Comparing Fracture Resistance of Provisional Restorations of 3-Unit Fixed Partial Dentures: An in Vitro Study of CAD/CAM versus Indirect Technique

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Abstract

Objective: To compare the indirect and CAD/CAM techniques and using acrylic and composites resins on the fracture resistance of provisional 3-unit fixed partial dentures (FPDs).

Materials and Methods: In in vitro setting, thirty samples were divided into three groups included 10 FPDs manufactured indirectly and made of composite based bis-acryl (Protemp 4) resin, 10 FPDs indirectly milled with polymethyl methacrylate resin (PMMA) and 10 FPDs fabricated by CAD/CAM PMMA blocks. Fracture resistance was measured using universal testing machine (UTM). The master model was made of NiCr-alloy which designed using CAD/CAM technology.

Results: FPDs fabricated using CAD/CAM PMMA blocks showed the highest fracture resistance values followed by Protemp 4 and then PMMA using indirect method. Statistically significant difference was found between the three groups (P=0.001). Bonferroni test was applied for pair wise comparison, in which the statistically significant difference was observed between FPDs fabricated by CAD/CAM which made of PMMA blocks and Protemp 4 and between CAD/CAM PMMA blocks and indirect/PMMA FPDs and between indirect/Protemp 4 FPDs and indirect/PMMA FPDs. Hence this suggested that PMMA significantly has minimum value of fracture resistance when compared to both CAD/CAM and Protemp 4.

Conclusion: This study proved the superiority of CAD/CAM PMMA blocks for fabricating 3-unit FPDs over Protemp 4 and PMMA using indirect method, and the superiority of Protemp 4 over PMMA in terms of fracture resistance using indirect methods.

Keywords: *computer-aided design; dental restoration- temporary; denture, partial, fixed; fracture resistance; polymethyl methacrylate*

Introduction

The word provisional, interim or temporary means established the time being.[1] A provisional restoration plays a considerable role during tooth preparation procedure in which the tooth structure becomes smaller in size and the time frame for the fabrication of the final restoration might exceed several weeks.[2] A provisional restoration has a wide range of functions as the intermediate stage of the treatment including easthatics, diagnosis in dentistry, gum health, protection of pulp, providing occlusal stability, improving masticatory efficiency, and determining the final form of the definitive restoration.[3,4]

At present, available provisional restoration materials can be divided into two categories according to their chemistry composition namely acrylic (monomethacrylates) resins including ploymethylmethacrylatic (PMMA) resins and polyethyl/

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butyle methacrylate (PEMA) resins or composite-resin (bis-acryle or dimethylmethacrylates) which include bisphonel A-glycidyl dimethacrylate (Bis-GMA) and urethane dimethacrylate (UDMA) resins. The light activated method is used for the polymerization of these two categories.[5] The chemical composition of these material has been improved in recent years to achieve good fracture resistance and aesthetics performance in clinical situations.[6]

The fracture resistance is the most important property influencing the success of interim restoration and may cause discomfort, financial and economic loads for the patient.[4] Clinicians should be aware of the range of available commercial materials and suitable fabrication techniques to minimize the probability of the fracture.[7,8]

CAD/CAM technologies definitely solve some of the issues raised with provisional restorations when fabricated by conventional methods (direct or indirect) such as reducing chairside time of the extra appointment prior to the preparation and fabrication of an interim bridge, eliminating the time of sending to the laboratory, and using resin based blocks which prevent voids within interims and increase the mechanical strength.[9]

Little in vitro research has examined the fracture strength of interim restoration materials such as Protemp 4 and CAD/CAM technique. Therefore, the aim of this in vitro study was to compare groups of indirectly fabricated provisional 3-unit FPDs (fixed partial dentures) using the PMMA resins and Protemp 4 materials and CAD/CAM fabricated FPDs milled of PMMA blocks, in terms of fracture strength.

Materials and Methods

The fracture resistance of the studied materials and manufacturing techniques were tested using an in vitro setup on a metal master model with a 3-unit FPD. The two resins based materials were PMMA molding powder and liquid (methyl methacrylate resin) and Protemp4 (bis-acryl composite resin). Table 1 summarizes the characteristics of materials used including their composition. All materials were cemented in accordance with the manufacturer's manual.

Table 1. Characteristics of materials used in the study.

