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Semi-permanent Restorations Just Temporary or Long-lasting Use?: A Review of the Literature

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Abstract

In some clinical situations, using a provisional fixed restoration for an extended period of time is unavoidable. However, traditional materials are unable to withstand this, resulting in restoration fracture, which leads to repair and/or replacement as well as increased chair time and treatment costs. Many practitioners have been developing their protocols to improve physical properties and longevities of these restorations. Currently, many manufacturers have launched novel products and several fabrication techniques; some are claimed to be "semi-permanent restoration" with improved strength and survivability. The purpose of this review article is to assist clinicians to decide the most appropriate provisional restorative materials for long-term usage in complex treatment procedures, including fabrication and cementation techniques.

Keywords: acrylic resin, cementation, composite resin, permanent restoration, provisional restoration

Introduction

The provisional restoration which usually infers to fixed restoration, may need to be able to survive up to 6 months or longer, under certain treatment plans.[1] However, the "semi-permanent restoration" or "long-term provisional restoration" is expected to last longer than the provisional restoration, but not as long as the permanent restoration. Müller *et al.*[2] characterized the semi-permanent materials as possessing adequate strength, which avoid failure while still provides reliable intended retrievability when needed. An indication of the provisional restorations includes a complicated prosthodontics case in which they are used for several months to assure and alter the occlusal surface to provide optimal guidance and functional scheme. They are also useful for evaluating soft tissue reactions and the restoration's acceptance. Moreover, patients can evaluate both esthetics and phonetics while having these restorations.

In addition to the advanced prosthodontic cases, provisional restorations can be used in several circumstances for various purposes. During the osseointegration process of a dental implant, semi-permanent restorations give the opportunity to load the implant progressively.[3] Furthermore, bruxism patients require stronger materials for the temporary restorations to decrease chair time for repair and/or replacement. In teeth with questionable prognosis or severe periodontitis which patient prefer not to undergo tooth extraction, these restorations can be used to reduce the treatment cost. In addition, they can be used in pediatric treatment with a high esthetic demand as well as in orthodontic treatment which requires a good longevity and bond with orthodontic adhesive. Lastly, semi-permanent restorations can reduce technician's fee and material cost compared to the permanent restorations which is very beneficial to the patients with low socioeconomic status. All of these applications massively improve treatment outcomes while making clinicians' work simpler.

Conventional provisional restoration materials can be divided into two groups according to their chemical composition including 1) Acrylic resin which based on monomethacrylates or acrylic resins, which include polymethyl methacrylate (PMMA) and polyethyl methacrylate) (PEMA) and 2) Composite resin which based on dimethacrylates or bis-acryl resins such as bisphenol A-glycidyl dimethacrylate (Bis-GMA) and urethane dimethacrylate (UDMA).[3] This review article summarizes the properties of provisional and semi-permanent restoration materials as well as the reinforcement and cementation techniques for these restorations.

Ideal properties

To achieve favorable treatment outcomes, semi-permanent restorations should have the similar characteristics to the provisional restorations[4,5], which can be remained for the extended period of time. It could also be considered that long-term provisional crowns should have equivalent properties to those of permanent materials.[3] Below are the desired properties of the semi-permanent restorations;

1. Good marginal adaption; adapts nicely to the tooth surface and matrix
2. Adequate retention and resistance to dislodgment due to the normal masticatory function
3. Strong, durable, and hard
4. Low thermal conductivity
5. Nonirritating to pulp and other tissues; low exothermicity
6. Nonporous and dimensionally stable
7. Comfortable
8. Esthetically acceptable for the shade selection; translucent tooth-like appearance
9. High color stability
10. Physiologic contours and embrasures
11. Easy to fabricate, reline, repair, and to mix and load in the matrix; relatively short setting time
12. Physiologic occlusion
13. Conductive to routine oral home-care cleaning procedures
14. Can be highly polished with plaque- and stain-resistant surfaces after finishing
15. Easy to remove and re-cement by dentists
16. Relatively inexpensive
17. Low incidence of localized allergic reactions

Conventional provisional restorative materials

Acrylic resins

PMMA was initially introduced around 1940[6] and has remained as one of the the most frequently used materials for the fabrication of provisional restorations.[7,8]

Plant *et al.,*[9] showed that the increased intrapulpal temperature associated with the polymerization of methyl methacrylate materials could be 5 times higher compared to which associated with the normal consumption of thermally hot liquid. However, several studies indicate that PMMA is preferred when provisional restorations are made by indirect techniques.[7,10]

PEMA, introduced in the 1960s,[11] has both advantages and disadvantages compared to methyl methacrylate. Osman *et al.,*[12] showed that ethyl methacrylate material has the highest value of fracture resistance compared to methyl methacrylate and bis-acryl materials. Therefore, ethyl methacrylate may be a better selection for direct provisional prosthesis fabrication[5] and is more appropriate for short-term usage relatively to methyl methacrylate.[13,14] Two other chemically similar materials, vinyl-ethyl and butyl methacrylate, also exhibit similar clinical behavior compared to PEMA.

