

An Audit of Shade Reproduction of Fixed Metal Ceramic Prostheses

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Abstract - This investigation aimed to evaluate the colour difference between metal ceramic restorations and their corresponding shades and any reasons for a colour mismatch in the dental laboratory. The colour of 50 consecutive metal ceramic restorations produced in a laboratory was measured using a spectrophotometer and compared to the shade tabs. Colour reproduction was optimal at porcelain thicknesses between 1.4-1.6mm, varied between technicians within the same laboratory and was better for shades in the 2M group. Most crowns were above the threshold for a clinically acceptable shade match and almost all crowns were lighter than the corresponding shade tab.

KEY WORDS: Shade reproduction, Spectrophotometry, Metal ceramic restoration

INTRODUCTION

A poor shade match is not uncommonly the reason for a patient to be unhappy with laboratory fabricated fixed prosthodontic work and thus repeated attempts must be made to rectify the problem. This of course brings added cost, whether it is to the patient, the dental practitioner, or the laboratory, in not only material terms, but in time spent making and remaking the prosthesis. There have been widespread reports regarding inaccuracies of shade taking, however there is little information regarding the reproduction of these shades in the laboratory and the effects that this can have on the end result of the prosthesis. Understanding the complications and weaknesses of current methods of reproducing shades for porcelain crown and bridgework should lead logically to the development of improved laboratory and clinical techniques and thus improved definitive shade replication.

A successful shade match is in most part down to the subjective opinion of the operator and patient, decided prior to cementation; however there are ways of quantifying the accuracy of such a shade match. One such way is spectrophotometry¹ which is becoming more widely used in dentistry. Shade match by spectrophotometry is based on the International Commission on Illumination L*a*b* 1971 system (CIELAB)². This uses 3 values, L*, based on the lightness of the colour, a*, the colours position between red and green, and b*, its position between yellow and blue. Using the values of L* a* and b* two colours can be compared to each other using the colour difference formula below to give a value, Delta E, for the difference between the two colours².

$$\text{Delta E} = \sqrt{(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2}$$

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Devices such as hand held spectrophotometers and colorimeters reveal figures such as 96.4% reliability and 92.6% accuracy for the VITA Easyshade³. Nevertheless, it should be noted that some devices are still showing poor accuracy even though repeatability seems to be of a fairly consistently high standard^{3,4,5}. The laboratory based spectrophotometer used in this study will not incur the same difficulties faced by those required to operate in a clinical setting as they do not need to consider infection control, abnormal lighting conditions, and difficulty of access often experienced when taking a shade intraorally.

This would provide a suitable means for testing the accuracy of shade reproduction within the dental laboratory. When interpreting Delta E values, a value of less than or equal to 1.0 is supposedly undetectable to the naked eye. Under intraoral conditions however, it has been shown that 50% of observers could perceive a colour difference at 2.6 Delta E units and that 50% of observers viewed a colour match as clinically unacceptable over 5.5 Delta E units⁶. Another study reported that the mean Delta E value between natural teeth and crowns that was classified as a perfect or excellent shade match was 1.6 Delta E units, although this ranged from 0.2-2.9⁷.

Errors are easily encountered when taking shades and a good shade is dependent on the lighting conditions^{8,9} and the quality of the shade guide^{10,11} amongst other factors. The clinician is also of great importance, females have been shown to be better at shade taking than men, whilst experience has shown to matter less and even the same clinician can select two different shades when trying to match the same tooth at separate occasions^{12,13}. Similar errors can also occur in the reproduction of shade within the dental laboratory, in addition to several other aspects of producing dental porcelain that can lead to an unsatisfactory final shade.

