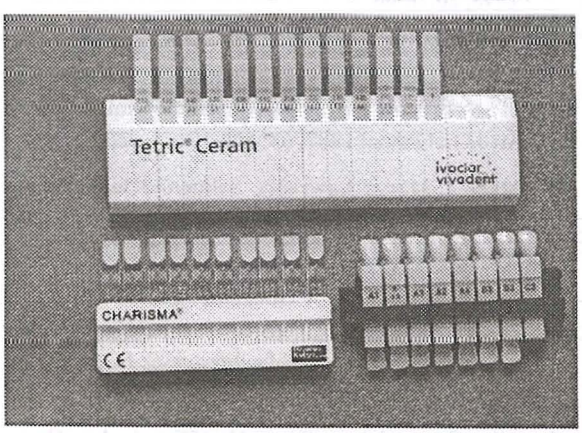
AN IN VITRO SPECTROPHOTOMETRIC ANALYSIS OF COLOUR DIFFERENCES BETWEEN COMPOSITE RESINS AND THEIR SHADE GUIDES

Samraj Raji V.*, Indira R. **, Srinivasan M.R. ***

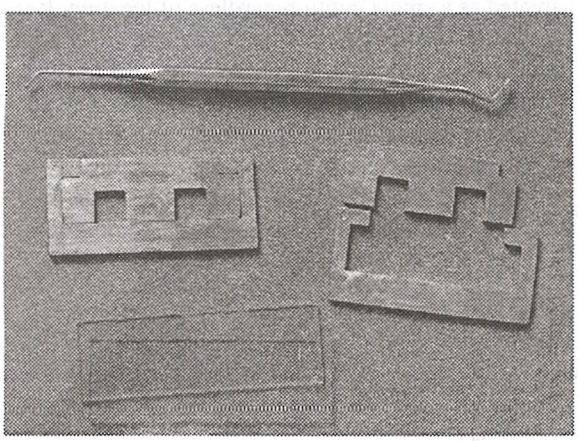
The purpose of this study was to compare the colour of the stock shade guides of resin composite products provided by the manufacturers and the colour of the custom made samples fabricated from the same shade of the resin composite restorative materials. The objective was to determine the colour difference that exists between the sample to be matched and the standard and/or how much of a difference is acceptable in a given clinical situation. Three different light-activated resin composite specimens and shade guides of same thickness were evaluated by a spectrophotometric analysis. Colour measurement data was plotted in the CIELAB color space. All resin samples showed statistically significant color variations when compared to their respective shade tabs.

The results highlight the inadequacies of stock shade guides and recommend the fabrication of custom shade guides from the restorative material itself for improved shade reproduction.

The demand for esthetic restorations has increased exponentially over the last few years due to the ongoing research and development of new esthetic materials and improved technologies[13]. Resin – based restoratives are good alternatives to other esthetic restorative materials aiming for excellence par with the natural teeth[5]. The high awareness of the esthetic sense of the patient poses a challenge to the dentist to choose a shade to mimic the natural tooth to its closest sense and form. Matching the tooth – coloured restoratives with the colour of natural teeth is still considered more of an art than a science[9].



Colour determination or shade matching in dentistry can be divided into two categories: visual and instrumental[7]. Visual colour determination is a subjective method based upon comparison of the tooth with colour standards. The colour standard (ie. commercially available shade guides) varies greatly. They do not represent the entire shade range of natural teeth and are not logically distributed[19]. Due to difficult-to-control parameters during fabrication, none