Composite resin

Composite provisional materials are at least composed of two main chemical ingredients. Most of these materials are made of bis-acryl resin (e.g. dimethacrylate bis-GMA, urethane resins, or resin containing at least 2 acrylic groups in the monomer).[15] When this resin is combined with an inorganic radiopaque fillers, it can be utilized as a provisional material similarly to restorative materials. In contrast to PMMA, Bis-acryl composite resins contain divinyl methacrylate monomers and filler particles. Hence, the polymerization shrinkage and exothermic release may be minimized, while color stability may be increased compared to PMMA. Moreover, it also has superior abrasion resistance and esthetics, as well as, less marginal misfit and free monomer elution.[16] These materials are available in several forms including auto-polymerized, dual-polymerized, or visible light-polymerized forms. Most composite materials are currently consist of an auto-mix delivery system which is fast and easy to use with less air entrapment; however, comes with higher costs.[16,17] While bis-acryl materials are compatible with other composite materials, they are difficult to manipulate for repair and addition.[5,18]

In the 1980s, visible light polymerized (VLC) materials were introduced,[11] they require the addition of urethane dimethacrylate (UDMA), a resin whose polymerization is catalyzed by visible light and a camphoroquinone/amine photo initiator.[19, 20] To improve physical properties such as reduced polymerization shrinkage, these materials typically include fillers such as microfine silica.[21] Unlike methacrylate resins, they do not produce residual free monomers after polymerization, which explains why they exhibit significantly decreased tissue toxicity relative to methacrylate resins.[22] Furthermore, Haddix[23] claimed that these materials can be used to fabricate provisional restorations with the same quality as heat-polymerized, laboratory-processed restorations, but in less time and at a lower cost. Dual-polymerized composite materials generally incorporate both auto-polymerized bis-acryl and light-polymerized urethane dimethacrylate resins in various ratios depending on the products.

Strengthening the provisional materials

Most of resins used for provisional restorations are fragile. Repairing and replacing fractured provisional restorations are concerns for both clinicians and patients because of the increased expense and time involved. Physical properties including strength, density, and hardness may predict the longevity of provisional restorations.[4] Several approaches were developed to overcome these issues aiming to convert conventional provisional materials into semi-permanent restorations.

Heat polymerization

Heat polymerization of acrylic resin materials can be used when the the increased strength and longevity of provisional restorations are required.[4] Fabrication with heat polymerization and indirect laboratory technique results in acrylic resin materials with higher density, strength, wear-resistant, color stability, and resistant to fracture compared to their autopolymerizing counterparts.[24] Chee *et al.,*[25] studied the effect of chilled monomer on the working time of 3 different autopolymerizing acrylic resins. Even though the working and setting periods were increased by up to 4 minutes, the transverse strength of the products was reduced by 17% when cold monomers were used.

Metal reinforcing structure

Hazelton and Brudvik[26] reported the benefits of stainless steel orthodontic band material adapted around abutment teeth. It can also be welded and fitted inside acrylic resin shell crowns to reinforce autopolymerizing acrylic resin materials.(25) The increased rigidity obtained by this technique reduce the fracture rate of the materials. In addition, Galindo *et al.,*(24) used cast metal substructure with metal beadings to reinforce heat-processed provisional restoration. Although there was no chemical surface treatment on metal substructure required in both studies, the application to base metal alloys of metal conditioners containing functional monomers, such as 4-methacryloyloxyethyl trimellitate anhydride (4-META) and 10-methacryloyloxydecyl dihydrogen phosphate (MDP), significantly increased the bond strengths of a denture base resin to the titanium alloys and Co-Cr alloy substructure.(27) The reduction in flexure by these techniques prevents the loss of temporary cement's retention leading to less dental caries on the abutment teeth and loss of the provisional restoration.

