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Comparative Evaluation of Optical Behaviour of Cad-Cam and 3D Printed Provisional Restorations Before and After Ageing on Different Implant Abutment Materials: An In-Vitro Study.

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Abstract:
The purpose of this in-vitro study was to investigate color stability and translucency of milled and 3D printed PMMA crowns and effect of artificial ageing, when different interim implant abutment materials are used.
Material and methods: A narrow diameter implant analogue at right and left lateral incisor site in a maxillary dentate stone cast was used. Forty-eight PMMA crowns were divided into two groups according to manufacturing process: milled (n=24) and 3D printed (n=24) and they were tested against titanium coated with ceramic opaquer and PEEK interim implant abutments before and after artificial ageing. For artificial ageing, 500 cycles of thermocycling containing water bath with temperature of 5° and 55°C with a dwell time of 30 secs were carried out. By using clinical spectrophotometer, the color co-ordinates of crown-interim abutment pair were measured. The color stability (ΔE) and translucency parameter (TP) values of the crown were calculated by CIELab formula. The data were statistically analyzed using one-way ANOVA, Mann-Whitney U test and post hoc test (α=0.05)
Results: The manufacturing process and underlying interim implant abutment material significantly affected the ΔE of interim crowns ($p<0.01$), but no significant difference was found for TP ($p>0.05$). Highest ΔE was noted for CAD-CAM crowns against PEEK abutment ($p=0.54$). No statistically significant difference was found between the CAD-CAM and 3D printed when tested against titanium abutment coated with ceramic opaquer and PEEK abutment.
Conclusions: The underlying abutment material affected the color stability of CAD-CAM and 3D printed crowns. But it did not affect the translucency of crown-interim abutment pairs. Artificial ageing influenced color stability but not translucency.

Key-words: *Implant provisional restoration, interim abutment, PEEK abutment, clinical spectrophotometer.*

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I. Introduction

Provisional restorations in anterior region after implant placement are used to enhance aesthetics, function, stabilization, and as a reference for final prosthesis.[1] Different materials and techniques have been practiced for fabrication of these provisional restorations.[2] To overcome the shortcomings of traditional techniques, recently, manufacturing of restorations using computer-aided design/computer-aided manufacturing

(CAD/CAM) and three-dimensional (3D) printing or additive manufacturing has become an important process in dentistry and has replaced traditional methods in many areas.[3] The optical properties and their stability over time, are critical issues to be considered while selecting a proper material and technique of fabrication. Colour stability and translucency are regarded as clinically important parameters.[4] The metallic hue of titanium hampers the optical outcome.[5] Recently, polyetheretherketone (PEEK), which may be an alternative to titanium and can also meet aesthetic expectations, has been used in dental implantology.[6] The aim of this study was to evaluate the effect of different implant abutment materials and artificial ageing on the optical behaviour of provisional restorations fabricated on different implant abutment materials by using two recent techniques in dentistry.

