial limb will look. We have received favorable response from our patients since we have instituted this system. In those few cases in which the color match has not been as good as we might have hoped, the patient feels he is at least partially to blame, and thus is not so critical of the prosthetist.

SUMMARY AND CONCLUSIONS

The prosthetics profession has an obligation to improve the color matching of artificial limbs to the respective skin colors of patients. Our minority patients, as they become more proud of their racial identities are beginning to insist on it.

We have presented our preliminary efforts at developing a standardized color system for use with plastic laminate prosthetic components. It involves forty-one plastic laminate color samples which cover the spectrum from the lightest Caucasian to the darkest Negro and include many tones suitable for the Mexican-American. Each color sample is numbered so that the prosthetist can refer to a chart and quickly determine what proportions of the basic pigments to use to reproduce it. The patient is asked to choose that color which most nearly matches his skin color. Variables are introduced by lighting, by the material over which the plastic laminate is applied and by variations in the pigments as they come from the supplier. These were discussed briefly.

Further development of a color matching system and better standardization of colors are required. We intend to continue working on this. As we learn more about the pigments and the color matching process, we hope to be able to extend the system to prosthetic feet, our molded plastic knees and our plastisol coatings for orthoses.