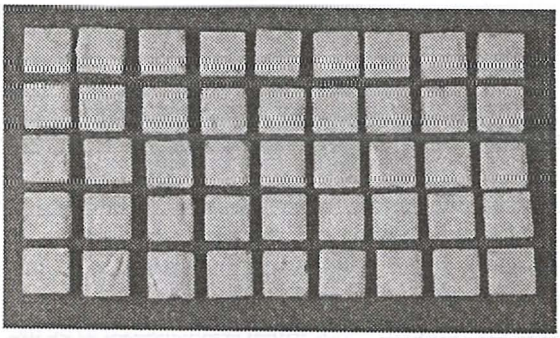
* *Reader, Department of Conservative Dentistry and Endodontics, Panineeya Mahavidhyalaya Institute of Dental Sciences, Hyderabad.*
** *Professor and Head of Department.*
*** *Professor, Conservative Dentistry and Endodontics, Ragas Dental College, Chennai.*

of the available shade guides are identical. In addition, they are not made of commercially available dental resins and have different light absorption and reflective properties. Despite this lack in standardization today, such shade guides are the only "*standard*" upon which determination of colour is based in clinical dentistry[8].

Instrumental colour analysis offers a potential advantage over visual colour determinations because the instrumental readings are objective, rapidly obtained and can be quantified. They enable the communication of colour to be more precise and uniform[7]. Advanced computerized colorimeters and spectrophotometers provide measurements in CIELAB units (L*a*b*), which when analyzed mathematically, can compare the colour parameters of different objects[4,20].

MATERIALS AND METHOD

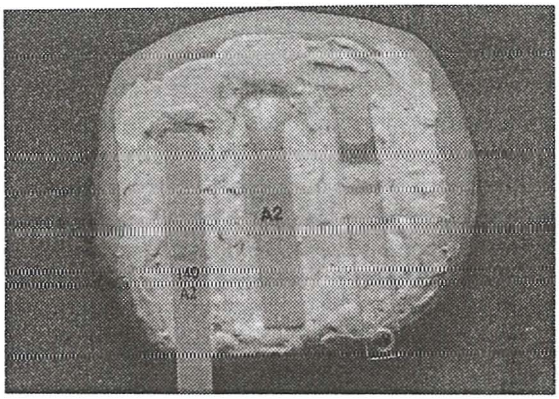
Three visible light – activated, resin – based restorative materials provided with their respective manufacturer's shade guides were used in this study.



For easy reference, identification and follow up of a sample, a code has been given for the material.

METHOD - SPECIMEN PREPARATION

Light-activated resin based materials of three different manufacturers provided with plastic shade guides were evaluated in this study (Table 1). Three shades - A 2, A 3.5 and A 4 were selected with each type of composite resin used. 5 samples in each shade group were prepared. The composite material was condensed into a metal die with a thickness of 2 mm, l x b = 1 x 1 cm and pressed between glass plates to



flatten the surfaces and care was taken to avoid porosities. **(FIG 2 and FIG 3)**

Each sample was polymerized on both sides of the glass surfaces with Spectrum 800 Dentsply visible light – activation unit. The specimen was kept directly in the beam within a distance of 2 mm. The light – polymerizing unit was monitored to ensure a consistent output and a 40 second curing cycle as recommended by the manufacturers was used. After completion of light activation, excess resin was removed and the specimens were separated from the metal die.

Since light can be lost through the translucent samples during spectrophotometer measurements, an opaque coating of barium sulfate was used to provide a consistent background[6]. $BaSO_4$ will not allow light to pass through the samples, as in accordance with the diffuse reflectance mode of measurement used with the spectrophotometer. Hence, all the samples were coated on one side with $BaSO_4$ and the measurement of colour was carried out on the other side of the samples. The shade tabs to be compared with the resin samples were stabilized in a silicone putty index, which was also coated with barium sulfate to standardize the procedure and minimize measurement errors.

The samples and their respective shade tabs were subjected to colour measurements.