Serial no	Name of the material	Manufacturer	Composition
1	PMMA resin	Yamahachi, Japan	Methyl-methacrylate resin
2	Protemp 4 composite	PARKELL inc Edgewood, USA	Bis-acryl composite resin
3	PMMA block	Ketten Bach, Japan	Bis-acryl composite resin

Preparation of master model using CAD/CAM technique

The master model was designed using CAD/CAM technique. For this goal, the dental impression tray was used to reproduce the cast from a patient with dental implant on positions of 37 and 35. The data of abutment on the cast was transmitted using laboratory scanning abutment (Arum Co., South Korea) and collected by a scanner (D850 3D scanner, 3Shape, Denmark). Then two anatomic abutments similar to shaved teeth (angle 6˚, chamfer margin thickness of 1 mm, and height 8 mm) were designed using CAD/CAM software (3Shape Co., Dental System, Dental). Then, 3D printed abutment with resin material was produced using 3D printer (3D printing system, Asiga Max UV, USA) and finally casted with alloy (Scheftner Dental Alloys , Magucera N, Germany) (Fig 1 and 2).

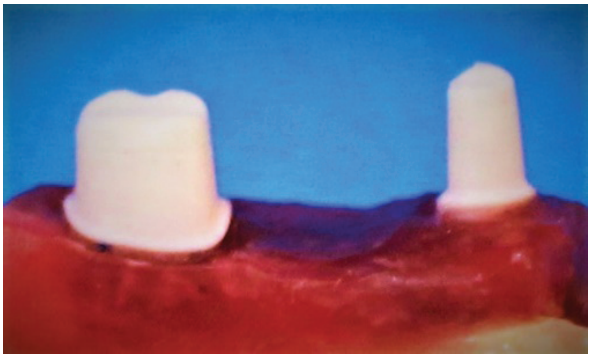

Figure 1. Final model in inlay wax;

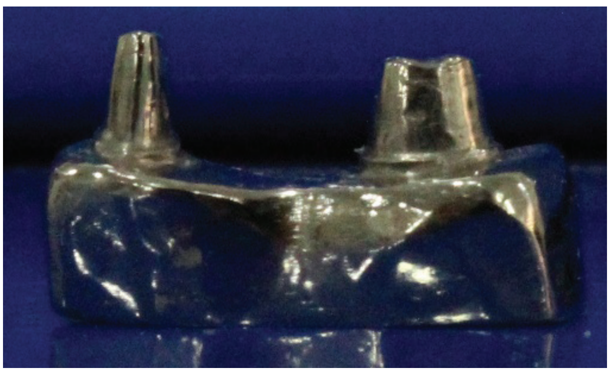

Figure 2. Final corpus model in NiCr-alloy

CAD/CAM fabrication of provisional 3-unit FPDs

The surfaces and margins of the master model were converted into data with the help of a scanner (3D scanner, 3Shape D850, Denmark), the data is then read and interpreted by the CAD/CAM (3Shape, Dental System, Denmark). The 3-unit FPDs was designed on tooth #36 as hygiene pontic with distance 2 mm from master model and retainers of buccal and lingual caps had 1.5 mm and 1 mm thickness, respectively. 10 samples were produced from PMMA blocks (Yamahachi, Japan) using milling machine (Arum model 5x 200, South Korea).

Indirect fabrication of provisional 3-unit FPDs

Ten samples of 3-unit FPDs from Protemp 4 materials (3M ESPE, North Ryde, USA) and Ten samples of PMMA martials (GC Tempron, Japan) were made based on the index of CAD/CAM 3-unit FPDs samples (Fig. 3).

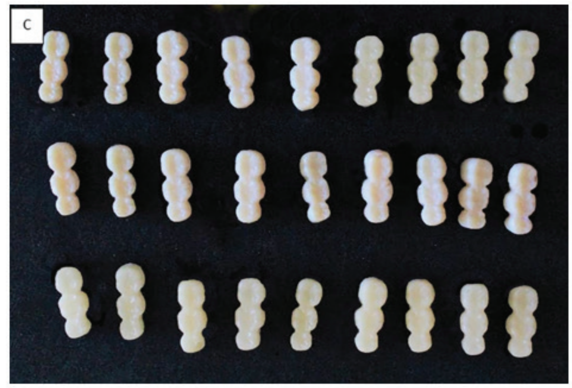

Figure 3. Trimmed temporary bridges

Fracture resistance Test

All FPDs were subjected to axial compression test at a cross-head speed of 1.2 mm/min until fracture occurred using a metal ball (6 mm in diameter) in a universal testing machine (Fig. 4). Fracture test was started at a crosshead speed of 1.2 mm/min until fracture occurred Maximum force at which the fracture occurred was recorded (Fig. 5).

