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An in vitro study to evaluate and compare the color stability and flexural strength of commercially available PMMA based computer-aided design/computer-aided manufacturing and heat cure polymethyl methacrylate provisional restorative materials.

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Abstract
AIM*: The aim of this study was to evaluate and compare color stability and flexural strength of three different commercially available CAD/CAM and conventional provisional restorative materials in multiple implant supported prosthesis at a time interval of 4 weeks.*
MATERIAL AND METHODS*: Total 18 samples were fabricated, each group containing 6 samples. Group A samples were made of DPI heat cure tooth molding powder. Group B were made of Telio CAD PMMA blocks. Group C were made of VITA CAD. Colour stability and Flexural strength were measured and values obtained were evaluated and compared.*
RESULTS*: Group B (Telio CAD) showed the highest color stability values (3.94 FSI) followed by group C (VITA CAD temp) (4.03 FSI) and group A (DPI) (4.37 FSI). The mean flexural strength values in group B (Telio CAD) (125.2 MPa) and (117.97MPa) were higher compared to the specimens of group C (VITA CAD temp) (106.7 MPa) and (99.30 MPa) and group A (DPI) (103.0 MPa) and (97.88 MPa) on posterior and anterior region respectively of each group.*
CONCLUSION*: Telio CAD group specimens exhibited highest colour stability and flexural strength values followed by VITA-CAD temp group and DPI heat cure tooth molding group in multiple implant prosthesis.*
Key Words*: CAD/CAM, flexural strength, colour stability, provisional restoration, multiple implant prosthesis.*

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I. Introduction

Edentulism is widespread among elderly people, and it is mainly accredited to dental caries and periodontal diseases. However, there is an association between sociodemographic factors, gender, age, lifestyle, low family-income and tooth loss.[1] Now a days, the progress made by dentistry, especially in the field of dental implant, offers many treatment options for edentulous patients. Among these are full arch implant rehabilitation, implant supported removable denture (overdenture) and combination of both solutions.[2]

Implant-supported prostheses are successful treatment modalities that can be used for single tooth replacement to full mouth rehabilitation. Depending on the number of the implants used in fully edentulous patients, the restoration can be removable or fixed.[3]

Another concept for restoring a fully edentulous arch with a fixed prosthesis is called the All-on-4 protocol. An All-on-4 prosthesis is a screw retained hybrid prosthesis supported by four dental implants.[3] The All-on-4 immediate loading concept was developed in 2003 by a dentist Paulo Malo and colleagues. This concept uses two vertical anterior implants in conjunction with two distally tilted inclined implants with their apices positioned anterior to the sinus wall or mental foramen. It involves the use of straight and angled multiunit abutments, which support a provisional, fixed and immediately loaded, full arch prosthesis.[4]

In restoration driven implant placement, implants are positioned in relation to anticipated requisites of the restorative phase rather than the availability of bone.[5,6] Provisional restorations are used as a diagnostic restoration to evaluate the position and contours of the planned definitive restoration prior to surgical implant placement and also during the healing phase. A provisional restoration immediately placed with ovate pontics extending into the extraction sockets can preserve the pre-extraction soft tissue morphology.[7] They can also guide the healing of the peri-implant tissue and allow clinician to determine any necessary aesthetic or phonetic

adjustments. The clinicians may use information such as shade and soft tissue contours from the provisional restoration as a communication tool to the laboratory. Provisional implant restorations can also allow the patient to visualize and evaluate the final restorative result, thus assisting in acceptance and guiding of modifications required for the definitive restoration.[8]

Immediate loading with provisional restoration is an important step during fixed Implant-supported full mouth rehabilitation for fully edentulous arches. According to Glossary of Prosthodontic Terms, provisional restoration can be defined as "a fixed prosthesis, designed to enhance esthetics, stabilization and/or function for a limited period of time, after which it is to be replaced by a definitive prosthesis." [9,10] Provisional restorations must satisfy the biological, mechanical and esthetic requirements. They serve the critical function of providing a template for the final restoration once they have been evaluated intraorally. Because a provisional restoration is subjected to masticatory forces in oral environment. Among mechanical properties, the flexural strength of the interim prosthesis is important, particularly in full mouth implant supported provisional prosthesis.[11]

When the provisional restoration is in aesthetic zone, color stability of provisional materials is a concern. Color stability of provisional materials not only relates to the chemico physical properties of the resin, but also to patient's drinking habits. The color stability of provisional materials may be influenced by saliva, food components, beverages and interaction among these materials in the oral environment.[9] as immediate temporary full mouth rehabilitation restoration has to be replaced after around 4 to 6 months, its colour stability plays vital role in esthetics and psychological impact in patient.

