Marginal fit comparison of conventional and CAD/CAM techniques of PMMA temporary crown

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ABSTRACT
Despite the weakness of PMMA as a temporary crown, this material has a high fracture resistance. PMMA can be used for a long time as a temporary and it can replace teeth loss. The marginal fit of the temporary crown must be as precise as that of the definitive crown to prevent irritation of the pulp tissue, inflammation of the periodontal tissues, and also produce an esthetic result. CAD/CAM temporary crown made of PMMA is a new concept in dentistry so it still needs to be investigated regarding the marginal gap in considering the use of conventional PMMA temporary crown. The objective is to review the comparison of the marginal gap of temporary crowns made from PMMA with CAD/CAM technology against conventional method. It is concluded that temporary crowns manufactured by CAD/CAM method produces a better marginal fit than the conventional method. Polymerization shrinkage is one of the causes of dimensional changes that cause a marginal gap.
Keywords: PMMA, temporary crown, CAD/CAM, conventional, marginal fit

INTRODUCTION

Temporary crowns play an important role in fixed prosthodontic treatment, especially when long-term care is required before the final restoration is placed. According to the Glossary of Prosthodontics, provisional or interim prostheses are fixed or removable dental restorations or maxillofacial prostheses designed to improve aesthetics, stabilization on and function within a limited period of time which will later be replaced with definitive dental or maxillofacial prostheses. The purpose of temporary crowns is to protect the pulp and periodontium tissue to provide healing according to the planned emergence profile, to evaluate oral hygiene, prevent migration of neighboring teeth, improve esthetics and phonetic function as well as provide an adequate occlusal scheme and evaluate intermaxillary relationships.[1]

The most commonly used materials for fixed temporary crowns include polymethyl methacrylate (PMMA) resin, polyethyl methacrylate (PEMA) resin, polyvinyl methacrylate resin, bis-acryl composite resin, and visible light-cured urethane dimethacrylates. The choice of temporary crown material depends on the mechanical properties, physical properties, ease of use, biocompatibility in intraoral that is chemical reactions due to monomer residues and exothermic reactions.[1]

Although PMMA has weaknesses in poor color stability, high shrinkage during polymerization, marginal discrepancy, easy to absorb liquids, unpleasant odor, but this material is more economical and has high fracture resistance so that it can be used for a long time or used in cases to replace a large number of teeth. This is what makes PMMA used for decades until now.[2–4]

The marginal fit of a temporary crown must be as precise as a definitive crown to prevent irritation of the pulp tissue and inflammation of the periodontal tissues and also produce an aesthetic result.[5] Minimizing marginal discrepancies results in a better biological response, especially for the soft tissues around the restoration and minimizes sensitivity and caries. Secondary to a clinically acceptable marginal opening of less than 120 µm is recommended. Material properties, such as shrinkage polymerization, thermal expansion and contraction, water sorption and plastic deformation play a role in dimensional stability that affects the marginal gap. The marginal gap in temporary crowns can increase when there are thermal changes and repeated occlusal loads in the oral cavity.[6] Marginal fit is a factor that influences the long-term success of all restorations. Optimal marginal fit results in better periodontal tissue and minimizes cement dissolution.[7]

In the fabrication of temporary crowns there is a direct technique where in this stage the teeth and gingival tissue are prepared directly and eliminate laboratory procedures. This technique is the most frequently used technique with the advantages of time saving, simpler, more precise, less expensive procedure but the disadvantages of presence of saliva, limited visibility, inadequate access, tissue trauma from the resin polymerization and poor marginal adaptation. Furthermore, the indirect technique where the temporary crown is made outside the oral cavity using the impressions of the pre-

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pared teeth, in this technique the monomer is free and heat during polymerization does not come into direct contact with the patient's teeth and gums so as to avoid injury to the patient's soft tissues and teeth, with this technique. This results in better marginal adaptation.[1]

Making a temporary artificial crown with the direct method requires waxing on the diagnostic model. In making this diagnostic model requires extra meetings and adds time and costs to the patient.[8] To overcome the shortcomings of the direct technique, the indirect CAD/CAM technique emerged which aims to overcome the shortcomings of the previous technique. Computer aided design and computer aided manufacture (CAD/CAM) are new methods introduced in the manufacture of temporary dentures which can be subtractive or milling and additive (3D printing) methods. The CAD/CAM method allows the temporary denture to polymerize well thereby improving mechanical properties, reducing discoloration and increasing precision.[6] The indirect technique can prevent pulp irritation due to exothermic reactions and residual monomer polymerization of the direct method. Digital technology provides precision and accuracy in the manufacture of definitive and temporary crowns.[7] CAD/CAM technology shortens the time and makes it easier to manufacture temporary crowns. The clinical goal of temporary artificial crowns is minimal marginal gap, can protect teeth, prevent caries and maintain healthy gingival tissue.[8]

The indirect fabrication technique has a better marginal fit than the direct technique for PMMA materials. Along with the development of technology, a method of indirect temporary crown fabrication has emerged using CAD/CAM technology. The CAD/CAM temporary crown made of PMMA is a new concept in dentistry, so it still needs to be investigated regarding the marginal gap in considering the use of conventional PMMA artificial crown. Currently, there are several journals regarding the marginal gap of temporary crowns fabricated with CAD/CAM technology but the results are varied.

