THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Color change of airborne particle–abraded acrylic resin surfaces: A palatography method

Shajidan Kelimu, BDS, DDS,[a] Mariko Hattori, DDS, PhD,[b] Shataer Awuti, BDS, DDS,[c] Mahmoud E. Elbashti, BDS, MSc, PhD,[d] Yuka I. Sumita, DDS, PhD,[e] and Hisashi Taniguchi, DDS, PhD[f]

ABSTRACT

Statement of problem. A palatogram aids prosthodontists and speech pathologists in evaluating the precise prosthetic treatment needed and the effectiveness of such treatment to improve speech intelligibility. Powder is commonly used to visualize tongue-palate contact, where wetted areas of powder in the oral cavity reveal such contact during palatography. However, discomfort and the risk of aspiration are among the shortcomings of this method, and an improved method is needed.

Purpose. The purpose of this in vitro study was to examine the feasibility of a new method of palatography that uses airborne-particle–abraded acrylic resin so that wet areas can be easily distinguished from dry areas.

Material and methods. Seventy-two specimens of heat-polymerized acrylic resin were prepared in 6 different resin colors. After the specimens had been airborne-particle abraded, CIELab color values for each specimen were measured using a colorimeter under dry and wet conditions and recorded. Color difference (ΔE) was then computed, and a paired Student *t* test, 1-way analysis of variance, and multiple comparison using the Tukey post hoc analysis were applied (α=.05).

Results. A significant color difference was found between the 2 conditions in all acrylic resin specimens examined. Mean ΔE ranged from 5.58 to 6.76.

Conclusions. The results indicated that an airborne-particle–abraded acrylic resin surface can show color differences made by wetting on palatograms. (J Prosthet Dent 2019;121:671-5)

A successful prosthodontic treatment involves considering not only the esthetics, functions, and comfort of use of the prosthesis but also speech.[1,2] The tongue, as a main articulator, plays a major role in the formation of speech sounds,[3,4] and prosthodontists should examine tongue contact with the palate in the evaluation of both normal and pathologic speech. Using a palatogram is one method of evaluation.

A palatogram is an image obtained by recording contact between the tongue and palate in the articulation of sound.[5] Palatograms can help speech pathologists in the assessment and treatment of speech disorders, indicating speech sound (phonetic) changes that have occurred after the placement of a removable complete denture.[6] Palatograms are also a diagnostic tool used by prosthodontists to determine how much the thickness of an oral prosthesis should be augmented to aid intelligible speech in patients with impaired tongue movement.[7] Palatography is a safe and convenient clinical technique that has become widely used. Coles[8] was the first, in 1871, to introduce painting of the tongue to visualize tongue-palate contact. Various extensions of the technique have been used to evaluate this functional contact, including methods using talcum powder,[9] colored aerosol marking media (Occlude; Pascal Co,

This study was supported by the Japan Society for the Promotion of Science, Grants-in-Aid for Scientific research (JSPS KAKENHI grant number: JP 15K20508 and 15KK0336). This study was presented at the fourth Joint Meeting of the International Society for Maxillofacial Rehabilitation (ISMR) and the American Academy of Maxillofacial Prosthetics (AAMP) held in San Francisco, California, from October 28 to 31, 2017.
[a]Graduate student, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Science, Tokyo Medical and Dental University (TMDU), Tokyo, Japan.
[b]Assistant Professor, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Science, Tokyo Medical and Dental University (TMDU), Tokyo, Japan.
[c]Graduate student, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Science, Tokyo Medical and Dental University (TMDU), Tokyo, Japan.
[d]Lecturer, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Science, Tokyo Medical and Dental University (TMDU), Tokyo, Japan.
[e]Junior Associate Professor, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Science, Tokyo Medical and Dental University (TMDU), Tokyo, Japan.
[f]Professor, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Science, Tokyo Medical and Dental University (TMDU), Tokyo, Japan.

Clinical Implications

Airborne-particle abrading the acrylic resin surface enabled the color change between wet and dry areas to be visualized. Airborne-particle–abraded surfaces of palatal prostheses can be used to visualize tongue-palatal contact on palatograms.