Polymethyl methacrylate (PMMA) has been long in use for the fabrication of provisional restorations. Although this material has provided satisfactory provisional restorations in regard to esthetics and function, it has been accompanied with drawbacks such as heat generation, shrinkage, excess monomer and color changes. Recently, computer-aided design and computer-aided manufacturing (CAD-CAM) technology have been utilized to fabricate provisional restorations. Crosslinked PMMA blocks which have been previously polymerized are milled to produce provisional restorations of better strength as well as homogeneity. Unlike conventional PMMA materials, PMMA blocks do not show any drawbacks. Moreover, studies have suggested superior physical and mechanical properties of this material and promoted its use for long-term provisional restorations.[12]

The importance of the provisional (treatment) restoration among the procedures required for successful completion of an implant supported fixed prosthesis is often overlooked.[13] As little research has been published on the efficacy of the flexural strength and colour stability of provisional restoration for implant supported fixed prosthesis the purpose of this in vitro study was to evaluate and compare the flexural strength and colour stability of provisional restoration prepared using commercially available CAD-CAM and conventional provisional materials in multiple implant prosthesis.

II. Aim And Objectives

The aim of this study is to evaluate and compare color stability and flexural strength of three different provisional restorative materials at time interval of 4 weeks in fixed implant prosthesis. The materials selected for this study are commercially available CAD/CAM based PMMA viz. VITA-CAD temp, Telio CAD and Heat Cure Poly Methyl Methacrylate.

III. Material And Method

Ethical committee approval and study design -

This study was carried out in the Department of Prosthodontics in 2019–2020. Ethics was granted by the Institutional Ethical Committee and research board approval. The study conducted according to the ethical standards given in the 1964 Declaration of Helsinki, as revised in 2013.

The sample size was calculated using the references of related articles, studies, reviews and sample size formula. The power of the study is less; thus, the sample size was taken as 18. The sample were divided into three groups, namely Group A, group B and group C. Each group was assigned 6 samples each.

Fabrication of samples-

Samples were made with three different provisional materials (VITA-CAD temp, Telio CAD and heat cure poly methyl methacrylate) as mentioned above to compare the color stability and mechanical property i.e. flexural strength.

• DPI heat cure tooth molding powder (Dental Products of India Limited): heat cure poly methyl methacrylate. Group A - six samples for colour stability and flexural strength. (Fig. 1)

• Telio CAD (Ivoclar Vivadent Marketing (India) Pvt. Ltd.): cross-linked PMMA blocks. Group B - six samples for colour stability and flexural strength. (Fig. 2)

• VITA-CAD temp (VITA Zahnfabrik, India): micro filler reinforced polyacrylic. Group C – six samples for colour stability and flexural strength. (Fig. 3)

Fabrication of die model-

Die model was prepared by placing 2 straight dummy implant / analogue in canine and 2nd premolar area each in edentulous stone model, over which respective specimen of each group were fabricated. (Fig. 4 A,B)

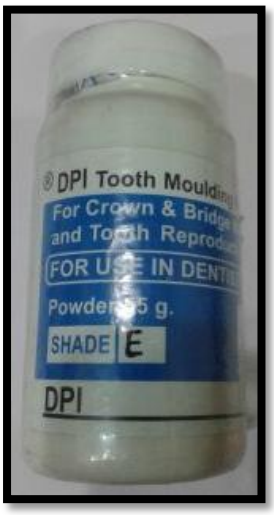


Fig. 1. Group A - DPI heat cure tooth molding powder : heat cure poly methyl methacrylate.

