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Research Article

Placement of Borders of Metal and Ceramic Copings and their Influence on Aesthetics of Crowns an *in vitro* study conducted on extracted premolars using spectrophotometer

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Abstract

Objectives: To find out the colour change that occurs in the metal-ceramic and all-ceramic crowns, with full collar, 1 mm and 2 mm cutbacks employed in the substructure, using spectrophotometer.

Materials and Methods: Three recently extracted maxillary premolars with no signs of damage or discoloration were mounted on an acrylic block. Color of the teeth was measured using spectrophotometer before the preparation and teeth were prepared conventionally to receive full coverage restorations. For each of the prepared tooth metal-ceramic and all ceramic (IPS Empress -lithium disilicate, Zirconia) crowns with full collar, 1 mm and 2mm cutbacks in their substructure were prepared and colour was measured using Spectrophotometer.

Results: Among the materials Zirconia showed the maximum colour change and among the collars full collar showed the highest colour change.

Conclusions: 1. Among the materials higher colour changes were recorded with Zirconia followed by IPS-Empress, and metal ceramic. 2. Among the three collars, higher colour changes were recorded with full collar, followed by 2mm cut back and 1 mm cut back. 3. Among all-ceramic crowns IPS Empress crowns showed less change in colour than the Zirconia. 4. Amongst the three types of crowns fabricated, zirconia exhibited higher change in colour than IPS Empress and metal-ceramic. 5.Presence of a full collar in the metal-ceramic crowns, IPS Empress and zirconia crowns can cause colour change. To obtain colour match it is desirable to employ cutback preferably of 2 mm.

Keywords: Metal Ceramic Crowns; Zirconia; IPS Empress Crowns; Cutback; Spectrophotometer

Introduction

Aesthetic quality of a fixed restoration to a greater extent dictates its success. A restoration should match the morphologic features and shade of the adjacent teeth and that is why colour matching has gained importance in fixed prosthodontics. Patients with high aesthetic expectations and demands make the restorative task very challenging [1-3].

Different materials like metals and ceramics have been proposed to make restorations. The metal ceramic crown is one of the most popular restorations used in Prosthodontics because of aesthetics, strength, fit, and reasonably good survival rate [4]. Traditionally, frameworks for metal-ceramic restorations incorporate a collar which is in fact an aesthetic handicap. Metal copings block light transmission through the tooth structure, darkens the root and cause discoloration of gingiva adjacent to the restoration. The opaque porcelain layer which is used to mask the dark colour of the underlying metal framework also act as a barrier to light transmission and impairs translucency, which is more evident in the cervical portion, where the porcelain is thinner [5]. Hence several techniques have been proposed to fabricate collarless metal ceramic restorations viz. metal framework reduction for variable distances from the labio-cervical line angle. When all-ceramic crowns with lithium disilicate and zirconia were introduced, they were considered to be the epitome of aesthetic quality. However, Zirconia cannot claim to provide superior translucency. Both in metal-ceramic and in all-ceramic restorations, the cervical region challenges the aesthetic achievement. Hence employing a cutback in the substructure is considered to be a viable technique, which can bring in aesthetic changes.

Generally, practitioners try to do the colour matching solely relying on their visual acuity. But it has been proved that human eye has limitations to make out distinctions of different shades of colour. Hence instrumental analysing systems are being utilised to improve reliability in colour matching [6].

The present study was designed in this context with the following objectives

- To find out the colour change that occurs after placement of metal-ceramic crowns with full collar, 1 mm and 2 mm cut back in the substructure using spectrophotometer.
- To find out the colour change that occurs after placement of IPS Empress crowns with full collar, 1 mm and 2 mm cut back in the substructure using spectrophotometer.
- To find out the colour change that occurs after placement of Zirconia crowns with full collar, 1 mm and 2 mm cut back in the substructure using spectrophotometer.