Inc),[6] and gothic arch-tracing ink.[10] Moreover, the evaluation of the dynamics of functional contact has improved with advances in imaging techniques such as cinefluorography,[11] electropalatography,[12] ultrasound,[13] and magnetic resonance imaging.[14] The technique using powder has also gradually developed from Coles' original use of wheat flour[8] through the use of dry black powder (a mixture of charcoal and chocolate),[15] talcum powder,[9] and tooth-polishing powder. Among the techniques of dynamic palatography, electropalatography is widely used in experimental phonetic laboratories and speech clinics, although mainly for research, rather than for clinical purposes.[16] Using powder is affordable, and today irreversible hydrocolloid impression powder is commonly used.

Irreversible hydrocolloid powder is easy for dentists to apply to the tongue, and the denture base is usually wiped with petroleum jelly to improve the adhesion of the irreversible hydrocolloid powder. The patient articulates monosyllables such as /sa/ and /ta/, which are palatolingual sounds formed by contact between the tongue and the hard palate, as well as /ka/, which is a palatolingual sound formed by contact between the tongue and the soft palate.[3] Wetted areas on the denture base will be observed where contact was made. However, speaking with powder in the oral cavity may be uncomfortable and can result in coughing. There is also a risk of aspiration, especially in elderly patients or patients with a glossectomy. An improved method that uses an alternative to powder is therefore desirable.

Airborne-particle abrasion of the denture surface could provide an alternative method for visualizing wetness on the surface during palatography. Airborne-particle abrasion involves spraying a stream of abrasive material at high speed onto an object under the power of compressed air to modify the surface and shape of an object by cleaning or roughening its surface. In dentistry, airborne-particle abrasion is used to clean the intaglio surfaces of restorations and enhance mechanical retention. The roughened surface also changes color after wetting. Compared with unmodified surfaces, airborne-particle–abraded surfaces look whiter because of diffuse light reflection[17] but darken when wetted. Thus, the objective of this in vitro study was to examine the feasibility of a new method of palatography that uses airborne-particle–abraded denture base surfaces. The null hypothesis was that no differences in color would be observed between wet and dry conditions on airborne-particle–abraded acrylic resin surfaces.

Figure 1. Airborne-particle–abraded specimen of acrylic resin before and after spraying with artificial saliva.

Table 1. National Bureau of Standards (NBS) system of expressing color difference

Critical Remarks on Color Differences	NBS Units
Trace	0.0-0.5
Slight	0.5-1.5
Noticeable	1.5-3.0
Appreciable	3.0-6.0
Much	6.0-12.0
Very much	>12.0

MATERIAL AND METHODS

The sample size (n=12 per group) was estimated by a power analysis, assuming statistical significance (α=.05) with a power of 0.95 based on data from a pilot study. Seventy-two 2-mm-thick specimens of heat-polymerizing acrylic resin were prepared in 6 different colors (Acron dark pink, live pink, clear pink, pink, light pink, and pale pink; GC) (n=12 per color group). The heat-polymerizing acrylic resins were processed according to the manufacturer's instructions in a denture flask. Once the acrylic resin was polymerized, the plate was divided with laboratory steel burs into 20×20-mm specimens. The primary polishing step was performed for all specimens by using an abrasive paper from #320 to #1000 (Waterproof Abrasive Paper DCC; Sankyo), and then all specimens were polished to a high gloss on a polishing machine (Kavo EWL Dental Lab Polishing Lathe System; Kavo) by using abrasive powder (NSK Ebisand; Shimomura Gypsum Co, Ltd) with glycerin (Glycerin; Toho