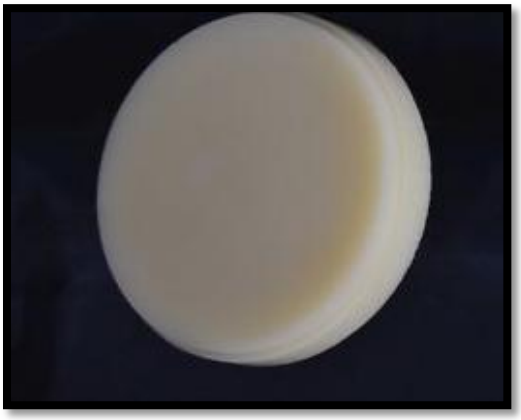


Fig. 2. Group B - Telio CAD cross-linked PMMA blocks.

Fig. 3. Group C - VITA-CAD temp : micro filler reinforced polyacrylic

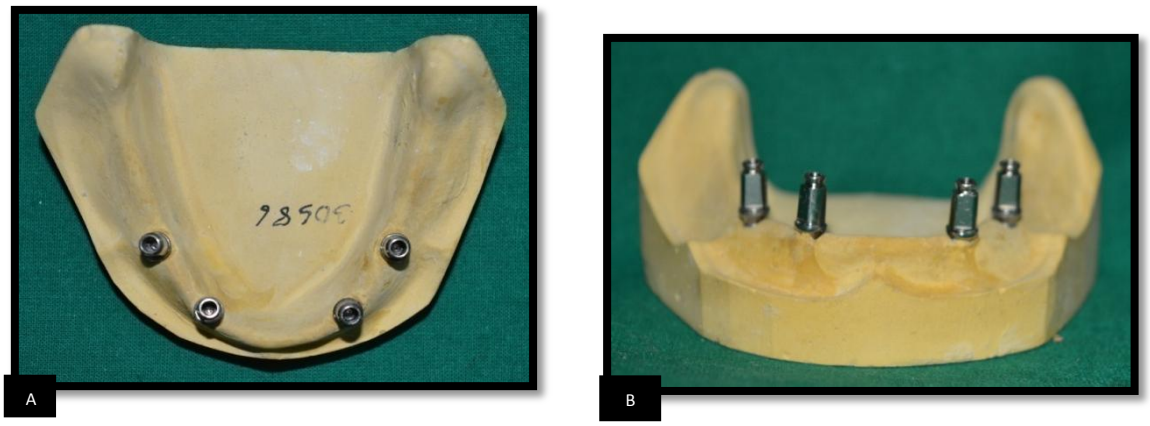


Fig. 4 (A,B) Die model with two anterior and two posterior straight implant placement

Heat cure poly methyl methacrylate specimens -

Final specimens for heat cure polymethyl methacrylate group A, specimens were prepared with pattern wax (Fig. 5). Further, these pattern wax specimens were invested in conventional flasks and the conventional PMMA test specimens were fabricated using the compression molding technique. (Fig. 6)

Fig. 5. Fabrication of heat cure poly methyl methacrylate provisional (Wax pattern)

Fig. 6 Fabrication of heat cure poly methyl methacrylate provisional (Final prosthesis)

Computer-Assisted Designing and Computer-Assisted Milling specimens –
In this study, Telio CAD (Ivoclar Vivadent Marketing (India) Pvt. Ltd.) and VITA-CAD temp (VITA Zahnfabrik, India) PMMA resin blanks were used to fabricate specimens for group B and group C respectively. The Die model with two anterior and two posterior implants were scanned with extraoral scanner (Fig . 7) and virtual image were obtained (Fig. 8). Designing of prosthesis was done on obtained virtual image. The computer file in STL format was transferred to CAD program, and the specimens were transferred to the milling unit. The specimens were milled in pre polymerized PMMA blanks (Telio CAD, VITA CAD) of the shade A2 (Fig. 9). Conventional cutters, trimmers were used for finishing and polishing within the milling machine. (Fig. 10)