The samples were individually analyzed in a Spectrolino spectrophotometer. It measured reflectance of the sample to a standard (white opal) every

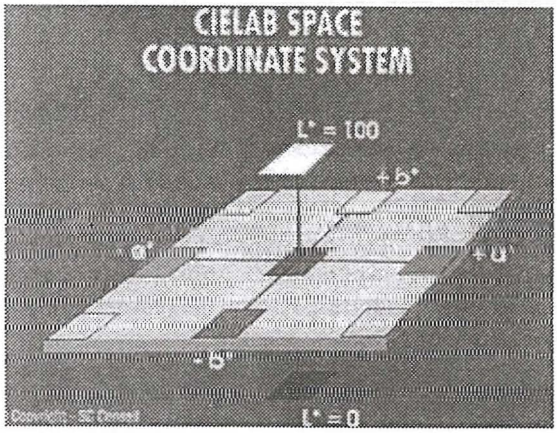
20 nm over the visible spectrum (400 – 700 nm) so that absolute reflectance of the sample is recorded. CIE standard illuminant Δ65 (corresponding to average daylight) was used as a light source, with 2 – degree standard observer. Calibration was accomplished at the beginning of each measurement period by using the white calibration tile supplied by the manufacturer. The spectro-photometer system was connected to a computer system. The spectrophoto-meter software automatically measured each sample three times and reported an average value.

The CIE system of colour specification provides a common means of analyzing and presenting colour measurements data. To specify a particular object's colour, the spectral distribution of light reflected from the object must be known and that spectral distribution must be averaged by three weighing functions. The weighing functions[1] are called colour-matching functions and characterize the colour matching properties of an average observer with normal colour vision, known as the 1931 CIE standard observer. They are weighed by relative spectral distribution of CIE standard illuminants. The resultant tristimulus values X, Y, Z are the standard response of the eye to the red, green and blue stimuli from the object. Knowing the tristimulus values for a particular specimen is beneficial in terms of labeling its colour and in showing graphically that it is different from another specimen in terms of colour stimulus.

COLOUR DIFFERENCES IN THE CIELAB SYSTEM

In the CIELAB system, the total colour difference (ΔE*) combines the difference of three independent variables[1] namely:

The lightness difference in the L* axis expressed by ΔL*, where ΔL is the difference in value between the standard and the sample. The sign of difference indicates the direction of the variation in relation to psycho sensorial perception, for Eg: a negative value means a shift to darker (black) and a positive value means a shift to lighter (white). The red – green colour difference in the a* axis expressed by Δa*, where Δa* is the difference between the standard and the sample. The yellow – blue colour difference in the b* axis expressed by Δb*, where Δb* is the difference between the standard and the sample.



Finally, the colour difference of the sample with the standard shade guide was calculated by using the 1976 CIE Lab (CIELAB) colour difference equation:

$$\Delta E^* = [\,(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\,]^{1/2}$$

Where, ΔL = L (sample) – L (standard)

Δa = a (sample) – a (standard)

Δb = b (sample) – b (standard)

ΔE values indicate overall colour differences in the L a b coordinates of the specimen studied. In dentistry, discoloration that is perceptible to the human eye (ΔE > 1.0) will be referred to as acceptable upto the value ΔE = 3.3, which is considered to be the upper limit of acceptability in subjective visual evaluation[5].

All measurements were tabulated and ANOVA was used to determine the DE between all the specimens in the three groups and it was found that the total colour differences between all specimens of Tetric Ceram, Z 100 and Charisma were statistically significant, $p < 0.05$ (0.012). Post Hoc Tests for multiple comparisons (Bonferroni) was done to detect differences between mean ΔE* values at the 0.05 significance level.

RESULTS

L*a*b* values and the total colour difference (ΔE*) for each resin composite and shade guide are listed in Tables 1 to 3.

DISCUSSION

Tooth – coloured resin based materials are good alternatives to other restorative materials to meet esthetic requirements[5]. These restoratives gained popularity because of their versatile properties like good adhesion to enamel and dentin, adequate strength, sculpting properties, command curing time and excellent polishability. However, the dental profession has long been hampered with the problem of matching the colour of these restorative materials to the colour of the patient's own dentition, despite the increasing number of shades and opacities available[18].