This paper aims to systematically compare the marginal gap of the PMMA temporary crown fabrication technique with the CAD/CAM technology against conventional methods.

LITERATURE STUDIES

This paper is a scoping review that summarizes and shows the results of existing research on a particular topic or field of science. The steps taken in the preparation of this scoping review are determining study questions, determining the appropriate type of research, conducting study selection, collecting data in a chart, and compiling and compiling a summary as well as a report on the results of the study. This scoping review is based on the staging framework from Arksey[7] and the Preferred Reporting Items for Systematic Review Extension for Scoping Review (PRISMA-ScR) guidelines.[8]

The research question in this scoping review is "Does PMMA temporary crowns made with CAD/CAM technology compared to conventional produce better marginal fit?".

This research is based on the PICO model, (P) conventional PMMA temporary crowns are prone to poor marginal fit, (I) PMMA temporary crowns made using CAD/CAM, (C) temporary crowns made of PMMA with conventional techniques, (O) marginal fit of PMMA temporary crown.

Data collection through the Pubmed and EBSCO data search engines on November 24, 2021, with the search strategy in Table 1. The inclusion and exclusion criteria used are as shown in Table 2.

This scoping review is based on Arksey's step, starting with identifying research question, "Does conventional temporary crowns compared to CAD/CAM technology produce a better marginal fit?". Next, identify articles that are relevant to searching and collecting data through Pubmed and EBSCO data search engines on November 24, 2021 where

Table 1 Search strategy

Source	Keyword	Total
PubMed	"CAD/CAM" AND "provisional" OR "interim" AND "marginal fit" OR "marginal discrepancy" OR "marginal integrity" AND "PMMA"	18
EBSCO	"CAD/CAM" AND "provisional" OR "interim" AND "marginal fit" AND "PMMA" published date 20150101-20211131	36

Table 2 Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Publication	Januari 2015–November 2021	Before Januari 2015
Language	English	Except english.
Concept	Marginal fit temporary crown made from CAD/CAM & conventional PMMA fabrication.	Temporary crown based on Bys-Acryl
Design	Randomized clinical trial, Experimental laboratorium	Clinical report, systematic review & meta-analyses, literature review
Full Text	Available	Not Available

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54 articles were obtained, then eliminating 2 duplicate articles followed by selecting articles according to the inclusion and exclusion criteria in Table 2. Furthermore, compiling, evaluating and reporting the results of the article.[9]

RESULTS

Search results using keywords on PubMed yielded 18 results and an EBSCO search yielded 36 results. Based on a search of each of the results, the total results obtained were 54 articles. Based on the search for titles and abstracts of the 54 articles, 2 duplications were excluded. A full text search was carried out from all the remaining findings. The title, abstract and full text are read thoroughly, then adjusted according to the inclusion and exclusion criteria that have been set. Then, 38 findings were eliminated according to the established inclusion and exclusion criteria and after reading, 9 articles were eliminated because the titles and abstracts did not match the inclusion criteria. Finally, 5 search results were obtained which were included in this scoping review.

The flow of the literature search that is included in the scoping review is shown in Fig.1. The results of the literature review included in the scoping review are shown in table 3.

DISCUSSION

Factors that cause marginal discrepancy in temporary artificial crowns are material type, fabrication process, thermal and mechanical aging and duration of use when functioning. In the research of Angwarawong et al, it was shown that differrences in materials and thermomechanical aging processes gave a significant marginal gap effect.[6] Polymerization shrinkage is one of the causes of dimensional changes that cause a marginal gap. This problem arises more in PMMA material than Bis-acryl which has a filler so that it results in lower shrinkage. Polymerization shrinkage is lower in the manufacture of temporary artificial crowns with CAD/CAM because PMMA blocks have gone through a prepolymerized process according to the manufacturer's regulations during fabrication and the 3D print method goes through a better polymerization process because they are polymerized layer by layer. This causes the CAD/CAM temporary artificial crown to have a lower marginal gap than the conventional method.[6] Mai et al reported that the marginal gap of 3D printing is comparable to the milling method and significantly better than conventional.[11]