Fig. 7. Scanning of model

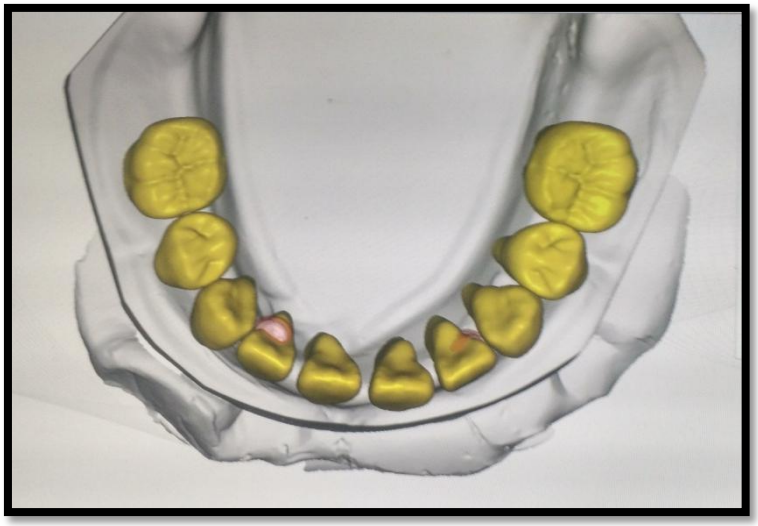


Fig. 8. Designing of prosthesis

Fig. 9. Milling of prosthesis

Fig. 10. Polished prosthesis

Testing of color stability

Solution preparation

The samples were immersed in 300 ml of test solution mixed with 600 ml of artificial saliva. Artificial saliva was prepared using a mix of 100ml of 0.34g Monopotassium phosphate, 0.44g of Disodium phosphate, 1.5g of Potassium bicarbonate, 0.58g Sodium Chloride and 0.03g Magnesium chloride hexahydrate. Then 6ml of 0.5g Citric Acid was added.[14]

Finally, 10ml of 0.22 Calcium Chloride was added. The final solution was diluted with distilled water to final volume of 100ml with pH range from 6.7 to 7.3. Then tea solution was added.

The tea solution was prepared by immersing 1 tea bag to 1 L of boiling water, immersed for 5 minutes and then filtered with filter paper and mixed with 600ml of artificial saliva, kept at 37^0 C. Before each measurement, the samples were rinsed with distilled water and specimens were immersed for 5 minutes in tea solution (Fig. 11). Afterwards, the specimens were dried using tissue paper. [14]

Color measurements were made after 1st week (T1), 2nd week (T2), 3rd week (T3) and after 4th week (T4). Thirty days is the maximum time duration for which provisional materials may be used.

Color differences of each specimen were measured by reflectance spectrophotometer. L*, a* and b* values of each specimen after immersion at each specified time interval (T1, T2, T3, T4) were measured three times by placing each specimen on the measuring head and covering with the black cover. The mean values of ΔL*, Δa*, Δb* after three measurements were automatically calculated by the spectrophotometer and recorded (Fig. 12). Color difference ΔE was calculated from the mean ΔL*, Δa*, Δb* values for each specimen with the formula:

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

Where ΔL*, Δa*, Δb* are the differences in L*, a* and b* values before (T0) and after immersion at each time interval (T1, T2, T3, T4).

Fig.11. Provisional prosthesis immersed in tea solution

Fig. 12. Photo spectrometer

Testing of Flexural strength

A Universal Testing Machine (Acme engineer, India) was utilized for this study and a three-point loading system was used for the application of load and all the Eighteen specimens of the three groups were subjected to the three-point bending test. The load was applied at a crosshead speed of 3 mm/min, between center of two anterior implants and center of one anterior and one posterior implants on right and left side, the loading was continued till fracture occurred and the breaking load was noted. These breaking load values were converted to flexural strength (σ) using the following formula:

$\sigma = 3FL/2bd2$,

where,

σ = Flexural strength

F = Load (force) at the fracture point

L = length of the support span

b = Width of specimen

d = Thickness of the specimen

The flexural strength values obtained were in Mega Pascals (MPa) by the software provided along with the machine.

Statistical analysis

Data obtained were compiled on MS-Excel sheet. Mean and standard deviation (SD) readings were calculated. Statistical tests were performed using SPSS Software Version 17.0 (Chicago, IL, USA). Intergroup comparison of color stability and flexural strength values were done using one-way analysis of variance (ANOVA) and pairwise post hoc comparison was done using Tukey's honest significant difference (HSD) *post hoc* test. $P < 0.05$ was considered to be statistically significant.

IV. Results

The color stability and flexural strength were recorded for each specimen. This raw data of the values obtained were compiled on MS-Excel sheet to get the mean and SD. The data were then statistically analyzed.