Figure 4. Setup with temporary bridge and sphere prior to fracture testing ;

Figure 5. Fracture of the bridge after load application.

Statistical Analysis

The one-way ANOVA analysis test was utilized to compare mean and SD of fracture resistance value between three groups. The P value was considered as <0.05.

Results

The maximum forces at fracture were recorded in Newton. These are listed in Table 2 and depicted in Fig. 6.

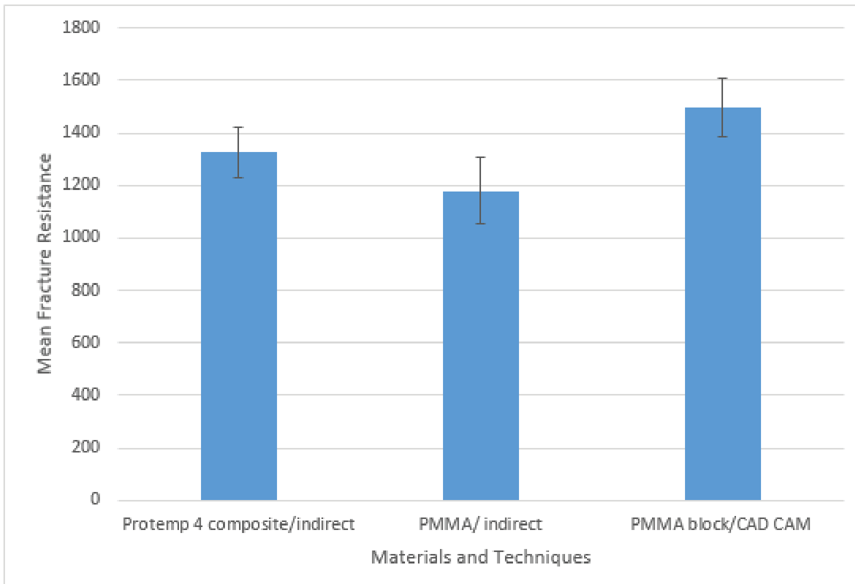

Figure 6. Comparison of fracture resistance between three groups.

Table 2. The maximum force at the moment of fracture (Newton)

Sample	Protemp 4/inderct	PMMA/indirect	PMMA block/CAD/CAM
Sample 1	1690	1208	1690
Sample 2	1375	1180	1375
Sample 3	1683	1002	1683
Sample 4	1460	1329	1460
Sample 5	1489	1199	1489
Sample 6	1500	900	1500
Sample 7	1470	1205	1470
Sample 8	1379	1225	1379
Sample 9	1345	1334	1345
Sample 10	1534	1209	1534
Mean ±SD	1326.6 ± 101.7	1179.1 ± 133.5	1494.3 ± 117.1

FPDs fabricated using CAD/CAM PMMA blocks showed the highest fracture resistance values followed by Protemp 4 and then PMMA using indirect method. Table 3 shows the comparison of the mean fracture resistance between the three groups using one way ANOVA analysis. Statistically significant difference was found between the three groups (P=0.001). Bonferroni test was then applied for pair wise comparison, in which the statistically significant difference was observed between FPDs fabricated by CAD/CAM which made of PMMA blocks and Protemp 4 and between CAD/CAM PMMA blocks and indirect/PMMA FPDs and between indirect/Protemp 4 FPDs and indirect/PMMA FPDs (Table 4). Hence this suggested that PMMA significantly has minimum value of fracture resistance when compared to both CAD/CAM and Protemp 4.

Table 3. Comparing the mean of fracture resistance between three groups.