Thermal and mechanical aging gave significant marginal gap changes in the CAD/CAM and conventional temporary crown groups. Thermomechanical aging affects the marginal gap in a number of ways including polymerizazion stresses, residual unreacted monomer, voids in resin and water sorption. Changes in temperature cause contraction and expansion, especially in the thin margin area, can cause cracks in weak or porous areas that cause an increase in the marginal gap. Humid conditions and the use of water in the aging simulation can be absorbed and disrupt the polymer chain causing a decrease in resin strength and dissolving the residual monomer thereby increasing the porosity in the marginal area. Apply occlusal pressure puts stress on the temporary crown and when the stress exceeds the elastic limit of the material it can cause distortion of the marginal area.[6]

PMMA autopolymerizing generally has more voids and unreacted monomer residues so that it has a higher water sorbption than bis-acryl, CAD/CAM milling and CAD/CAM 3D printing. Research by Angwarawong et al. reported that PMMA who had received stress simulation in an oral cavity simulation had a significant increase in the marginal gap compared to other groups.[6]

The vertical discrepancy is clinically very important because it will expose the luting cement and tooth structure to the oral environment while the horizontal discrepancy also has a clinical effect because it will produce a step defect between the tooth and the crown which makes it difficult for the patient to clean the area so that it becomes the cause of plaque accumulation.[6]

It is necessary to increase the default space on the CAD/CAM crown due to the surface roughness of the stereolithic impression. Although the ideal cement space is between 20-40 µm, in Yong et al study, the setting was 60 µm for Cerec crowns and 120 µm for E4D crowns, so this setting affects the dye penetration results where E4D has the highest value. Thermocycling and occlusal loading have been shown to increase the size of the marginal gap in temporary crown restorations. In this study, it was found that the vertical discrepancy of the facial portion of the Caulk transient crown was due to the polymerization of PPMA undergoing shrinkage in air.[8] According to the study of Ogawa et al, it was shown that marginal adaptation was significantly increased when the interim PMMA material was polymerized in water at 20-30°C.[12] Research of Peng et al. also used the default 60 µm setting in the CAD/CAM method to create a cementation chamber with die spacers as well to compensate for polymerization shrinkage of the resin.[7]

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Table 3 Marginal fit comparison of conventional and CAD/CAM techniques PMMA temporary crown

Author;Year; Design	Research Purposes	Subject	Result	Conclusion
Angwarawong et al.[6] (2020) *In vitro*	Evaluating the marginal gap of temporary artificial crowns made from different materials and techniques before & after receiving simulated oral stress.	10 specimens per group 2 Conventional resins: PMMA (Unifast Trade) & Bis-Acryl (Protemp 4) 2 CAD/CAM: Milling PMMA (Brylic Solid) & 3D printing BisAcryl (Freeprint temp) All temporary crowns were thermocyled 5000 cycled & 100,000 cycled occlusal load 100 N with 5 mm metal ball in the central fossa representing 6 months of the oral environment.	• The type of material and the aging process have a significant effect on marginal gap (p<0.001) • Conventional group had a significant marginal gap change compared to the CAD/CAM group both before and after the aging process (p<0.01) • All groups had an increase in the marginal gap after aging (P<0.001) • The largest increase in the marginal gap in the Conventional PMMA group	• Type of material & the aging process affected significantly marginal gap changes in all temporary artificial crown groups • CAD/CAM group had better marginal gap adaptation than conventional both before & after the aging process. • The marginal gap of all groups after the aging simulation are still clinically acceptable (<120 µm)
Penate et al.[5] (2015) *In vitro*	Compare marginal fit & fracture strength of conventional crown (direct tech) (Structure 3, Trim, Duralay) with the CAD/CAM (Telio CAD)	60 specimens each from Conventional group. The temporary crowns were stored for 24 hours at 37°C before thermocycling. Marginal fit was evaluated at 6 points before and after thermocycling 2500 and 5000 cycles with a stereomicroscope (x40; Olympus Corp)	• Conventional PMMA group had the largest marginal discrepancy compared to other groups before thermocycling (93.7) & after 5000 cycles of thermocycling (169.7). All groups experienced an increase in marginal gap after thermocycling process but did not differ significantly (p>0.001)	• The conventional PMMA Duralay group had the largest gap margin before the thermocyling process compared to other CAD/CAM groups but after 5000 cycles it was not significantly different from the other groups.
Yong et al.[8] (2016) *In vitro*	Evaluating the marginal integrity of temporary crowns made from CAD/CAM and conventional PMMA	Dentoform model of the left second premolar prepared (1 mm axial, 2 mm occlusal and subgingival chamfer margin) for the ceramic crown was scanned with (Lava COS, 3M ESPE) and 60 resin dies were printed. Interim created: 15 Telio CAD-CEREC (milling system), 15 Paradigm MZ100-E4D (milling system), 15 autopolimerisasi resin (Caulk Dentsply), 15 autopolimerisasi resin Jet (Lang Dental). Cementation tempgrip 17.8 N, thermocycled 100 cycles, soaked 0.5% fuschin acid for 24 hours. The marginal gap is examined with a microscope (4x)	• Marginal vertical gap in conventional temporary crown is larger than CAD/CAM (p = 0.06) • Marginal horizontal gap in the temporary crown was not significantly different between groups (p=0.276)	• Significantly less vertical marginal difference in temporary crowns made with CAD/CAM compared to Conventional • Temporary crowns made from Caulk have the largest mean marginal discrepancy on the facial and lingual surfaces and the smallest mean by Paradigm MZ100-E4D.
Peng et al[7] (2020) *In vitro*	Evaluating the internal fit and marginal discrepancy of temporary artificial crowns from various manufacturing methods.	Tooth 36 dentoform was prepared for a ceramic crown, scanned and printed for 48 specimens: • 16 Autopolymerized PMMA (Jet) direct • 16 CAD/CAM Milling PMMA (Zcad Temp fix) indirect • 16 CAD/CAM 3D print Methacrylic oligomers (Nextdent) indirect	• In the PVS evaluation, the marginal discrepancy of the autopolymerized PMMA group was statistically significantly higher than that of the CAD/CAM milling and 3D print groups (p<0.05) • There was no significant difference in the CAD/CAM Milling & 3D printing groups (p>0.05)	Temporary crowns made by the digital method has a smaller marginal discrepancy than the conventional method.
Lee et al[10] (2017) *In vitro*	Evaluate marginal gap of temporary crowns produced by CAD/CAM Milling and 3D printing.	Master model (stainless steel) is duplicated with the VPS to create a working model. The working model is scanned, STL data is served for 10 CAD/CAM Milling (VIPI Block), 10 CAD/CAM 3D printing (Stratasys), 10 CAD/CAM 3D printing (Dentis). Marginal gap evaluation with silicone.	All groups experienced marginal discrepancy CAD/CAM Milling discrepancy of 119.1±54.8 µ, CAD/CAM 3D printing (Stratasys) 115.6±68.8 µ CAD/CAM 3D printing (Dentis) 64,3±30 µ. There were no significant differences and all groups were clinically acceptable (< 120 µ)	Method of making temporary crowns with digital additive CAD/CAM (3D printing) technology produces a better marginal gap than subtractive (milling). The 3D printing method can be considered to be applied to the manufacture of more complex prostheses.