Methodology

Three recently extracted premolars with no sign of damage or discoloration were selected and stored in a solution of thymol in water which was kept at room temperature. Each tooth was mounted on a self-cure acrylic resin block (Figure 1,2). Putty index of each mounted tooth was made and colour of each tooth was measured using spectrophotometer (Datacolor USA) before the tooth preparation (Figure 3,4). Mounted teeth were conventionally prepared to receive full coverage restorations. For each of the prepared tooth metal-ceramic and all ceramic (IPS Empress, Zirconia) crowns with full collar, 1 mm and 2mm cutbacks in their substructure were prepared and colour was measured using the spectrophotometer. Colour measurement was done at the cervical region in the midline, towards the mesial surface and distal surface.

Figure 1: Maxillary premolar.

Figure 2: Maxillary premolar - occlusal view.

Figure 3: Putty index that guides tooth reduction.

Figure 4: Spectrophotometer.

Tooth preparation

- **Occlusal reduction:** Occlusal reduction was done with a round end tapered diamond. The inclined planes of the occlusal surface were maintained and functional cusp bevel was incorporated. Occlusal reduction was limited to 2 mm.
- **Axial wall reduction:** A flat end tapered diamond was used for axial wall reduction and shoulder finish line was incorporated. Shoulder depth was limited to 1.2mm. Axial surfaces were smoothened with finishing bur.
- **Impression Procedures:** Two layers of wax spacer was adapted on the prepared tooth and a custom acrylic tray was made. Impression was made in putty (addition silicone). Wax spacer was removed and the impression was lined with light body (addition silicone) (Figure 5). The impression was poured using die stone.

Figure 5: Prepared tooth and impression.

Laboratory procedures

Metal ceramic crowns

The dies were coated with two layers of die spacer, 1mm short of the preparation margin. Three wax patterns were prepared on the die of each tooth, one with full collar and other two with axial cut back of 1 mm and 2mm from bucco gingival line angle (Figure 6). These wax patterns were sprued and invested in phosphate bonded investment. The investment was allowed to set for 45 minutes, followed by burnout and casting using induction casting machine. Three Nickel chromium (Ivoclar Vivadent, Germany) copings were fabricated, one with full collar and other two with axial cut back of 1mm and 2mm (Figure 7). These copings were layered with opaque, body and enamel porcelain (Feldspathic porcelain - Noritake, Japan). (Figure 8).

All ceramic crowns- Lithium di silicate (IPS Empress)

The mould was prepared using the lost wax technique as described for metal ceramic crowns. For the burnout, the ring was placed in the furnace where it was heated from 200°C to 900°C in 1 hour and maintained at the latter temperature for 30 min. Meanwhile, the pressing furnace was preheated to 700°C for 45 minutes. Lithium disilicate ceramic ingots and the plunger were then heated

Figure 6: Wax patterns used for making metallic copings.

Figure 7: Metal copings with opaquer.

Figure 8: Completed metal ceramic crowns.

in the burnout furnace for 5-10 minutes. The heated ingots and plunger were introduced in the heated mould that was placed in the pressing furnace (Figure 9). The temperature was increased at the rate of 60°C per minute till it reached 1075°C and was maintained for 20 minutes. At the end of this cycle the plunger pushed the ingots into the mould. The ring was then cooled for 45 minutes. The ceramic casting was divested using 250μm aluminium oxide particles. Three copings were fabricated, one with full collar and other two with axial cut back of 1 mm and 2 mm from bucco cervical line angle (Figure 10). These copings were layered with deep dentin, dentin and incisal porcelain (Figure 11). Final glazing was done with universal glazing paste.

Figure 9: IPS Empress hot press.

Figure 10: IPS Empress copings.

Figure 11: IPS Empress crowns.

Figure 13: Ceramill Zirconium CAD-CAM block.