This investigation negates the effect of a clinician error in shade taking by simply comparing the requested shade to the shade that has been produced by the laboratory. There are many difficulties in accurately reproducing a shade in the dental laboratory. Firstly there may be differences in

shade on the laboratory technicians shade guide to that of the clinician. This may be due to differences in shade guides direct from the producer or due to the staining or discolouration of the porcelain on the shade guide over time leading to the technician matching the crowns shade to a different colour than prescribed. The lighting in the dental laboratory may also affect the shade produced as the porcelain may appear different if made in the absence of a similar light source to which the shade was taken. The actual porcelain used for build-up may also differ slightly from the shade tab. The porcelain shade may also be affected by over firing, although no significant difference has yet been found to confirm this¹⁴. Aside from this, differing porcelain build-up techniques may lead to variations as could the thickness of the porcelain on the final restoration. It has been shown that the ability to reproduce a porcelain shade varies significantly between different technicians in different laboratories and that shade reproduction in the incisal portion of the crown was significantly more accurate than that of the middle third¹⁵. The effect of varying the thickness of porcelain disks has also been shown to significantly alter the shade of the final restoration¹⁶; however this investigation is aimed at evaluating any significant differences when these varying thicknesses of porcelain are applied to metal ceramic restorations in more clinical situations. The metal used behind the porcelain also has an effect on the accuracy of shade match, porcelain fused to metal crowns exhibit a poorer shade match in comparison to gold electroformed crowns or In-ceram alumina crowns¹⁷. Finally, in many cases varying proportions of multiple shades are prescribed when reproducing the shade of a single tooth, this may be as dentine and enamel porcelain layers, differing shades of enamel porcelain on the outer surface of the tooth, or even the use of artificial staining.

AIM

The aim of this study was to investigate the accuracy of shade reproduction for fixed metal ceramic prostheses in the dental laboratory by use of a spectrophotometer as a means of consistently and accurately assessing shade. This study used metal ceramic restorations that were later cemented in a patient's mouth and as such it can be seen as an accurate representation of the standards of production of these restorations in the laboratory. The null hypothesis is that there will be no difference in colour between metal ceramic prostheses produced in the laboratory and the corresponding VITA 3D shades using the difference of 5.5 Delta E as an acceptable threshold.

METHOD

A sample size of 50 metal ceramic restorations was collected. These were any metal ceramic restorations on for any tooth, produced from the start of data collection in June, till the end of July 2009, within Liverpool University Dental Hospital (LUDH). The crowns had to be porcelain bonded to metal crowns and any bridges sampled must be porcelain bonded to metal abutments.

Data collection forms were produced and distributed to each of the six laboratory technicians for completion with each metal ceramic restoration they produced. This included the technician that completed the work (each as-

signed a random number for anonymity), the tooth to be restored, the type of restoration constructed, the base metal alloy used, the alloy thickness prior to the porcelain build-up measured with callipers (accuracy of +/- 0.1mm), and finally the shade with any proportions of shade variance on the tooth. There was also an extra box to be completed if the technician did anything that may also affect the shade on construction of the restoration, such as adding surface staining. The data were then transferred to a data table by one of the investigators upon recording of the shade.

A portable bench colour measurement instrument (Minolta CM-2600d spectrophotometer) was used which has an integrating sphere system and uses (d/8) diffuse illumination and 8-degrees viewing geometry. The spectrophotometer was used with the following settings: D65 illumination curve; 2° observation angle curve; specular component included (SCI); ultraviolet light (UV) included; and small aperture size (SAV) of 3mm/6mm measurement area. Prior to recording any values, the spectrophotometer was calibrated to zero and white using the standard white tile in accordance with the manufacturer's instructions. The total thickness of the restoration was then measured, again using callipers and this was used to calculate the thickness of the porcelain by subtracting the thickness of the alloy from the total thickness. The shade was then taken in the laboratory under the same ordinary lighting conditions used to construct the prostheses by holding the middle third of the restoration to the measuring area of the spectrophotometer. Three readings were taken in succession without repositioning for each restoration and the average of the three values for each of L*, a* and b* were calculated and recorded. Every five samples taken, the spectrophotometer was recalibrated as outlined above. This was done twice each week for the duration of the investigation.

The shades of all the tabs on the Vita 3D shade guide were also taken by the same method as above. Delta E values were then calculated for each restoration compared to the requested shade on the Vita shade guide using the aforementioned formula².

The data (Delta E values) was transferred to a spread sheet (SPSS, 15) and the mean, standard deviation and 95% confidence interval was calculated for the most common shades (2M2, 2M3, 3M3 and 4M2) in order to compare the colour differences at a 0.05 significant level. The colour difference Delta E was also compared to the acceptability threshold of 5.5 Delta E. The colour measurements of 10 samples were repeated and Intraclass Correlation Coefficient was calculated in SPSS to evaluate the precision of the used colour spectrophotometer.