3 different shades – A 2, A 3.5 and A 4 were selected with each type of composite resin used. Since the human eye is more perceivable to variations in value, rather than in hue or chroma, the shades were selected based on their value in comparison with value-oriented Vita shade guide. A 2 was chosen, as it is a lighter shade routinely used in esthetic dentistry. A 4 is at the darker end of the spectrum with A 3.5 in between. For acceptable colour reproducibility, a thickness of 2 mm was standardized for all samples. When lack of uniformity occurs in depth, the reflection properties of the material depends markedly on the area, depth and angle of illumination of the light. Also at depths of 2mm or more, the influences on cure were related solely to the intensity of the light source. Resin shade and type had minimal influence at this depth[21].

Shade matching in restorative dentistry is inherently complex and involves understanding the science of colour, determining the shade and surface characteristics of teeth and duplicating the chosen shade in the restoration[3]. The entire process of shade matching in dentistry is referred to as colour or shade replication. It comprises of 2 distinct steps, the shade – selection (matching) phase and shade – duplication (reproduction) phase. The shade – matching or colour determination[7] can be divided into 2 categories: Visual and instrumental.

During the visual shade matching phase the dentist matches the colour of the natural tooth to a shade tab in the shade guide supplied by the manufacturer. Colour matching with shade tabs is extremely difficult to standardize chair side because of variable viewer interpretation and environmental influences[10].

Visual colour assessment is dependent on the observer's physiologic and psychologic responses to radiant energy stimulation. Inconsistencies may result from uncontrolled factors such as fatigue, aging, emotions, lighting conditions, previous eye exposure, object and illuminant position and metamerism. These factors have different interpretive effects on each observer. In addition, the shade guides do not represent the entire shade range of natural teeth and the shades available are not systematically or logically distributed. Furthermore, the shade tabs are generally made of plastic (rather than the actual composite material) and so they do not accurately depict the true shade, translucency or opacity of the resin composite after polymerization[5,18]. Culpepper pointed out the errors in the inconsistencies among individual dentists in matching natural tooth shades and the inability of some dentists to duplicate their own shade selection reliably. Some of the errors in colour matching are attributed to the human variables always present, but other errors are attributed to the inadequacy of available shade guides[2,15].

Instrumental measurements can quantify colour, express it in a numerical representation and enable the communication of colour to be more precise and uniform[7]. Development of more advanced computerized colorimeters and spectrophotometers have increased their use in dental research. However, results of a colorimeter can be altered because the standardized illuminating light emitted from the device can be scattered, absorbed, transmitted, reflected and even displaced in a sideways direction as a result of the translucent optical properties of the teeth and the dental composite (Hunter, 1975; Bosch et al, 1985). Most colorimeters are designed[1] for a flat surface

rather than the curved surfaces found on the teeth. The use of a positioning template to read the same general area of the tooth should be incorporated, to reduce the problem of non uniformity, as it not only affects the readings of the colorimeter, but also challenges the human eye as to which portion of the tooth to focus on.

The objective of this present study was to evaluate the errors in the shade duplication phase by quantifying the variation between the resin samples and their respective shade guides.

From **Table 1**, it can be inferred that all specimens of **Tetric Ceram** showed perceptible colour differences. None of the samples showed DE values less than 1, which are less discernible.

The ΔE value of A 4 shade of Tetric Ceram was within the acceptable range, (ΔE = 1.828) with DE = 3.3, considered to be the upper limit of acceptability). The A 2 shade showed greatest discrepancy with the A 2 shade tab, (ΔE – 5.40) and was not within the acceptable range. This discoloration is easily discernible. The ΔE value of shade A 3.5 was less than those of A 2 shade but greater than that of A 4 shade, (ΔE – 3.88) and was not within the acceptable range.

The L* values of A 2 and A 3.5 of the shade guides of Tetric ceram were slightly lower than that of the resin composites, indicating that the resin samples were lighter in value than their respective shade tabs. For the A 4 shade, the resin composite showed a lower L* value. The sign of difference indicates the direction of variation. A positive value means a shift to the lighter (whiter) range.