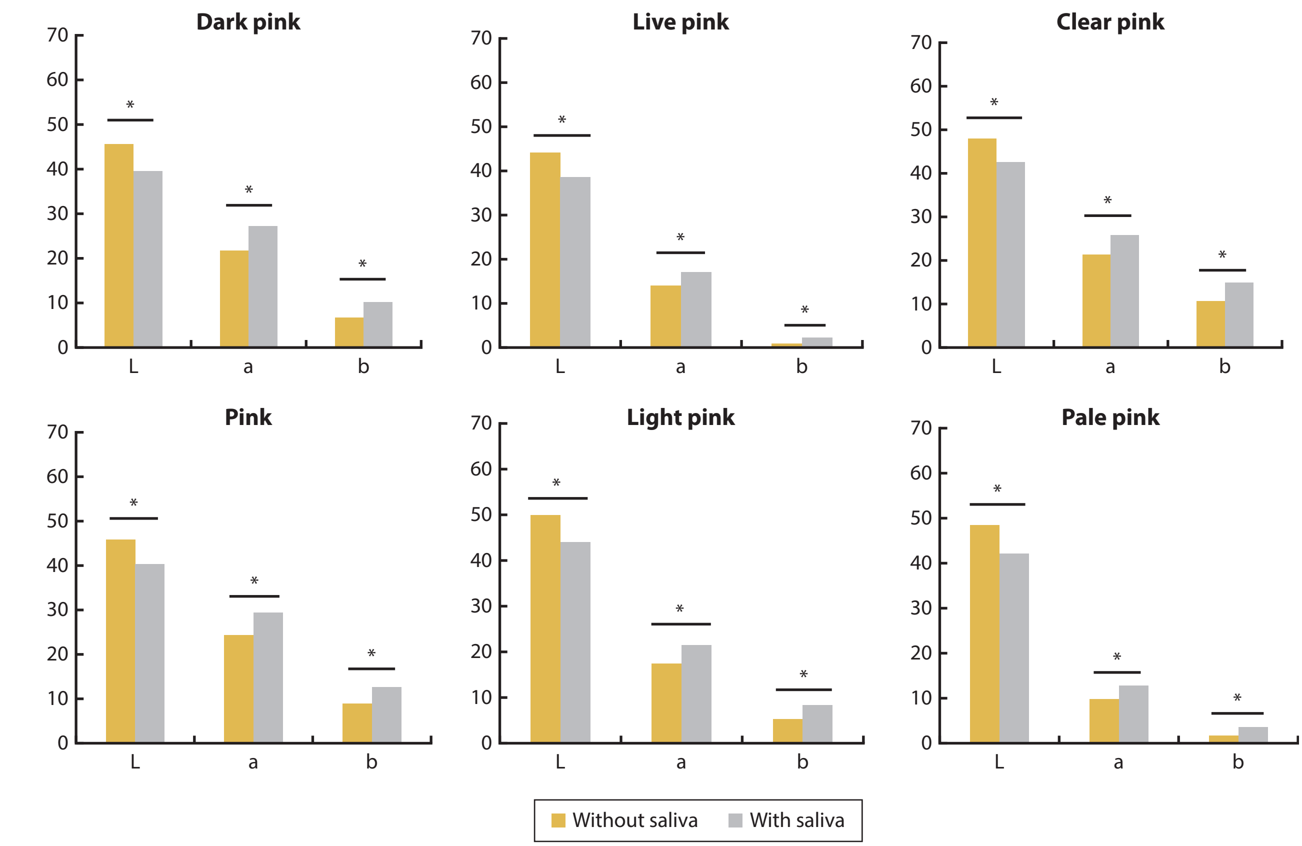

Figure 2. Mean CIELab color values for each of the 6 colors of airborne-particle–abraded acrylic resin specimens with and without application of artificial saliva. *Statistically significant (*P*<.05).

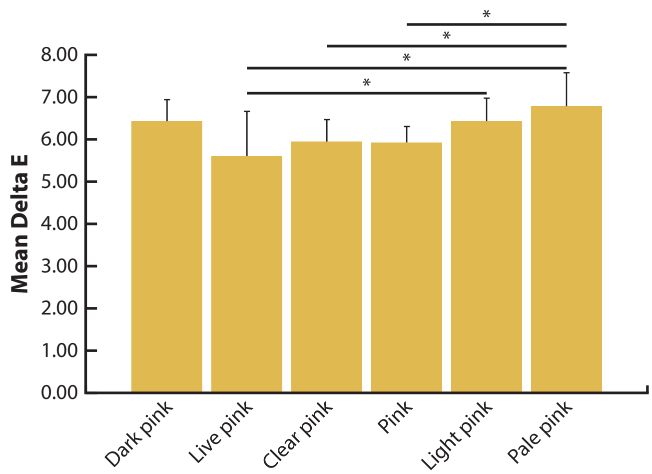

Figure 3. Mean color difference (ΔE) for each of the 6 colors of airborne-particle–abraded acrylic resins. *Statistically significant (*P*<.05).