RESULTS

Table I summarizes the mean Delta E results for shade match.

Of the 50 samples taken, shades ranged between 2L1.5 and 5M2, the most commonly used shades being 2M2, 2M3, 3M3 and 4M2. Reproduction of Vita 3D shade 2M2 (mean Delta E of 5.55, standard deviation 1.41) was more accurate than reproduction of shades 3M2 (mean Delta E 8.11, standard deviation 1.08) and 4M2 (mean Delta E 9.01, standard deviation 1.74). Illustrated in figure 1. Mean Delta

Table 1. Data for mean Delta E values compared using different variables of shade, technician and porcelain thickness.

<i>VITA Shade</i>	<i>2M2</i>	<i>2M3</i>	<i>3M3</i>	<i>4M2</i>		
Mean Delta E	5.55	6.02	8.11	9.01		
<i>Technician number</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>
Mean Delta E	8.36	4.98	7.23	7.55	9.15	7.38
<i>Porcelain Thickness (mm)</i>	<i><1.1</i>	<i>1.1-1.3</i>	<i>1.4-1.6</i>	<i>>1.6</i>	<i>1.4-1.8</i>	
Mean Delta E	8.52	7.79	6.33	6.83	6.05	

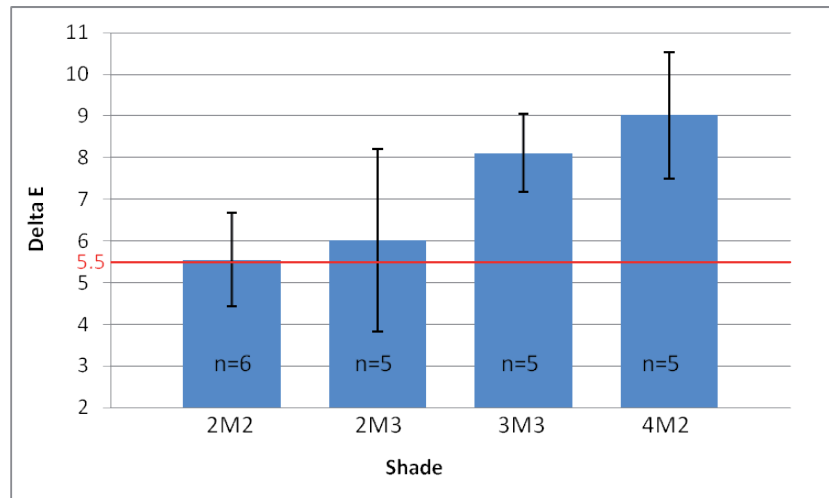


Figure 1 - Mean Delta E differences for the four most common shades produced with 95% confidence intervals and the upper limit of the acceptable shade mismatch for a crown

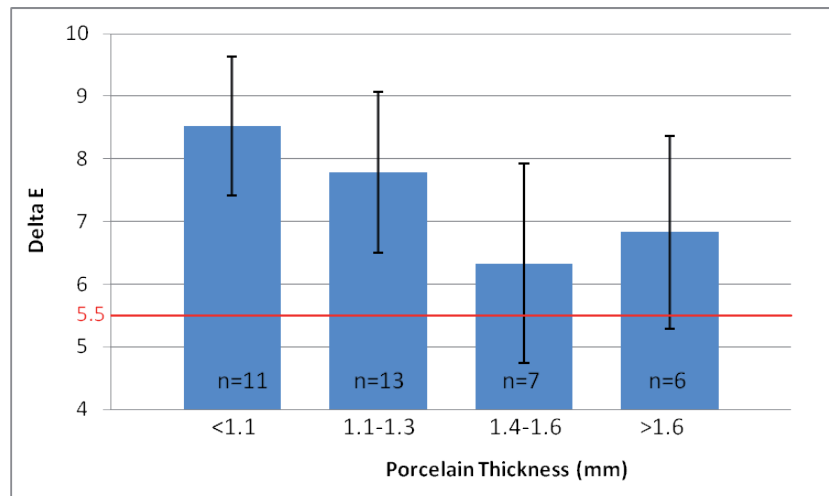


Figure 2 - Mean Delta E difference for varying porcelain thicknesses with 95% confidence intervals and the upper limit of the acceptable shade mismatch for a crown

E differences in shade match for different technicians varied between 4.98 (standard deviation 1.69) and 9.15 Delta E units, illustrated in figure 2. Sections of porcelain thinner than 1.1mm demonstrated a large shade discrepancy (mean 8.52 Delta E units, standard deviation 1.88) compared with those between 1.4mm and 1.6mm (mean 6.33 Delta E units, standard deviation 2.15). Illustrated in figure 3.