Color stability

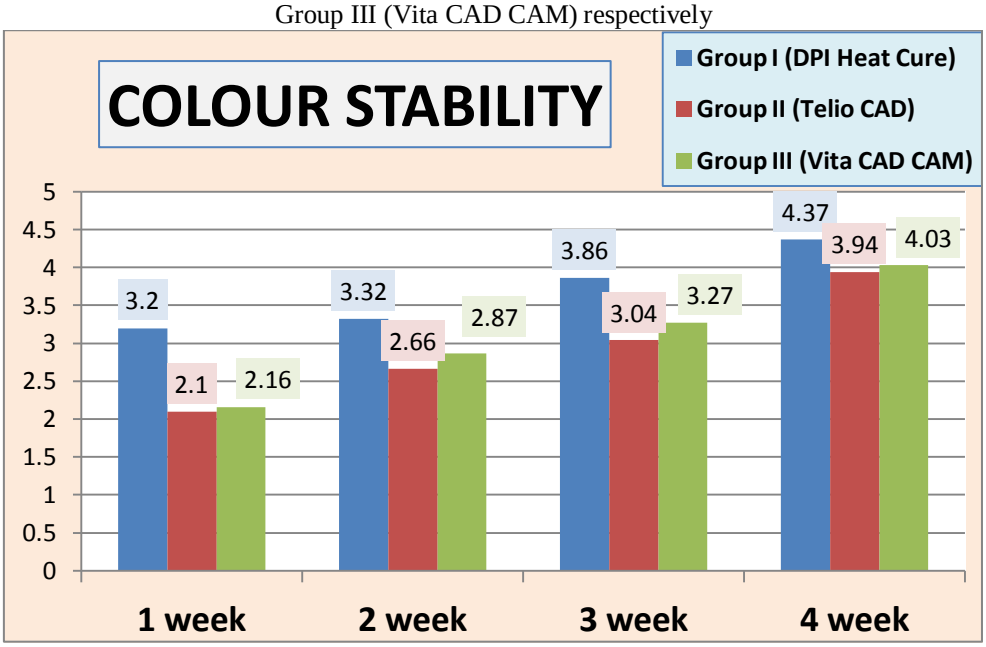
Group B (Telio CAD) showed the highest color stability values (3.94 FSI) followed by group C (VITA CAD temp) (4.03 FSI) and group A (DPI) (4.37 FSI) . The difference in color stability values of the three groups were statistically significant according to ANOVA as well as the intergroup comparison done using the Tukey's HSD (post hoc) test (P < 0.05) (Table 1, Graph 1).

Table 1: Comparison of colour stability measurement of group I (DPI Heat Cure), Group II (Telio CAD) and Group III (Vita CAD CAM) respectively

Materials	1 week	2 week	3 week	4 week
Group I (DPI Heat Cure)	3.20 (0.11)	3.32 (0.03)	3.86 (0.06)	4.37 (0.08)
Group II (Telio CAD)	2.10 (0.07)	2.66 (0.10)	3.04 (0.06)	3.94 (0.10)
Group III (Vita CAD CAM)	2.16 (0.06)	2.87 (0.08)	3.27 (0.06)	4.03 (0.05)
ANOVA F TEST (Group I vs II vs III)	F = 302.08	F = 108.19	F =254.24	F = 44.21
p value^	p <0.001**	p <0.001**	p <0.001**	p <0.001**
Grp I vs Grp II$	p <0.001**	p <0.001**	p <0.001**	p <0.001**
Grp I vs Grp III$	p <0.001**	p <0.001**	p <0.001**	p <0.001**
Grp II vs Grp III$	p =0.570	p=0.001*	p <0.001**	p = 0.177

*p < 0.05 - significant difference ** p <0.001 – highly significant difference ^p value calculated using ANOVA F test (overall comparison) $p value calculated using Tukey's post hoc test (for individual pair wise comparison)

Graph 1: Comparison of colour stability measurement of group I (DPI Heat Cure), Group II (Telio CAD) and Group III (Vita CAD CAM) respectively