Yakuhin Co, Ltd) and zinc oxide (Zinc Oxide; Kozakai Seiyaku Co, Ltd) powder with water.

After drying, each of the specimen surfaces was airborne particle abraded at an inclination of 90 degrees for 10 seconds with 50-µm alumina (RONDOflex Abrasive Powder; Kavo), with a pressure of 392 kPa. The distance between the specimen surface and the tip of the abrader was standardized at 10 mm. The color of each specimen was then measured by using an electric colorimeter (Color Reader CR-13; Konica Minolta, Inc) with a measuring head of an 8-mm aperture. To determine the color of test specimens, the colorimeter was calibrated according to the manufacturer's instructions by using the white calibration standard supplied. Measurement was performed at 3 different locations for each specimen. Mean levels of L*, a*, and b* were automatically calculated by the colorimeter and recorded in the CIELab color system, a color order space with coordinates for lightness: white-black (L*), red-green (a*), and yellow-blue (b*). After artificial saliva (Butler Gel Spray; Sunstar, Inc) was applied to the whole specimen surface with a disposable brush (Fig. 1), the color measurement of CIELab color values was repeated in the same manner immediately after wetting. The color difference (ΔE) was then calculated by using the following formula[18]:

$$\Delta E^*_{00}=\sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2+\left(\frac{\Delta C'}{K_C S_C}\right)^2+\left(\frac{\Delta H'}{K_H S_H}\right)^2+R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)},$$

where ΔL′, ΔC′, and ΔH′ represent CIELab lightness, chroma, and hue differences. S_L, S_C, and S_H are weighting functions for the lightness, chroma, and hue components. K_L, K_C, and K_H are the respective parametric factors, and R_T is a hue rotation term.

A paired Student *t* test was used to determine the difference in color between dry and wet conditions for all specimens. One-way analysis of variance was applied to compare ΔE in all specimens. Multiple comparison was made using the Tukey post hoc analysis to determine the most effective acrylic resin color resulting from airborne particle abrasion in the 2 conditions (α=.05). All analyses were performed using a statistical software program (IBM SPSS Statistics, v21.0; IBM Corp). Critical marks of color difference (ΔE) were calculated by using the standard National Bureau of Standards (NBS) units[19] shown in Table 1 to reflect the clinical setting, which was expressed by the formula NBS units=ΔE×0.92.

RESULTS

The color change was observed after wetting all specimens regardless of acrylic resin color. Mean CIELab color values of the colored specimens in dry and wet conditions are shown in Figure 2. A significant color difference was found between the dry and wet conditions in all the specimens. Mean ΔE values are shown for each color type of specimen in Figure 3 and ranged from 5.58 to 6.76. A significant difference in ΔE was found among the different color types. The Tukey test showed significant differences between live pink and light pink, live pink and pale pink, clear pink and pale pink, and pink and pale pink (P<.05).

DISCUSSION

The null hypothesis was rejected as the colors of different acrylic resins appeared different under dry and wet conditions. Color is produced by a combination of the 3 principal color elements known as the 3 chromatic characteristics of hue, brightness, and chroma. The human eye can detect a difference in hue (red, yellow, green, blue, and so on), chroma (saturation), or lightness to the same degree or extent. As a result, when the lightness (L*) of the specimens was decreased by wetting with saliva, the surface looked darker, with the coordinates for red-green (a*) and yellow-blue (b*) increased. Thus, specimens had greater color components of redness and yellowness when wet. Seghi et al[20] reported that a color difference of ΔE>2 could be detected visually by an observer all the time. In the present study, all color differences before and after wetting of the airborne particle–abraded specimen surfaces with artificial saliva were greater than 2 and were categorized as ‘appreciable’ and ‘much’ according to the NBS system.[18]

The pale pink and light pink acrylic reason colors had a greater ΔE than other color pairs. By contrast, clear pink and pink had a lower ΔE, with live pink showing the lowest ΔE. The results indicate that among the materials tested, pale pink and light pink airborne particle–abraded acrylic resin specimens are the best base materials for palatography.