II. Methods:

1. Coating of titanium abutment: The titanium abutment was coated with metal primer and allowed to dry for 30 minutes in open air. Onto the primed abutment two layers of metal opaquer (Ivoclar vivadent, IPS classic opaquer A2) were painted and light polymerized for one minute according to manufacturer's instructions.
2. CAD design and scan: The abutment was attached to the implant analogue placed at a maxillary right lateral incisor position and scanned for fabrication of implant provisional restorations by CAD-CAM and 3D printing for evaluation of optical properties. A titanium (Osstem, TS) (Fig. 5) and PEEK (Osstem, TS) hexed temporary abutment of gingival height 2 mm were attached to lab analogues at right and left maxillary lateral incisor position respectively. A digital maxillary and mandibular scans (Figure 1) were obtained by scanning the dental cast using an extraoral scanner (BSM) and saved as Standard Tessellation Language (STL).
3. Fabrication of samples: A cement retained single unit crown was designed with the parameters in Exocad, cement gap 80 micro-meter, minimal thickness 0.7mm. The design was then exported as an STL file and all the samples were fabricated using same STL file. 24 implant provisional restorations were milled by the five axis (BSM-520D) CAD/CAM system using the STL file obtained after scanning of the abutments in the cast. The milling process lasted about 8 hours. They were cleaned in an ultrasonic bath with 70% Isopropyl alcohol for 3 minutes. Similarly, 24 implant provisional restorations were printed using the 3D printer (Anycubic, Photon mono 4K), with a slice thickness of 100 µm, exposure time of 6 seconds, bottom exposure time of 50 seconds, lifting distance of 5 mm with lifting speed of 65 mm/min. The printing process lasted about 40 min. Provisional cement (Tempolink Clear Temporary resin cement) was used for cementation of implant provisional restoration on respective abutments.
4. Evaluation of colour stability: Implant provisional restorations were evaluated for colour stability by spectrophotometer against the black background under D65 illumination in the viewing box. Spectrophotometer was calibrated by placing contact tip probe on the calibration holder; built in the machine (One standard for calibration) before each specimen measurement (Figure 2). Each Implant provisional restoration was measured with single tooth mode by probe tip (5mm in diameter) at 90^0 to the surface on the centre of the disc and L*a*b value was recorded.
5. Evaluation of translucency parameter: Implant provisional restorations were evaluated for translucency parameter by spectrophotometer against the black and white background under D65 illumination in the viewing box (Figure 3). Each Implant provisional restoration was measured with single tooth mode by probe tip (5mm in diameter) at 90^0 to the surface on the centre of the disc and L*a*b value was recorded (Figure 4). After recording L*a*b values against both black and white background the translucency parameter was calculated using following formula:TP= [(L*B — L*W)2 + (a*B — a*W)2 + (b*B — b*W)2]1/2 [7]
6. Artificial ageing: For artificial ageing of samples, a thermocycling protocol was used. It has 2 chambers containing water bath with temperature of 5° and 55°C. 500 cycles were completed. Implant provisional restorations evaluated before artificial ageing were termed as S1 and after artificial ageing as S2. After artificial ageing of implant provisional restorations, by the protocol mentioned above, colour stability (Graph 1) and translucency parameter (Graph 2) were again evaluated and compared with the pre ageing values.
7. Statistical analysis: Normality of numerical data was checked using Shapiro-Wilk test. Inter group comparison (>2 groups) was done using Kruskall Wallis ANOVA followed by pair wise comparison using Mann Whitney U test (Table 1).

III. Results:

There is a difference in colour stability of CAD-CAM AND 3D printed implant provisional restorations on titanium coated with ceramic opaquer and PEEK abutment before and after thermocycling. There is a difference in translucency parameter of CAD-CAM AND 3D printed implant provisional restorations on titanium coated with ceramic opaquer and PEEK abutment before thermocycling.

IV. Discussion:

A multi-step nature of dental implant treatment requires long-term temporary restorations, intended to be used over a period of several weeks. For this, provisional restorations become utmost important for protecting the grafted tissue site during the healing phase and provides a tool for sculpting the surrounding gingival architecture, until a final prosthesis is fabricated.[8] In cases with dental implant placement in anterior region, it becomes more aesthetically significant for the provisional material to have good aesthetic properties.[9] They also help in preservation of post-extraction soft tissue morphology, guide the peri-implant soft tissues while healing, also allow the patient to visualize end prosthetic result.[10]

Traditionally, acrylic resin, bis-acrylic and micro-filled resin are used to make provisional restorations. Among the acrylic resin poly methyl meth acrylate is the most common material of choice.[11] Their low cost and easy to repair property contributes to its high preference among clinicians. Disadvantages of the material include high polymerization shrinkage and exothermic heat reaction. This disadvantage led to development of variants of PMMA and new materials. Composite resins include bisphenol A-glycidyl dimethacrylate and urethan dimethacrylate.[12]

Conventionally, to fabricate a provisional restoration, monomer and polymer is mixed in a fixed quantity according to manufacturer's instructions. It has certain disadvantages, as polymerization occurs after manipulation, such as residual monomer, polymerization shrinkage and poor dimensional stability, marginal fit, color stability, flexural strength.[13,14] Recently, the advent of technology has contributed to development of CAD-CAM and different milling systems. This method uses pre-polymerized blocks of PMMA for fabrication of restorations. Industrial pre-polymerization provides good homogeneity without polymerization shrinkage.[15] Additive manufacturing is becoming popular as well with the development of CAD-CAM. It is emerging as a new technology that overcomes the limitations of conventional manufacturing process. By polymerizing a photopolymer resin, only a part of prosthesis can be produced, which reduces the cost of fabrication as compared to milling. [16]