Fiber reinforcement

Various materials have been used for fiber reinforcement, for instance, metal, glass, sapphire, Kevlar®, polyester, and rigid polyethylene. However, most of these materials fail to improve resin strength(4), therefore, more proper materials for this purpose are much required. Carbon fibers have been shown to massively increase the flexural strength of polymers,(28) however, their black color limits their use for provisional restorations due to the esthetic concern.(29) In addition, polyethylene fibers have been studied. Nevertheless, they did not enhance transverse strength in the absence of surface treatment because of the inadequate adhesion between the fibers and the polymer matrix.(30) However, surface treatment by plasma can increase the strength of polyethylene fibers.(31) Indeed, Samadzadeh *et al.,*(32) showed that the fracture strength was improved in bis-acryl materials with plasma treated woven polyethylene fiber (Ribbond® (Ribbond, Seattle, WA, USA)). Plasma treatment has been shown to improve the physical and mechanical properties of provisional restoration materials. Plasma is created by exciting gas molecules with an electrical energy source. During the activation, electrons are ejected from the molecules resulting in extremely reactive disassociated molecules. The removal of hydrogen atoms from the polymer backbone and their replacement with polar groups is the key mechanism of polymer surface modification. This improves the reactivity of the resin matrix and promotes excellent adherence.(33) Although the Ribbond® fibers did not improve the fracture strength of PMMA prosthesis, they could prevent advanced catastrophic fracture. As repairing and/or remaking provisional restorations can be very time-consuming, the increased strength of the PMMA with these fibers can reduce clinical failures of provisional fixed partial dentures. Additionally, these fibers have a superior esthetic property which can be beneficial in the restorations in the anterior region because the fibers become invisible when integrated into the PMMA.(31)

Silanized glass fibers have also been used for fiber reinforcement due to their strong adherence to the polymer matrix, outstanding esthetic quality, and enhanced strength of the resin composite. The silane treatment can be done in the dental office by soaking the glass fibers in a silane coupling agent for at least half an hour before usage.(34)

Resin matrix modification

Zuccari *et al.*(35,36) studied solutions to produce a resin matrix with increased strength by reducing crack propagation. They reported that adding admixed zirconium oxide granules to unfilled methyl methacrylate resin enhanced modulus of elasticity, transverse strength, toughness, and hardness drastically, even though the water sorption had a deleterious effect on mechanical properties over time.

Semi-permanent restoration materials

Several semi-permanent restorative materials have been introduced in recent years, with the manufacturer claiming that these products can last for months or years in the oral cavity. By their fabrication techniques, these materials can be categorized into 2 groups: direct and indirect restorations.

Direct restoration

The stainless steel crowns (SSC) are prefabricated metal crown restoration which consist of various sizes and can be adapted to each individual tooth. While they have been used routinely in primary teeth, the success rate of these materials in semi-permanent restorations can be ensured by if managed properly. Though the use of SSC as full coronal restorations in the permanent teeth has largely been overlooked(37), it is the most conservative full coronal coverage restoration in an incompletely erupted permanent molar with large pulp spaces with the minimal tooth preparation required to seat the crown. Tooth preparation and crown placement are similar to SSC in primary molars; however, the short clinical crown height in immature permanent molars may result in the instability of intracoronal restorations. Nevertheless, because of their ability to be trimmed and crimped, SSC can be placed subgingivally in these teeth with an acceptable retention. They do not disturb further tooth eruption and are enable for the placement of a lab-fabricated complete coronal restoration in the future if needed.(37) According to Discepolo and Sultan,(38) SSC satisfactorily perform as provisional restorations with an average of 45.18 months of the service period. However, another study stated that these crowns are more difficult to adapt to a conventionally prepared mature permanent tooth.(17) Another disadvantage of the SSC restorations include impaction of the adjacent teeth, and periodontal defects which might lead to long-term consequences.(38) Furthermore, hypersensitivity to nickel-based restorative materials has been observed in SSC materials.(39) Thus, proper case selection and frequent follow-up are important in SSC semi-permanent restorations.

For the novel composite resin materials, 3M™ has introduced Protemp™ Crown (3M ESPE, Seefeld, Germany)(3), which was claimed to be the world's first preformed, malleable temporary crown. Protemp™ Crown materials mimic wax and can be simply carved and reshaped with a composite instrument, making them malleable and adaptable to the prepared teeth before light curing with comparable properties to resin composite materials. A combination of a unique crystalline resin system and highly interacting aggregated inorganic fillers are used in Protemp™ Crown. As a result, the material possesses a 3-dimensional, physically crosslinked structure. Light-activated curing is another feature which enables the clinicians to control the setting of the material. This light-curable resin is composed of bis-GMA and a functionalized dimethacrylate resin. Physical strength, radiopacity, and wear resistance are provided by silanated zirconia-silica and fumed silica fillers. The filler contains approximately 78 percent silanated inorganic filler by weight, with an average particle size of 0.6 micrometers. Protemp™ Crown also contains pigments and is available in various sizes for maxillary and mandibular molars, premolars, and canines making it feasible to perform on most teeth promptly and successfully.