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The use of silicone impression as a material to evaluate the marginal gap and internal fit gives greater results than the CT scan technique. Kim et al study found 1.5x greater results and Peng et al also found 3x greater results than CT scan.[7] Abdullah et al evaluated the marginal gap for temporary artificial crowns using lightbody silicone material as cementation material and found a material gap variation of 47-193 µm. The results of the cementation thickness depend on the cementation material used, namely based on the composition, viscosity and flowability of the material.[7]

Peng et al study stated that the largest marginal gap was in the direct method PMMA autopolymerization group. CAD/CAM milling and 3D printing groups had no significant differences. The use of CAD/CAM for the manufacture of temporary crowns has better adaptation than conventional.[7]

The disadvantage CAD/CAM milling method is that a lot of material wasted and the resulting prosthesis is not smooth because it has micro hollows due to the influence of the diameter of the cutter bur used which can result in poor marginal gaps. In contrast to additive CAD/CAM which is more precise in results however, in sharp, protrusive and undercut conditions it is more difficult to reproduce with 3D printing.[10]

Minimizing marginal discrepancies results a better biologic response especially for the soft tissue surrounding the restoration, minimizing tooth sensitivity and secondary caries. Clinically acceptable marginal area opening is recommended to be less than 120 µm. Material properties, such as shrinkage polymerization, thermal expansion and contraction, water sorption and plastic deformation play a role in dimensional stability that affects the marginal gap. The marginal gap in the temporary crown can increase when there are thermal changes and repeated occlusal loads in the oral cavity.[6]

It is concluded that CAD/CAM method to manufacture temporary crowns produces a better marginal fit than the conventional method. Polymerization shrinkage is one of the causes of dimensional changes that cause a marginal gap. Polymerization shrinkage is lower in the manufacture of temporary artificial crowns with CAD/CAM technology because PMMA blocks have gone through a prepolymerized process according to the manufacturer's regulations during fabrication and the 3D print method goes through a better polymerization process because they are polymerized layer by layer.

There are several weaknesses in scoping review. The studies that reviewed all were in vitro studies so they did not simulate the actual conditions of the oral cavity such as the direction and magnitude of masticatory forces, temperature degradation of the material due to enzymes in saliva, pH, oral hygiene as well as diet and masticatory function. In CAD/CAM studies on artificial crowns made from PMMA, it is still relatively new so that the results obtained are not many and are still in the form of laboratory research, so further studies are needed to get more accurate results.

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