The a* values of all samples in Table 1 for Tetric Ceram were negative values. This indicates that the samples were more green than red, along the red – green colour coordinate. The a* values of the resin samples were higher than those of the shade guides.

The b* values of all samples in Table 1 were positive values. This indicates that the samples were more yellow than blue, along the yellow – blue coordinate. The resin composites showed higher b* values than their respective shade tabs.

From **Table 2**, it can be inferred that all specimens of **Z 100** showed perceptible colour differences. None of the samples showed DE values less than 1, which are less discernible. The colour discrepancy seen with the darker shade A 4 was less in comparison with the lighter shades.

The ΔE value of A 4 shade of Z 100 was within the acceptable range, (ΔE = 2.438) with ΔE – 3.3, considered to be the upper limit of acceptability). The A 2 shade showed greatest discrepancy with the A 2 shade tab, (ΔE = 4.085) and was not within the acceptable range. This discoloration is easily discern-

Table 1: **Products, shades, filler composition and manufacturers of resin composites**

PRODUCT	SHADE / SHADE TABS	FILLER COMPOSITION	MANUFACTURER	CODE
Tetric ceram	A 2 A 3.5 A 4	Micro hybridBa glass, yterrbium trifluoride, Ba-Al fluorosilicate 60% vol, particle size 0.04-3.00 micron	Vivadent	T
Z 100	A 2 A 3.5 A 4	HybridZirconia or Silica 66 % by volume, particle size 0.01-3.50 micron	3M Dental	Z
Charisma	A 2 A 3.5 A 4	HybridBarium aluminum fluoride glass 64% filler volume, particle size of 0.02 – 2.0 micron	Heraeus Kulzer	C

ible. The ΔE value of shade A 3.5 was less than those of A 2 shade but greater than that of A 4 shade, (ΔE = 3.701) and was not within the acceptable range.

The L* values of A 2, A 3.5 and A 4 shade guides of Z 100 were slightly higher than that of the resin composites, indicating that the resin samples were darker in value than their respective shade tabs. The sign of difference indicates the direction of variation. A positive value means a shift to the lighter (whiter) range.

The a* values of all samples in Table 2 were negative values. This indicates that the samples were more green than red, along the red – green colour coordinate. The a* values of the resin samples were higher than those of the shade guides.

The b* values of all samples in Table 2 were positive values. This indicates that the samples were more yellow than blue, along the yellow – blue coordinate. The resin composites showed higher b* values than their respective shade tabs.

From **Table 3**, it can be inferred that all specimens of **Charisma** showed perceptible colour differences. None of the samples showed ΔE values less than 1, which are less discernible. The colour discrepancy seen with the darker shade A 4 was less in comparison with the lighter shades.

The ΔE value of A 4 shade of Charisma was within the acceptable range, (ΔE = 1.567) with ΔE = 3.3, considered to be the upper limit of acceptability). The A 2 shade showed greatest discrepancy with the A 2 shade tab, (ΔE = 3.678) and was not within the acceptable range. This discoloration is easily discernible. The ΔE value of shade A 3.5 was less than those of A 2 shade but greater than that of A 4 shade, (ΔE = 2.380) and was within the acceptable range.

The L* values of A 2 and A 4 shade guides of Charisma were slightly lower than that of the resin composites, indicating that the resin samples were lighter in value than their respective shade tabs. For shade A 3.5, the resin composite showed a lower value. The sign of difference indicates the direction of variation. A positive value means a shift to the lighter (whiter) range.

The a* values of all samples in Table 3 were negative values. This indicates that the samples were more green than red, along the red – green colour coordinate. The a* values of the resin samples were higher than those of the shade guides, except for shade A 2.

The b* values of all samples in Table 1 were positive values. This indicates that the samples were more yellow than blue, along the yellow – blue coordinate. The resin composites showed higher b* values than their respective shade tabs.