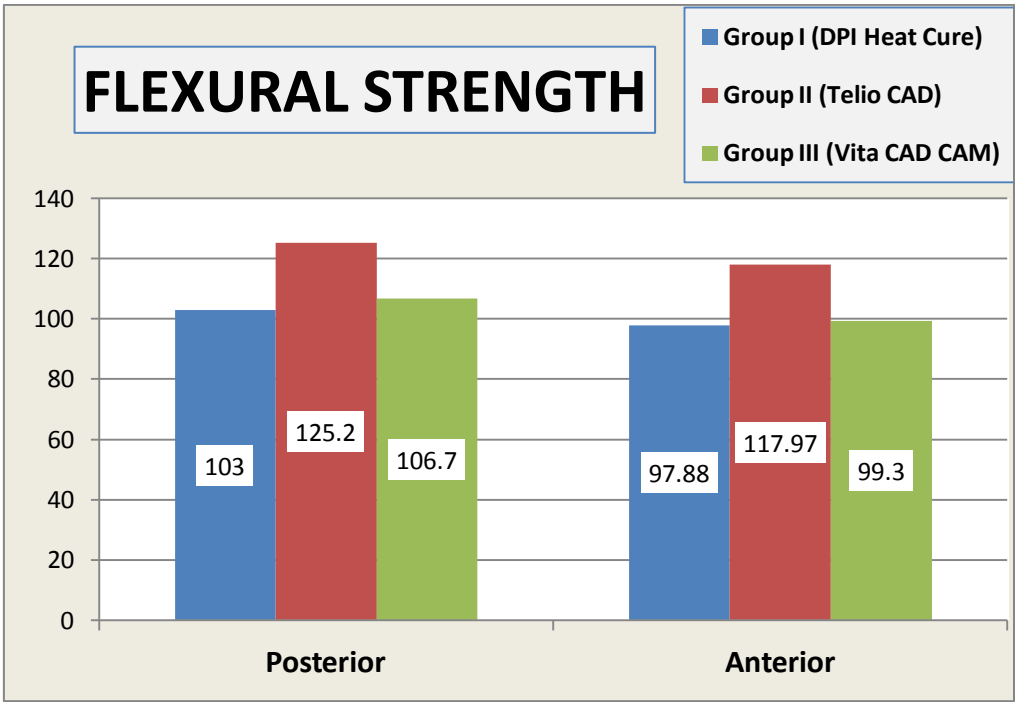
Flexural strength

The mean flexural strength values in group B (Telio CAD) 125.2 MPa and 117.97MPa were higher compared to the specimens of group C (VITA CAD temp) 106.7 MPa and 99.30 MPa and group A (DPI) 103.0 MPa and 97.88 MPa on posterior and anterior region respectively of each group. The ANOVA Test shows that there is statistically significant difference in the flexural strength values of the three groups ($P < 0.05$). However, according to the pairwise comparison of Tukey's HSD test, flexural strength values of group A vs group C were higher and statistically significant on posterior ($p = 0.269$) and anterior region ($p = 0.705$) and there was no significant difference between flexural strength values of group A vs group B and group B vs group c i.e.($p< 0.001$) and ($p = 0.003$) (Table 2, Graph 2).

Table 2: Comparison of flexural strength measurement of group I (DPI Heat Cure), Group II (Telio CAD) and Group III (Vita CAD CAM) respectively

Materials	Posterior Mean (S.D)	Anterior Mean (S.D)
Group I (DPI Heat Cure)	103.0 (2.65)	97.88 (2.47)
Group II (Telio CAD)	125.2 (3.87)	117.97 (0.32)
Group III (Vita CAD CAM)	106.7 (2.83)	99.30 (1.50)
ANOVA F TEST (Group I vs II vs III)	F = 56.730	F =88.716
p value^	p <0.001**	p = 0.002*
Group I vs Group II$	p <0.001**	p =0.003*
Group I vs Group III$	p = 0.269	p =0.705
Group II vs Group III$	p <0.001**	P =0.003*

*p < 0.05 - significant difference ** p <0.001 – highly significant difference ^p value calculated using ANOVA F test (for overall comparison) $p value calculated using Tukey's post hoc test (for individual pair wise comparison)



Graph 2: Comparison of flexural strength measurement of group I (DPI Heat Cure), Group II (Telio CAD) and Group III (Vita CAD CAM) respectively

V. Discussion

Providing the most appropriate provisional restoration for a given patient is both challenging and rewarding. Provisional restorations must satisfy proper mechanical requirements to resist functional and non-functional loads. At present, there is no provisional restorative material that meets the optimal requirements for all situations. Clinicians typically choose the product based on ease of manipulation, cost and esthetics. The provisional fixed partial dentures are subjected to various compressive, tensile and shear stresses during functions, which can result in fracture of the restoration. Mechanical properties of provisional restorations were assessed using flexural strength or transverse strength. The flexural strength is a combination of tensile and compressive strength tests and includes elements of proportional limit.[15,16]

In cases of multiple unit implant prosthesis, immediate loading with provisional restoration plays a vital role in success of treatment. CAD CAM temporaries have been proven for their better marginal integrity and axial wall adaptation, decreasing micro movement at implant surface. Thus, this study was aimed for evaluation of mechanical properties i.e Flexural strength for long span and long-term treatment.