Material/technique	Mean Fracture resistance (N)	Degree of freedom	P value
Protemp 4/Indirect	1326.6	29	0.001
PMMA/Indirect	1179.1		
CAD/CAM / PMMA block	1494.3		
One way ANOVA test			

Table 4. Comparison of mean between groups (Post HOC test)

Materials and techniques	Protemp4/indirect	PMMA/ indirect	CAD/CAM block (PMMA)
Protemp4/indirect	-	0.025	0.01
PMMA/ indirect	0.025	-	0.001
CAD/CAM block (PMAA)	0.01	0.001	-

Discussion and Conclusion

One of the most important steps in fixed prosthesis treatment is the fabrication of provisional restorations.[10] Various materials for provisional restorations are commercially available including PMMA, PR'MA, microfilled composite and light-cured polymerized composites.[11] Fabrication of temporary restorations are performed by two methods namely direct and indirect techniques. Recently, emerging of digital molding and CAD/CAM enhanced the accuracy of provisional restorations.[12]

In current study, the zero hypothesis indicating no difference in fracture resistance of three groups was rejected. Our findings showed that the fracture resistance of 3-unit FPDs interim restorations fabricated by CAD/CAM technology was significantly better than those fabricated by Protemp 4 indirectly (P value=0.025). In addition, the fracture resistance of 3-unit FPDs made by Protemp 4 was significantly better than PMMA. On the other words, CAD/CAM is superior to two other groups. Several studies showed similar findings with current study.[13-15] In addition, Balkenhol et al. in their study have found that fracture resistance of Protemp 4 is higher than methacrylate (PMMA) in indirect method.[7] Moreover, Gujjari et al., in their study have reported that of bis acryl resin (Protemp 4) showed better mechanical properties than PMMA in indirect method.[16] A systematic review has showed that methyl methacrylate e.g. Protemp 4 has better fracture resistance than methacrylate due to its chemical structure and cross-link property.[5] The difference in fracture resistance of these materials is attributed to chemical composition variables such as monomer composite and polarity.[14,17] Bis-acryl contains organic matrix and filler non organic particles in addition to multifunctional monomers. Moreover, it contains cross-link polymer structure between monomer chains.[18] Whereas, conventional PMMA contains linear and mono functional molecules.[19] The researches have reported that usual PMMA resins absorbs more water in their polymer network.[20] However, polymer-based PMMA blocks have better homogeneities, less water absorption and solubility. In addition, PMMA blocks are kept under air prior to utilization which provides opportunity for the process of post polymerization and rest.[21] There are few studies have compared fracture resistance of 3-unit FPDs made of PMMA blocks with conventional materials (PMMA and Protemp 4). Alp et al.[22] and Karaokutan et al.[13] in their studies have compared fracture resistance crowns fabricated by PMMA blocks using CAD/CAM technology with crowns fabricated indirectly with PMMA and Protemp 4. Their findings are compatible with our results. Recently, a study conducted by Pop et al., in which fracture resistance of provisional restorations of 3-unit FPDs indirectly fabricated by two types of PMMA has been compared with those made of PMMA blocks by CAD/CAM technology.[23] They have demonstrated that fracture resistance in CAD/CAM technology was significantly higher than indirect method. In the study by Alt et al., it has been shown that fracture resistance of interim restorations of 3-unit FPDs fabricated directly by PMMA is lower than those fabricated by CAD/CAM PMMA blocks.[12] PMMA blocks own better mechanical properties, lack of air voids, reduced porosities in turn decrease water absorption and higher fracture resistance.[24] Previous studies have suggested to enhance the mechanical properties of bis-acryl and methacrylate.[25,26] A study by Haselton et al., found contrary results in which the PMMA and Protemp 4 did not have significant difference in terms of fracture resistance.[27] In contrast with our study, Sharma et al.[28] and Poonacha et al.[6] also found that PMMA is superior than Protemp 4 in terms of fracture resistance and elasticity.

The strengths of the current study were the evaluation of 3-unit FPDs fabricated by CAD/CAM PMMA blocks which rarely studied by previous researches. Moreover, the master model was designed by CAD/CAM technology which enhance the accuracy of the model. The relatively higher sample size and design and manufacturing of the samples according the clinical standards are other strength points of current study. The limitations of current research were no applying fatigue test and thermocycling. In addition, the effects of intra oral factors such as saliva were not assessed. At the same time, the dentist skill was ignored in indirectly manufacturing interim restorations.

In conclusion the results of the current study proved the superiority of CAD/CAM PMMA blocks for fabricating 3-unit FPDs over Protemp 4 and PMMA using indirect method, and the superiority of Protemp 4 over PMMA in terms of fracture resistance using indirect methods. The findings of previous research also support our results.

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