The **hue** angle is denoted by h and is defined by the relation: $h = \text{arc tg } (b^* / a^*)$

If the hue angle is 90^0, the hue observed is yellow. If the hue angle is 160^0, the hue observed is parrot green. For all the specimens studied the hue angle is within this range, indicating that the hue observed lies within the yellow to green range.

Several studies[5,12] have evaluated a large number of natural teeth by using the Munsell colour system and CIELAB system. The commercially available shade guides pose further problems. They are not constructed to match natural teeth as evidenced from Sproull's studies in human extracted teeth[10]. Recent spectrophotometric evaluations have shown that shade guides may have different generations of teeth within a given guide and that there is a variation between different manufacturer's shade guides. There is also an inadequate control of the different batches of one shade from the manufacturer. Quality control is generally perceptual, not spectrophotometric.

Manufacturers are cognizant of these problems and many have developed resin composites that are keyed to the Vita Lumin shade guide[5,18]. As it was designed for porcelain there are many technical problems involved in the development of resin composites to match a porcelain shade guide[11].

Clark has cited the four great problems in colorimetry as being fluorescence, metamerism, translucency and samples that are not homogenous[14,15,16]. Natural teeth also present the problems of having a glossy surface that incurs specular reflectance and

an irregular surface. It is obvious that the natural tooth is not an easy object to measure.

It should also be remembered that the uncured resin generally differs in shade from the cured material. The chromatic shift of the cured resin is towards the blue – green region of colour space, resulting in a perceived decrease in yellow chroma. This may explain in part, the generally poor match observed between the composite materials evaluated and their shade guides[21]. It is therefore vital to use a cured sample of the chosen material, as a shade guide.

Due to the inherent shortcomings in almost all stock shade guides, clinicians have often recommended the fabrication of custom shade guides[15]. As an alternative many dentists manage without custom shade guides and devise other shade selection techniques, such as the "dab on" technique[5,17], where a small amount of resin is placed on the tooth to be restored and is polymerized. The shade of this dab is then compared to the shade of the tooth to be restored.

The failures of the present shade matching systems are proven to be of significant importance. So newer systems should be developed that can generate colour in the same manner, as does a natural tooth and transmit, reflect, scatter light and fluoresce naturally[10].

There is no doubt that fabrication of an artificial complement to the natural dentition will always require artistic skills and accurate colour perception. However, the potential elevation of colour matching from the abysmal level at which it has hovered for so long upto the level of true science is exhilarating. The advent of improved techniques is encouraging and the anticipation of further progress in the colour replication procedure seems justified.

CONCLUSION

- All resin specimens of Tetric Ceram, Z 100 and Charisma showed perceptible colour differences in comparison with their respective shade guides.
- None of the materials showed ΔE^* less than 1.0, hence the colour difference is easily discernible.
- The colour difference between the standard and the samples for the darker shades is less than that for the lighter shades (A 4 shade showed the least colour variation).
- Charisma showed less mismatch or discrepancy between the resin product and the shade tab.
- The L* values were positive, indicating a shift to white, the a* values were negative, indicating a shift to green and the b* values were positive, indicating a shift to yellow, in accordance to their respective coordinates in the three – dimensional colour space.
- The hue observed is within yellow to green, as denoted by the hue angle between $90^0 - 160^0$.

The results of this study highlight the inadequacies of stock shade guides and recommend the fabrication of custom shade guides from the restorative material itself for improved shade reproduction.