Jiajing Yao *et al* compared and evaluated the flexural strength of 2 CAD/CAM interim materials (Teilo CAD and VITA CAD-Temp) and had statistically significant result with CAD CAM interim materials, he reported similar findings as this study.[17] Teilo CAD (124.10 Mpa) possessed the highest flexural strength, whereas VITA CAD-Temp (96.84 Mpa) possessed the lowest strength before thermal cycling similar to the results seen in this study i.e. Telio CAD (125.2 MPa) (117.97MPa) , VITA CAD (106.7 MPa) (99.30 MPa) in posterior and anterior respectively.[17]

Teilo CAD is a prefabricated mono methacrylate based PMMA, which has long chain, linear molecules with minimal intermolecular crosslinking and it has high strength, in addition this material is also milled extra orally, thus avoiding pulpal discomfort and polymerization shrinkage, which makes it suitable for interim prosthesis. Where as VITA CAD-Temp is an acrylate polymer which contains vinyl groups, i.e, 2 carbon atoms double bonded to each other and attached to carbonyl carbon. Thus, acrylates easily form polymers because the double bonds are very reactive and exhibit lower strengths.[17] Hence in this study, VITA-CAD Temp demonstrated the lower flexural strength than TELIO CAD. Besides the difference in chemical composition of the materials, the filler plays a significant role in flexural strength of the material. As High filler content and small average filler size improves flexural strength of the material.

So-Yeon Song *et al* studied Color stability of provisional restorative materials with different fabrication methods and concluded that the degree of discoloration increases with time, and a visually perceptible color difference value was shown regardless of the materials and solutions used for the study. Study showed that the CAD/ CAM milling block, Telio CAD, was stable with relatively small color difference when immersed in coffee solution for 4 weeks (4.06FSI).[18] Another study was performed by Thamer Almohareb *et al* where Telio CAD provisional material at 4 weeks showed the least color change i.e. (4.69FSI) among all the study groups

when immersed in different solutions the values of the study were similar to this study i.e. (3.94 FSI) after 4 weeks of immersion in coffee solution.[19]

Different results among studies may be due to differences among the products used and concentration of solution used for the study. In this study group B(Telio CAD) showed higher flexural strength and colour stability as compared to the other groups i.e. group C(VITA CAD) and group A (DPI). No significant difference between group C (VITA CAD) and group A (DPI) was found for flexural strength as well as colour stability.

It should be mentioned that flexural strength is only one of the number of factors influencing the success of provisional prosthesis. A strong material may also possess other less desirable characteristics. For example, a restorative material may be difficult to manipulate or have tendency to stain easily, lack polishability, or not be esthetically pleasing.[20,21] Hence there are no published studies regarding exactly which measured mechanical properties may best aid the clinician in predicting performance of provisional restorative materials. The clinician must always be aware of all the attributes of various materials and choose the interim material appropriate for each patient.

VI. Conclusion

Within the limitations of this *in vitro* study, and on the basis of the results obtained, it can be concluded that:

- Telio CAD group specimens exhibited highest flexural strength values followed by VITA-CAD temp group and DPI heat cure tooth molding group.
- The flexural strength values of all the groups were higher than minimal acceptable flexural strength of provisional FDP materials which is 50 MPa.
- Similarly, Telio CAD group specimens showed high colour stability values followed by VITA-CAD temp group and DPI heat cure tooth molding group.
- The colour stability values of all the groups were higher than minimal acceptable colour stability of provisional FDP materials.

It may be further concluded that:

- When the strength of the provisional FDPs is of prime concern in long term and long span conditions, provisional FDPs fabricated by CAD/CAM milling of the PMMA blanks may be used.
- CAD/CAM showed the highest flexural strength and colour stability values.

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