All ceramic crowns- Zirconia using CAD-CAM

Titanium dioxide powder was sprayed on the dies and scanned under digital scanner (Figure 12). Using 3D software, a three-dimensional virtual image of the specimen for full collar and other two with axial cut back of 1 mm and 2 mm from bucco gingival line angle were made. Zirconium CAD blocks were selected (Figure 13). The block was inserted in the work piece spindle and the door of the milling unit was closed. The milling procedure was completed and the copings were taken out of the milling unit. These copings were layered with opaque, body and enamel porcelain (Figure 14).

Figure 12: Ceramill CAD-CAM Scanner and Milling Unit.

Figure 14: Zirconia crowns.

For each tooth, different types of crowns were fabricated repeatedly ten times.

Determining the colour of specimens

The colour of each crown was determined using Spectrophotometer and Δ L*, Δ a* and Δ b* values were be obtained. The change in colour was determined using the formula,

$$\Delta E = [(L^*1 - L^*2)2 + (a^*1 - a^*2)2 + (b^*1 - b^*2)2] ½$$

Statistical analysis

The results were subjected to Factorial ANOVA to detect statistically significant differences among the groups (Figure 15).

Figure 15: Flow chart on methodology.

Results

In this experiment, there were three factors that influenced the ΔE values viz. different types of restorative materials, different collar designs and the different regions used for colour measurement. Materials are three in number - Metal-ceramic, Lithium di silicate (IPS-Empress) and Zirconia. Collars are of three types - Full collar, 1mm cutback and 2mm cutback. Region at which colour measurement is done are three in number - distal, mesial and midline.

Factor	Level
Material	Metal-ceramic, IPS-Empress, Zirconia
Collar	Full collar, 1mm cutback, 2mm cutback,
Region	Midline, Mesial, Distal

Table a

Null hypotheses

- **H0(a):** There is no significant difference between the different types of Materials.
- **H0(b):** There is no significant difference between the different types of Collars.
- **H0(c):** There is no significant difference between the different types of regions.
- **H0(d):** The interaction (joint effect) of material and collar is not significant.

Alternate hypotheses

- **H1(a):** There is a significant difference between the different types of Material.
- **H1(b):** There is a significant difference between the different types of Collars.
- **H1(c):** There is a significant difference between the different types of regions.
- **H1(d):** The interaction (joint effect) of material and collar is significant.

Level of significance: $\alpha = 0.05$.

Decision criterion

The p-values were compared with the level of significance. If $P < 0.05$, the null hypothesis was rejected and accepted the alternate hypothesis. If $P > 0.05$, the null hypothesis was accepted. If there is a significant difference, multiple comparisons (post hoc-test) were carried out using Bonferroni method to find out among which pair or groups there existed a significant difference. Statistical technique used was Factorial ANOVA. Mean ΔE values recorded with different materials, collars and regions are given in table 1 and 3.

The most important factor in this experiment was found to be the restorative material followed by the region of colour determination and the type of collar respectively. Mean ΔE values were found to be higher in Zirconia followed by IPS-Empress and Metal-ceramic respectively. The difference between them was found to be statistically significant ($P < 0.001$). Mesial region had a higher mean ΔE value followed by Midline and Distal regions respectively. The difference in mean ΔE values among the regions was found to be statistically significant ($P < 0.001$). Full collar had a higher mean ΔE value followed by 1mm cutback and 2mm cutback respectively and the difference between them was found to be statistically significant ($P < 0.001$). (Figure 16).

Figure 16: Main effects plot.

Zirconia always gave a higher mean ΔE value with all the three types of collars. Between Metal-ceramic and IPS-Empress restorations, higher mean ΔE value was recorded in IPS-Empress when used with 1mm cutback or 2mm cutback, but Metal-ceramic restorations gave a higher mean ΔE value than IPS-Empress when full collar was used. Zirconia always gave a higher mean ΔE value compared to the other two materials irrespective of the region used. Full collar always provided a higher mean ΔE value compared to 1mm cutback and 2mm cutback (Figure 17).