The value for L* is almost always considerably lower (darker) on the shade guide than the value for L* on the

crown specimen itself. The mean difference between the two L* values was 6.59. Figure 4 shows the differences between L* a* and b* values for the crowns compared to the corresponding shade tab.

The Intraclass Correlation Coefficients using an absolute agreement definition for repeated measurements was 0.998 (CI 0.996-0.999), which was significant at 0.0001 level.

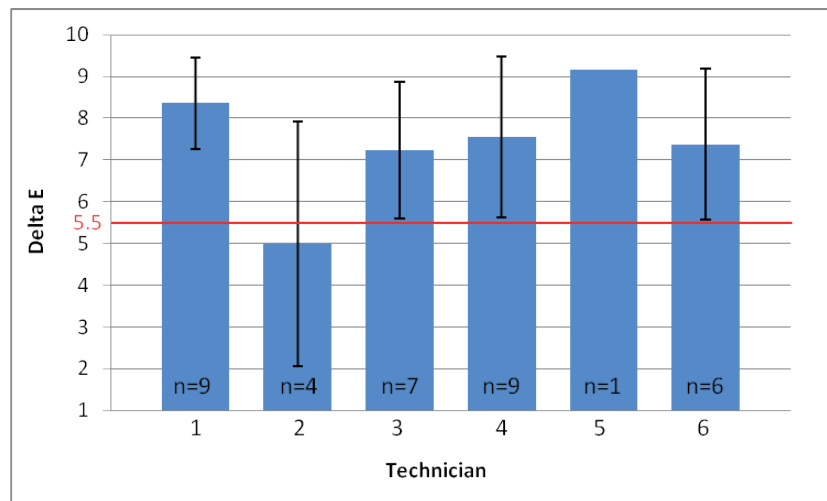


Figure 3 - Mean Delta E difference for individual technicians with 95% confidence intervals and the upper limit of the acceptable shade mismatch for a crown

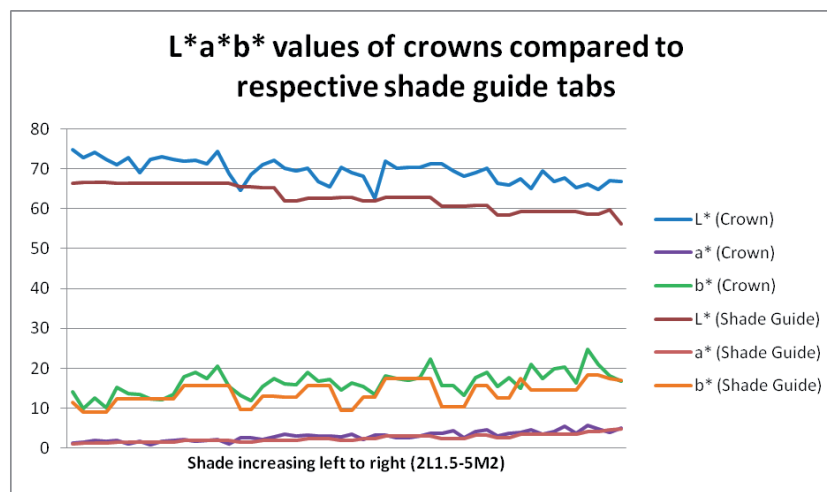


Figure 4 – L*a*b* values of crowns compared to the respective shade guide tab

DISCUSSION

Analysis of the investigation results shows increased accuracy of shade reproduction within the 2M group when compared with 3M and 4M shade ranges. The mean Delta E value for crowns produced to shade 2M2 was still greater than 5.50 Delta E units, the level at which 50% of observers would classify a shade match as clinically unacceptable⁶. Only one metal ceramic restoration produced through the duration of this study would have been deemed a clinically a perfect or excellent shade match⁷, this was made in shade 3M2. One possible problem noted by the investigator was that if a technician has seen the patient for which the crown will be fitted, they may use additional colour enhancement in order to improve the colour match the patient's adjacent teeth rather than a specific shade on the shade guide. The use of staining in the laboratory is also often to modify the shade of the metal ceramic restoration to improve the colour match. In any cases such as this, where staining was used, it was recorded and when comparing the results from the spectrophotometer, there were no significant differences.