In addition to 3M™ Protemp™ Crown, DMG has launched LuxaCrown (DMG America, Ridgefield Park, NJ, USA)(40-42), a self-curing bis-acryl composite material for the chair-side fabrication of semi-permanent crowns and bridges. It can be cemented with either permanent or temporary luting cement and is designed to last up to five years. LuxaCrown is composed of a matrix of multifunctional methacrylates, catalysts, stabilizers, and additives with a 0.02-1.5 µm glass filler particle (46 wt% = 26 vol%). Importantly, it is free of methyl methacrylate.(41) LuxaCrown also exhibits a natural appearance, great polishability, remarkable color stability, plaque reduction, superior fracture toughness, and wear properties similarly to the enamel.(40-42)

Indirect restoration

The visible light polymerized resin, such as SR Adoro® (Ivoclar vivadent, Schaan, Liechtenstein) which is manufactured by Ivoclar Vivadent is one of the commonly used materials in indirect restorations. SR Adoro® is the micro-fill composite material that possesses the UDMA matrix, the component well-known for its toughness which is higher than that of its first generation and the frequently-used bis-GMA.(43)

Nowadays, computer-aided design and manufacturing (CAD/CAM) technologies have led to major improvements in dentistry(44) and have increasingly gained attention from many clinicians. Compared to the traditional fabrication processes, CAD-CAM subtractive technologies create dependable restorations with the exact dimensions while reducing the production time and labor.(44) For PMMA material, CAD/CAM exhibits significant improvement in flexural strength, impact strength, and flexural modulus when compared to the conventional heat-cured PMMA.(45) The subtractive manufacturing technique was often thought to be synonymous with CAM; a PMMA block is milled, ground, drilled, turned, or polished into a desired shape and dimension in this procedure. While having several advantages, subtractive manufacturing has the procedural and environmental disadvantages of restricted surface resolution. The milling process can result in up to 90% of material loss(46) and generate both surface and sub-surface machining defects.(44) Furthermore, the subtractive approach can generate only a limited number of restorations in each machining cycle and cannot produce advanced or complicated designs. Additionally, the instruments can be worn after a certain of cycles which might lead to several problems. In contrast to the subtractive approach, additive procedure can save materials and generate more complex shapes resulting in an increased popularity in the dentistry industry.[44,46]

In the recent study comparing 3D printing and milling technologies, provisional crowns produced by 3D printing generated superior intaglio surface trueness with uniformity than milled crowns.[47] Thus, many clinicians are currently more interested in 3D-printed provisional crowns due to the numerous advantages including reduced manufacture cost and time with higher accuracy and predictable results.

Cementation for semi-permanent restoration

To prevent contamination and bacterial penetration, luting agents must have high mechanical properties, low solubility, and strong adhesion to teeth.[48] to ensure that the restoration and prepared tooth are properly sealed[49] and to prevent marginal leakage and pulpal irritation.[48,49] For temporary restorations, various luting materials are used including calcium hydroxide, zinc oxide eugenol, as well as, zinc oxide non-eugenol.[48] However, all of these have weak mechanical qualities which are prone to degrade over time. This can have a detrimental impact on marginal leakage, While it is easier to remove the provisional restorations cemented with these materials from teeth, marginal leakage is likely to be observed.[48]

For the semi-permanent restoration, Spear[50] suggested two types of cement. First, reinforced zinc oxide eugenol because of its sealing property, sensitivity protection, ease of removal, and palliative effect on the pulp.[51] When using reinforced zinc oxide eugenol, the restorations must be thoroughly polished and patients have to be followed up every 8 to 12 weeks. Zinc oxide eugenol require a complex acid-base reaction to form cement which is different from other aqueous dental cement that requires the presence of an accelerator (often acetic acid). Exposure to water speeds up the setting time in the latter. Although fully-set zinc oxide eugenol has an excellent sealing ability, the physical properties (compressive strength, tensile strength, solubility, etc.) are still compromised leading to remarkable creep and flow under pressure. For these reasons, zinc oxide eugenol is not commonly used for luting definitive restorations.[52] In the late 1950s, 2-ethoxybenzoic acid (EBA) was added to zinc oxide eugenol cement to improve its properties; the example of this product is SuperEBA® (Keystone Industries, Gibbstown, NJ, USA). However, the presence of EBA may have a negative impact on the film thickness and solubility.[51]