Figure 17: Interaction plot.

Discussion

Absence of the metal framework in all-ceramic restorations minimizes or in fact eliminates the undesirable aesthetic effects, produced by the metal collar of metal ceramic restorations. It is generally accepted that in all-ceramic restorations, increased light transmission and diffusion can be achieved. However, all ceramic restorations made of Zirconia have opacity and the optical behaviour has been considered similar to that of metals. Eliminating the metal frame work and the ceramic core materials is expected to improve the aesthetic properties of fixed restorations. The present study was conducted in this context.

Delta-E (ΔE) is a measurement used to indicate how much a colour deviates from an accepted standard. Higher the ΔE, the more inaccurate the colour is. Perfect colour match has a ΔE of zero. The minimal detectable difference is about 1 ΔE [7]. The following table gives the range of ΔE and its relevant meaning.

Delta-E Value	Meaning
0-1	A normally invisible difference
1-2	Very small Difference, only obvious to trained eye
2-3.5	Medium difference, also obvious to trained eye
3.5-5	An obvious difference
> 6	Very obvious difference

Table b

The objective of the present study was to measure the colour change that occurs after placement of metal-ceramic and all-ceramic crowns viz. IPS Empress and Zirconia, with different substructure designs viz. full collar, 1mm cutback and 2mm cutback. Recently extracted maxillary premolars were used to make the specimens. Colour of the tooth was measured before preparation using spectrophotometer and tooth preparation was done for full coverage restoration. Metal ceramic, IPS Empress - Lithium di silicate and Zirconia crowns were fabricated on each of the prepared tooth with substructure having full collar, 1 mm cutback and 2 mm cutback. The crowns were placed on the prepared tooth and colour was measured using spectrophotometer.

Among the three materials, Zirconia recorded higher mean ΔE values of 8.83 ± 2.44, followed by IPS-Empress 5.2 ± 1.19 and metal-ceramic 4.62 ± 1.64 respectively. The difference in mean ΔE values among them was found to be statistically significant (P < 0.001). While considering the ΔE values metal-ceramic and IPS Empress crowns fall in to the category of an obvious difference and zirconia fall into the category of very obvious difference (Table 1).

Material	Mean	Std dev	SE of Mean	Median	Min	Max
Metal-ceramic	4.62	1.64	0.17	4.49	1.67	8.19
IPS-Empress	5.20	1.19	0.13	5.43	2.78	8.56
Zirconia	8.83	2.44	0.26	9.53	3.68	13.29

Table 1: Mean ΔE values recorded in different materials.

Among the collars highest mean ΔE values of 6.79 ± 2.69 was recorded in the case of full collar, followed by 6.05 ± 2.68 for 1 mm cutback and 5.81 ± 2.39 in for 2 mm cutback. The difference in mean ΔE values among them was found to be statistically significant (P < 0.001). On considering mean ΔE values all collars fall into the category of very obvious difference (Table 2). Among the different areas of the buccal surface were compared, highest mean ΔE values of 6.90 ± 2.38 was recorded in case of 2 mm mesial to midline, followed by 5.90 ± 2.81 in case of midline and followed by 5.86 ± 2.52 in the case of 2 mm distal to midline. The difference in mean ΔE values among them was found to be statistically significant (P < 0.001). On considering the mean ΔE values all the areas fall into the category of very obvious difference (Table 3) (Figure 16,17).

Collar	Mean	Std dev	SE of Mean	Median	Min	Max
Full collar	6.79	2.69	0.28	6.23	3.59	13.29
1mm cutback	6.05	2.68	0.28	5.38	1.67	10.32
2mm cutback	5.81	2.39	0.25	5.92	2.02	10.95

Table 2: Mean ΔE values recorded with different of collars.