REFERENCES

7. Alain Chrisment. Colour and colorimetry. III Edition. Datacolour.
8. Culpepper W. D: A comparative study of shade – matching procedures. J. Prosthet. Dent. 1970; 24: 166 –173.
9. Durbuhinn K et al: The science of communicating the art of esthetic dentistry. Part III: Precise shade communication. J. Esthet. Restor. Dent. 2001; 13: 154 – 162.
10. Johnston W. M and Kao E. C: Assessment of appearance match by visual observation and clinical colorimetry. J. Dent. Res. 1989; 68; 819 – 822.
11. Kim H. S and Um C. M: Colour differences between resin composites and shade guides. Quint. Int. 1996; 27: 559- 567.
12. O'Brien w. J, Groh C. L and Boenke K. M; A one – dimensional colour order system for dental shade guides. Dent. Mater. 1989; 5; 371 – 374.
13. Okubo S. R et al: Evaluation of visual and instrument shade matching. J. Prosthet. Dent. 1998; 80: 642 – 648.
14. Paul S et al: Visual and spectrophotometric shade analysis of human teeth. J. Dent. Res. 2002; 81: 578 – 582.
15. Pizzamiglio E: A colour selection technique. J. Prosthet. Dent. 1991; 66: 592 – 596.

16. Preston J. D: Current status of shade selection and colour matching. Quintessence International. 1985; 47 –58.

17. Ryther J. S, Lund P. S and Aguilino S. A: Colorimetric evaluation of shade guide variability [abstract 890]. J. Dent. Res. 1993; 72: 215.

18. Schwabacher W. B and Goodkind R. J: Three- dimensional colour coordinates of natural teeth compared with three shade guides. J. Prosthet. Dent. 1990; 64: 425 – 431.

19. Sim C. P. C, Yap A. U. J and Teo J: Colour perception among different dental personnel. Op. Dent. 2001; 26: 435 – 439.

20. Sproull R. C: Colour matching in dentistry. Part I. The three – dimensional nature of colour. J. Prosthet. Dent. 1973; 29: 416 – 424.

21. Sproull R. C: Colour matching in dentistry. Part II. Practical applications of the organization of colour. J. Prosthet. Dent. 1973; 29: 556 –566.

22. Sproull R. C. Colour matching in dentistry. Part III. Colour control. J. Prosthet. Dent. 1973; 29: 146 – 154.

23. Sturdevant C.M: The art and science of operative dentistry. IV Edition.

24. Swift E. J. Jr, Hammel S. A and Lund P. S: colorimetric evaluation of Vita shade resin composites. Int. J. Prosthodont. 1994; 7: 356 – 361.

25. van der Burgt T. P et al: A comparison of new and conventional methods for quantification of tooth colour. J. Prosthet. Dent. 1990; 63: 155 – 162.

26. van der Burgt T. P et al: A new method for matching tooth colours with colour standards. J. Dent. Res. 1985; 64: 837 – 841.

27. Yap A.U. J et al: Shade match of tooth coloured restorative materials based on a commercial shade guide. Quint. Int. 1995; 26: 697 – 702.

Statement about ownership and particulars of the Journal

"JOURNAL OF THE PIERRE FAUCHARD ACADEMY - INDIA SECTION"

Required by Rule 6 of the (Central Rule, 1956)

1.	Place of Publication	:	4, Amber Apartment, 13-2, M.G. Road, Indore-452 001
2.	Periodicity of its Publication	:	Quarterly (March, June September & December)
3.	Printer's Name	:	Dr. Ved Prakash Jalili
	Nationality	:	Indian
	Address	:	4, Amber Apartment, 13-2 M.G. Road Indore-452 001
4.	Pubisher's Name	:	Dr. Ved Prakash Jalili
	Nationality	:	Indian
	Address	:	4, Amber Apartment, 13-2 M.G. Road Indore-452 001
5.	Editor's Name	:	Dr. Ved Prakash Jalili
	Nationality	:	Indian
	Address	:	4, Amber Apartment, 12-2 M.G. Road Indore-452 001
6.	Name and Address of individuals who own the Newspaper & or partners of shareholders holding more than one percent of the total Capital	:	Pierre Fauchard Academy, India Section 24/12C, Laxmipuram Gandhi Road Salem, Tamil Naud - 638 007

I Dr. Ved Prakash Jalili hereby declare that the particular given above are true to the best of my knowledge and belief.

Dated 31st March 2008

Signature of publisher

V.P. Jalili