This study evaluated color change within different airborne particle–abraded acrylic resin surfaces for palatography. Limitations of this study include that artificial saliva was used rather than natural saliva. Human saliva shows variation, so natural saliva might give different results. In addition, the material used was a newly processed acrylic resin, but dentures that need to be examined in patients with speech problems are not newly processed in the clinical setting. Future work should involve the clinical study of the airborne particle–abraded palatography method.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. Airborne-particle–abraded denture base material can show color differences with wetting.
2. Therefore, airborne-particle–abraded acrylic resin surfaces can be used to visualize tongue-palatal contact on palatograms.

REFERENCES

1. Hagino A, Inohara K, Sumita YI, Taniguchi H. Investigation of the factors influencing the outcome of prostheses on speech rehabilitation of mandibulectomy patients. Nihon Hotetsu Shika Gakkai Zasshi 2008;52:543-9.
2. Jain AR, Venkat Prasad MK, Ariga P. Palatogram revisited. Contemp Clin Dent 2014;5:138-41.
3. Rothman R. Phonetic considerations in denture prosthesis. J Prosthet Dent 1961;11:214-23.
4. Yoshioka F, Ozawa S, Sumita YI, Mukohyama H, Taniguchi H. The pattern of tongue pressure against the palate during articulating glossal sounds in normal subjects and glossectomy patients. J Med Dent Sci 2004;51:19-25.
5. Erb DP. Speech effects of the maxillary retainer. Angle Orthod 1967;37:298-303.
6. Farley DW, Jones JD, Cronin RJ. Palatogram assessment of maxillary complete dentures. J Prosthodont 1998;7:84-90.
7. Christensen J, Hutton J, Hasegawa A, Fletcher S. Evaluation of the effects of palatal augmentation on partial glossectomy speech. J Prosthet Dent 1983;50:539-43.
8. Coles OJ. On the production of articulate sound. *Trans. Odontol. Soc.* Great Britain 1872;4:110-23.
9. Allen LR. Improved phonetics in denture construction. J Prosthet Dent 1958;8:753-63.
10. Tsumita M, Arai M, Sato Y, Kitagawa N, Sugiyama I, Sugiyama M. Improved visibility of a palatogram. Prosthodont Res Pract 2005;4:107-10.
11. Gay T. A cinefluorographic study of vowel production. J Phon 1974;2:255-66.
12. Gibbon FE, Yuen I, Lee A, Adams L. Normal adult speakers' tongue palate contact patterns for alveolar oral and nasal stops. Int J Speech Lang Pathol 2007;9:82-9.
13. Bernhardt B, Gick B, Bacsfalvi P, Adler-Bock M. Ultrasound in speech therapy with adolescents and adults. Clin Linguist Phon 2005;19:605-17.
14. Bresch E, Kim Y, Nayak K, Byrd D, Narayanan S. Seeing speech: capturing vocal tract shaping using real-time magnetic resonance imaging. IEEE Signal Process Mag 2008;25:123-32.

15. Abercrombie D. Direct palatography. STUF-Lang Typol Universals 1957;10:21-5.
16. Kelly S, Main A, Manley G, McLean C. Electropalatography and the Linguagraph system. Med Eng Phys 2000;22:47-58.
17. Blinn JF. Light reflection functions for simulation of clouds and dusty surfaces, Computer Graphics, 1982;16:21-9.
18. Sharma G, Wu W, Dalal EN. The CIEDE2000 color-difference formula: implementation notes, supplementary test data, and mathematical observations. Color Res Appl 2005;30:21-30.
19. Polyzois GL, Yannikakis SA, Zissis AJ, Demetriou PP. Color changes of denture base materials after disinfection and sterilization immersion. Int J Prosthodont 1997;10:83-9.
20. Seghi RR, Hewlett E, Kim J. Visual and instrumental colorimetric assessments of small color differences on translucent dental porcelain. J Dent Res 1989;68:1760-4.

Corresponding author:
Dr Mariko Hattori
Department of Maxillofacial Prosthetics
Graduate school of Medical and Dental Science
Tokyo Medical and Dental University (TMDU)
1-5-45, Yushima, Bunkyo-ku, Tokyo, 113-8549
JAPAN
Email: sasamfp@tmd.ac.jp

Acknowledgments
The authors thank members of the Department of Maxillofacial Prosthetics, Tokyo Medical and Dental University, for their help and support.

https://doi.org/10.1016/j.prosdent.2018.09.002