Region	Mean	Std dev	SE of Mean	Median	Min	Max
Midline	5.90	2.81	0.30	5.03	2.65	13.29
Mesial	6.90	2.38	0.25	6.27	2.72	12.51
Distal	5.86	2.52	0.27	5.62	1.67	11.35

Table 3: Mean ΔE values recorded at different regions.

Among the three materials, higher mean ΔL values (lighter value) were recorded in IPS-Empress followed by Metal-ceramic and Zirconia respectively. The difference in mean ΔL values among them was found to be statistically significant (P < 0.001). The difference in mean ΔL values among the three collars was not statistically significant (P > 0.05) with 2mm cutback recording a higher ΔL value followed by 1mm cutback and full collar respectively (P > 0.05). The interaction (joint effect) of material and collar on mean ΔL value was also not statistically significant (P > 0.05) (Table 4).

Source	df	Sum of Squares (SS)	Mean SS	F	P-Value
Material	2	365.047	182.523	40.070	< 0.001*
Collar	2	2.867	1.433	0.310	0.731
Material x Collar	4	18.114	4.528	0.990	0.416
Error	81	369.006	4.556	---	---
Total	89	755.032	---	---	---

Table 4: ANOVA - ΔL.

*Denotes a significant factor.

On considering the mean ΔL values for different materials highest value of -1.68 ± 1.49 was recorded in the case of IPS Empress, followed by -2.96 ± 1.63 in the case of metal-ceramic, and -6.45 ± 2.93 in the case of zirconia. The difference in mean ΔL values among them was found to be statistically significant (P < 0.001).

On considering the mean ΔL values for collar, highest value of -3.47 ± 2.92 was recorded in the case of 2 mm cutback followed by -3.71 ± 2.50 was recorded for 1 mm cutback and 3.91 ± 3.34 for full collar. The difference in mean ΔL values among the three collars was not statistically significant (P value - 0.731) (Figure 18,19).

The most important factor in the present *in vitro* study to determine the shade change was found to be the restorative mate-

Figure 18: Main effects plot delta L values.

Figure 19: Interactions plot delta L values.

rial followed by the design of Collar. Mean ΔL values were found to be superior in IPS-Empress (between 1-2) followed by Metal-ceramic (3) and Zirconia (between 6-7) respectively. The difference between them was found to be statistically significant ($P < 0.001$). 2mm cutback had a higher mean ΔL value followed by 1mm cutback and full Collar respectively. The ΔL values were between 3 and 4. The difference between them was not statistically significant ($P > 0.05$). Vertical cut back was found to produce consistent effect matching natural tooth shade by some authors[8]. When used with any of the collars, IPS-Empress always gave a superior ΔL value followed by Metal-ceramic and Zirconia respectively. 2mm cutback yielded a superior mean ΔL value when used with IPS-Empress and metal-ceramic where as full collar yielded an inferior ΔL value when used with zirconia. The best ΔL value was always recorded when IPS-Empress was used with 2mm cutback.

Conclusions

The following conclusions were drawn from the present study

- Among the restorative materials higher colour changes were recorded with zirconia followed by IPS-Empress, and metal ceramics.
- Among the three collars, higher colour changes were recorded in the case of full collar, followed by 2mm cutback and 1 mm cutback.
- Mesial region had a higher mean ΔE value followed by Midline and Distal regions respectively.
- Among all-ceramic crowns IPS Empress crowns showed less change in colour than the zirconia.
- Amongst the three crowns fabricated with metal-ceramic (Nickel chromium/feldspathic ceramic), IPS Empress (Lithium disilicate) and zirconia, zirconia exhibited higher change than IPS Empress and metal-ceramic crowns.
- Zirconia crowns have higher potential of colour change when compared to IPS Empress crowns and metal ceramic crowns.
- Presence of a full collar in the metal-ceramic crowns, IPS Empress and zirconia crowns can cause colour change. To obtain colour match it is desirable to employ cutback preferably of 2 mm.

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