The second cement that Spear[50] suggested is resin-modified glass ionomer (RMGI) which is indicated for patients who require one to two years of orthodontic treatments. This cement remarkably eliminates the possibility of caries, leakage, sensitivity, and loosening, but the modification and/or renewal of the provisional restorations is required when the orthodontic treatment is done. RMGI is a hybrid material combining water-soluble polymers or polymerizable resins with conventional cement The examples of RMGI products are GC Fuji Plus® (GC America, Chicago IL, USA), 3M RelyX™ Luting Cement (3M ESPE, Seefeld, Germany) and Dyract® Cem (DENTSPLY DeTrey, Konstanz, Germany). RMGI was created in the 1980s attempting to overcome the two important weaknesses of conventional glass-ionomer cement including low early strength and high solubility. Upon two separate reactions occur: 1) the resin phase which polymerizes quickly (either by chemical or light initiation) and 2) the glass ionomer phase which proceeds slowly toward normal maturation via an acid-base reaction over an extended period of time. When compared to the conventional glass ionomers (GI), fully-set RMGI cement offer superior physical and mechanical properties. A very important characteristic which is superior to GI is that RMGI has the cariostatic potential as a consequence of fluoride release, as well as, the ability to induce remineralization. Although RMGI has higher strength and lower early solubility, loss of adhesion to tooth structure and a propensity for dimensional change due to water uptake during the resin phase can be found.[52]

Burke[3] suggested using self-adhesive resin cement for the resin-based crown material used as a semi-permanent restoration. Though future studies are needed, it is believed that the self-adhesive resin luting cement bonds to the resin-based crown, hence, maximizing its retention. However, some do not recommend GI and resin-based adhesive cements to retain provisional restorations because their bond to the prepared tooth surface is too strong making the removal of the provisional restoration, cleaning of the tooth surface, and cementation of the final restoration more difficult.[53]

Conclusions

Based on the current literature, numerous advantages of semi-permanent restoration materials are suggested and new approaches to strengthen these materials are also proposed. As strengthening the conventional provisional materials can be expensive, inconvenient, and time-consuming in some cases, CAD/CAM technologies and novel chair-side fabricated composite resin materials have been introduced to overcome these limitations. Table 1 provides a summary of compositions, fabrication techniques, advantages and limitations of semi-permanent restoration materials. Furthermore, some of the ideal properties described earlier were listed in the advantages of each material in this table.

Additionally, cementation is also a crucial step contributing to the success of the semi-permanent restorations. The cementation procedures and materials of choice are determined by the duration of the treatment and restoration lifetime. RMGI and self-adhesive resin cements are excellent choices for 1-2 years of orthodontic therapy due to their high retention, while reinforced zinc oxide eugenol cement is preferred for a shorter treatment time. Therefore, a proper selection of restoration and cementation materials is very crucial as it can enormously contribute to the success of the treatment with semi-permanent restorations.

Table1: A summary of compositions, fabrication techniques, advantages and limitations of semi-permanent restoration materials

Semi-permanent restoration materials	Fabrication techniques	Main compositions	Advantages	Limitations
Stainless-steel crown	Direct restoration	Nickel-based metal	• Long-term success for primary teeth • Various sizes and shapes • Mostly conservative full coronal coverage for erupting permanent molars	• Difficult to adapt to mature permanent teeth leading to food impaction, periodontal defect, and hypersensitivity
Protemp™ Crown	Direct restoration	Bis-Acryl	• Chairside carving and adaptation • Various sizes and shapes • Equivalent physical properties to resin composite materials • Light-curable	• More chair time and clinician's skills are needed compared to the indirect restoration
LuxaCrown	Direct restoration	Bis-Acryl	• Long-lasting (up to 5 years) • High esthetics • Excellent polishability • Exceptional color stability • Plaque reduction • Improved fracture toughness and wear resistance similar to the enamel	• More chair time and clinician's skills are needed compared to the indirect restoration
Milled PMMA crown	Indirect restoration	PMMA	• Superior flexural and impact strength, and flexural modulus compared to the conventional heat-cured PMMA	• Higher cost than the direct restoration • Reduced surface resolution • Material waste and machine errors
3D-printed PMMA crown	Indirect restoration	PMMA	• Less material waste and more uniformity when constructing advance designs • Superior intaglio surface trueness compared to milled crowns	• Higher cost than the direct restoration

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