This study has indicated that there is significant variation in porcelain colour reproduction amongst different techni-

cians working within the same laboratory using the same materials. Technician 2 produced more accurate shade matches comparing to the shade tab than technician 1. Each of the technicians working in the laboratory has a different level of experience and used different methods to build and fire the porcelain. These results indicate that the porcelain build up in the laboratory is a very technique sensitive procedure, whether it is related to thickness of the underlying alloy, application of the opaque layer, proportions of dentine and enamel built up, or possibly in the firing of the porcelain. Further investigation is required in this area to identify more accurately any specific factor that may affect the reproduction of shade greater than others. Some research has been done in this area focussing on certain elements alone but no comparative studies were found relating to any individual stage having a greater affect on shade reproduction than another¹⁶.

The effect of varying the thickness of porcelain has been shown on disks of porcelain¹⁶ and this study would seem to support the findings of that study in that thicker sections of porcelain allow for better shade reproduction. The ideal porcelain thickness for shade reproduction appears to peak at between 1.4-1.6 mm, however there were no significant findings indicating that porcelain shade reproduction in

thicker sections had greater Delta E values. It should be noted though that increasing porcelain thickness will obviously require heavier preparation on the tooth itself, preparations thicker than 1.5mm may have significant risks for the health of the pulp. It has been shown that failure rate of crowns due to pulp necrosis after preparation is 15.6%¹⁵. For heavier preparations that are closer to the pulp the risk is even higher, bridge preparations showed signs of pulp necrosis in 32.6% of cases¹⁸.

Almost all of the crowns fabricated in the laboratory throughout this study were shown by the spectrophotometer to be a lighter shade than the respective shade tabs. This is one area which would require further study to try and establish why this occurred. It wouldn't be unreasonable to propose that this was due to the opaque layer overlying the metal and due to insufficient porcelain thickness. There appears to be a greater difference in L* values when the prescribed shade itself becomes darker. If the opaque layer was white (high L* value), this would be the expected pattern with darker shades being affected more. Perhaps a way to reduce this affect would be to produce different shades of opaque layer overlying the metal, corresponding to the desired shade of the final restoration. A darker opaque layer for instance would in theory produce a better shade match if the prescribed shade was darker.

The measuring area of the spectrophotometer used in this study was 6mm for illumination and 3mm for measurement, using a spectrophotometer with a smaller lens it may be argued would have been advantageous, however the larger lens enabled a larger portion of the specimen to be sampled, therefore reducing the risk of anomalies due to small areas of shade variation. This also reduced the affect of taking shades from slightly different points on the tooth which has been shown to be done more accurately nearer the incisal edge¹⁴.

Further work that would aid this study would be to investigate the numbers of metal ceramic restorations of the samples measured that were returned to the laboratory as unacceptable due to colour mismatch. This would give an indication of the dentists view on the acceptability of the work and also give further insight as to the standard that is generally accepted for a shade match.

Any further work should also include a thorough visual assessment of the metal ceramic restorations being investigated. This would help identify any anomalous results or any factors that may have a significant impact when viewed using the spectrophotometer but that are less significant when viewed in a normal clinical setting by naked eye.

CONCLUSION

Within the limitations of this study, it can be said that most metal ceramic restorations produced in the dental laboratory are above the acceptable shade mismatch (5.5 Delta E units). Shades are better reproduced amongst the 2M group of shade tabs than darker ones, porcelain thickness should be above 1.4mm to allow best shade reproduction and that shade reproduction depends on a technician's ability rather than simply materials used. Finally, the definitive restorations were almost always produced lighter than the shade guide when analysed spectrophotometrically.

MANUFACTURER'S DETAILS

- Vita™: Vita Zahnfabrik H. Rauter GmbH & Co. KG, Postfach 1338, D-79704 bad Sachingem, Germany
- Minolta 2600d portable spectrophotometer, Nieuwegein, Netherlands

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