Optical properties of the restoration are an important consideration to be considered, especially in the anterior aesthetic region. Several studies have been done for optical properties of interim restorations fabricated by conventional and CAD-CAM method. One such study was done by M.M. Rayyan in 2015, comparing poly methyl methacrylate interim restorations fabricated manually with those of CAD-CAM. They compared parameters like colour stability, water sorption, wear resistance, surface hardness, fracture resistance, and microleakage. Study results showed that the CAD/CAM interim crowns presented stable physical and mechanical properties and may be used for long-term interim restorations.[17]

Few studies have also been conducted on 3D printed interim restorations. Anthony Tahayeri in 2017 examined the mechanical properties of provisional crown and bridge restorations using a low-cost stereolithography 3D printer against conventionally cured materials. Results suggest that a 3D printable provisional restorative material allows for sufficient mechanical properties for intraoral use.[18] In 2020 Jong-Eun Kim examined and compared colour and translucency stability of 3D printable crown and bridge restoration materials after storage in different Medias. Results showed a great colour change after 6 months, whereas changes in translucency were relatively small.[19]

Long term provisionalization uses interim implant abutments. They can be non-tooth coloured titanium or titanium alloys or tooth coloured PMMA with ti-base, poly etheretherketone (PEEK). As titanium has a metallic greyish hue, it presents a challenge to the clinician to achieve optimal aesthetic results. Requirements for excellent aesthetics increases in case of patients with thin gingival biotype. To mask the underlying hue of titanium, efforts have been made.

Chandur P.K. in 2015 developed a laboratory technique to that can alter the abutment colour by anodization using household items. The components used were cleaning agents, acids, diet soda and 9-V battery cells. They concluded that this technique can be used on any titanium-based material, including interim and definitive abutments.[20] In 2022, Gülce et al. compared the colour and translucency of CAD-CAM PMMA crowns on titanium interim abutments after different surface treatments. The surface treatments done were, Al2O3 airborne-particle abrasion and opaque application and airborne-particle abrasion by Al2O3. The results concluded that the colour of PMMA was different when compared to the shade tab after surface treatments. Translucency was not affected by surface treatments of crown-interim abutment pairs.[21]

Recently, the use of thermoplastic polymers like PEEK has been introduced which has some advantages over metallic restorations used in dentistry such as titanium. Due to being tooth coloured material PEEK has a more aesthetic appearance, fewer allergic reactions and it is radiolucent. In a review by Suphachai et al. in 2022 suggested the use of PEEK as an alternative to titanium abutments for long-term implant provisional restoration.[22]

The present study compared the colour stability and translucency against two interim implant abutment materials that are titanium and PEEK. The titanium is surface treated with ceramic opaquer. the effect of thermocycling has also been studied. Translucency is more important for final restoration as it gives a life like appearance and colour stability is important for both provisional and final restoration. Visible shades of

prosthesis are nothing but wavelength of light reflected by the surface from the natural white light. Two common methods used to analyse colour are visual comparison and instrumental measurement.[23]

In visual method, subjective variation could be one of the errors. Hence, a spectrophotometer was used to determine the colour. It gives CIE Lab co-ordinates given by Commission Internationale de L'Eclairage (CIE) in 1978. The L*a*b* space consists of a lightness L* coordinate, coordinate a*, indicating where the colour falls along the red/purple-green/blue axis, and coordinate b*, indicating where the colour falls along the blue/purple-yellow axis.

Translucency is the ability of a layer of a coloured substance to allow an underlying background to shoe through. The translucency parameter is given by the formula TP = [(L*B ─ L*W)2 + (a*B ─ a*W)2 + (b*B ─ b*W)2]1/2, where L*B, a*B, and b*B were measured against the black background and L*W, a*W, and b*W against the white background.[19] The greater the translucency parameter values, the higher the translucency of the material. In this study the Vita Easyshade Advance 4.0m clinical spectrophotometer was used. It is a contact, cordless and compact device. The measurements were recorded in a viewing box with neutral grey background and tube light of D65 illumination to standardize the natural illumination. Colour stability was evaluated against black tile to simulate oral condition where no light is present. Translucency parameter measurements were recorded against black and white tiles.[24] To minimize the edge loss phenomenon, distilled water was used. The optical properties were evaluated before and after artificial ageing. For artificial ageing thermocycling was performed.

Color stability was higher before and after thermocycling for CAD-CAM implant provisional restorations against PEEK abutment. Translucency parameter was high for 3D printed implant provisional restorations against titanium abutment coated with ceramic opaquer before thermocycling. Translucency parameter was high for CAD-CAM implant provisional restorations against titanium abutment coated with ceramic opaquer after thermocycling. There is no significant difference present for translucency parameter before and after thermocycling between the groups.

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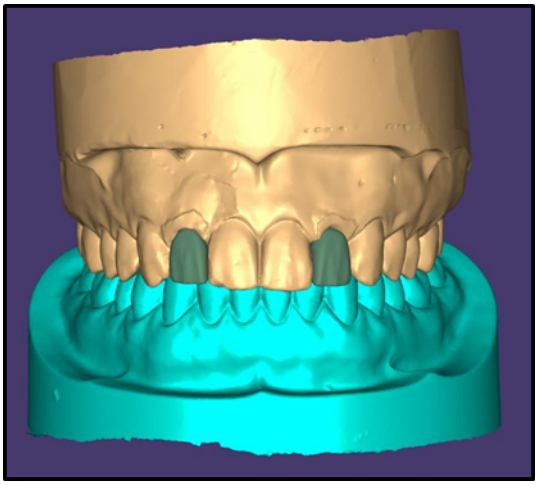


Figure 1: maxillary and mandibular scans

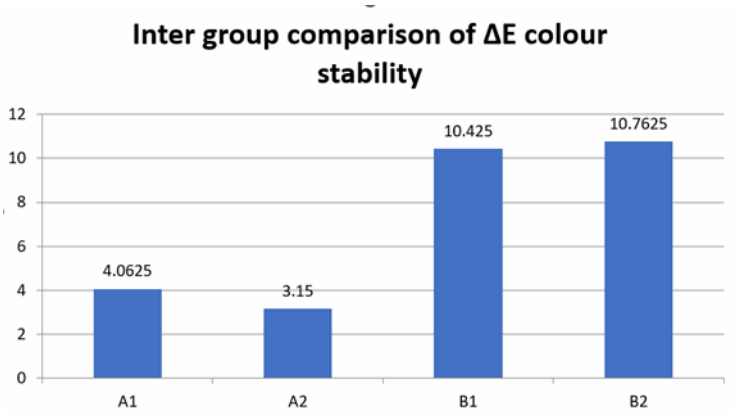
Figure 2: Clinical spectrophotometer

Figure 3: Spectrophotometric evaluation

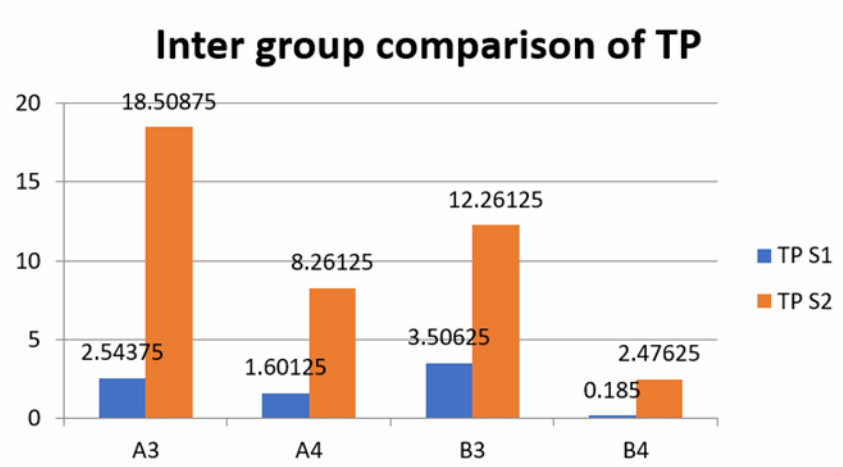
Figure 4: CIE L*a*b* values

					95% Confidence Interval for Mean	
Groups	**N**	**Mean**	**SD**	**SEM**	**95% lower bound**	**95% upper bound**
A1	8	4.06250	2.595016	0.917477	1.89301	6.23199
A2	8	3.15000	1.074377	0.379850	2.25180	4.04820
B1	8	10.42500	2.098128	0.741800	8.67092	12.17908
B2	8	10.76250	1.390722	0.491694	9.59983	11.92517
Total	32	7.10000	3.991766	0.705651	5.66081	8.53919

Table 1: Descriptive statistics of the colour stability of implant provisional restorations of the four groups



Graph 1: Inter group comparison of ΔE colour stability



Graph 2: Inter group comparison of translucency parameter