

The Advantages of High-density Polymer CAD/CAM Interim Restorations in Oral Implantology

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Fabrication of temporary restorations is an essential part in dentistry and especially in oral implantology. Polymethyl methacrylate is used for a long time as material for temporary restorations and many improvements has been done to increase its properties, especially fracture resistance. Crosslinking and computer-assisted design/computer-assisted machining permit fabrication of long-term temporary restorations with flexural strength high enough and good modulus of elasticity that do not fracture easily under functional loads.

Keywords: high-density polymer, CAD/CAM technology, oral implantology

Making of temporary (provisional or interim) restorations is an essential part in dentistry, especially in oral rehabilitation and oral implantology. One of the longest-used materials for the fabrication of provisional restorations is polymethyl methacrylate (PMMA), which has a good compatibility with human tissues [1, 2]. The advantages of PMMA are: good marginal fit with good transverse strength, providing a durable restoration [3] and good polishability [4], but its abrasion resistance is low [5].

As traditional PMMA resin possesses low mechanical properties, attempts have been made to reinforce this material with different fillers like: glass, silica, carbon fiber, steel wires, and polyaramid [6] or to strengthen using heat curing or light curing [7]. Improved polymers and technologies have brought progresses to conventional materials and technologies obtaining finite materials with better physical and chemical characteristics (low porosity, colour-stable, high strength, better adaptation) [8], but fracture resistance remains a major problem for provisional restorations [9].

Due to unfavourable conditions under which PMMA-resin is polymerized and fabricated, direct provisional restorations are prone to inhomogeneity, pores, and fissures, which may lead to discoloration, bacterial adherence, and a significant decrease in long-term stability and biocompatibility [10].

Therefore, for a prolonged period indirect provisional restorations are usually fabricated in the dental laboratory and they need a metal alloy or glass fiber-reinforced framework to increase their load capability.

Today, new manufacturing technologies and innovative materials such as high-density polymers offer outstanding possibilities for oral rehabilitation and implantology because

allow obtaining of long-term interim restorations necessary for progressive bone loading.

Crosslinking, a bond that links one polymer chain to another, changed fundamentally the mechanical properties of a linear polymer by creating a stronger and more resistant crosslinked polymer with a three-dimensional network instead of a linear structure (fig. 1). It has been experimentally observed that when crosslinked, PMMA has a characteristically more ductile response to mechanical loading than does linear PMMA [11]. It suggests that the formation of covalent cross links in the polymer composite remarkably improves the fracture toughness of randomly distributed PMMA composites [12].

At present, many manufacturers offer high-density polymers based on highly cross-linked PMMA acrylic resins for CAD/CAM manufacturing methods. Computer-assisted design/computer-assisted machining (CAD/CAM) allows the milling of 3D designed objects from a bulk material, known as block or disk, and the technique is reported to provide high precision in fitting crowns on teeth and abutments [13, 14].

Long-term temporary restorations needed in oral implantology can be done using CAD/CAM technology from preprocessed PMMA blocks. CAD/CAM resin blocks are industrially polymerized under standardized parameters at high temperature and pressure to assure that the microstructure and the mechanical properties of resin blocks exhibit constant quality [15]. Therefore, industrial fabricated resin blocks have higher mechanical properties in comparison with conventional ones [16] and better optical properties [17] and temporary restorations done from resin blocks can be used for fabrication of long-term period.



Fig. 1. Structure of a linear polymer (left) and crosslinked polymer (right). M is monomer, basic structures of a polymer, called **mer** unit, Y another type of **mer** unit, continuation of polymer segment.

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Since long-term temporary restorations have to face extended functional loading, the interim restorative material should possess good mechanical properties, colour stability, and also to act as a guide for soft tissue healing [18].

The aim of this study is to evaluate the outcome of temporary crown made of PMMA disk using CAD/CAM technique for long-term temporary restorations on dental implants.

Experimental part

Fabrication of PMMA-resin CAD/CAM temporary implant-supported crown details following workflow: evaluation of the implant site (fig. 2), impression with polyvinyl-siloxane in open tray (fig. 3), pouring de model and preparation for scanning, design and CAD/CAM fabrication of crown from a monolithic block Telio CAD (Ivoclar Vivadent) (fig. 4 and 5) utilizing a three-axis milling unit (Cerec inLab MC XL system, Sirona), verification of adaptation of crown on implant abutment (fig. 6) and placement in oral cavity (fig. 7). Temporary crown was delivered with light contacts in centric position and without contact in excursive jaw movements.



Fig. 2. Clinical aspect of osseointegrated implant in lateral mandibular area

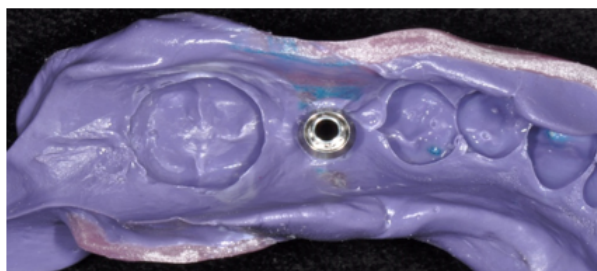


Fig. 3. Impression with abutment transfer in open tray

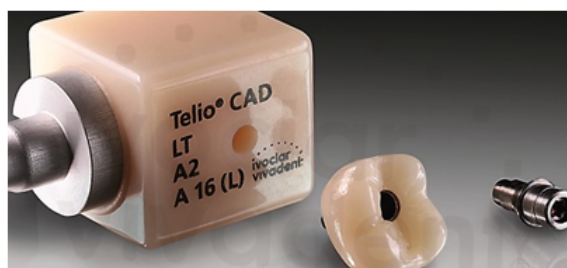


Fig. 4. Monolithic polymer CAD block

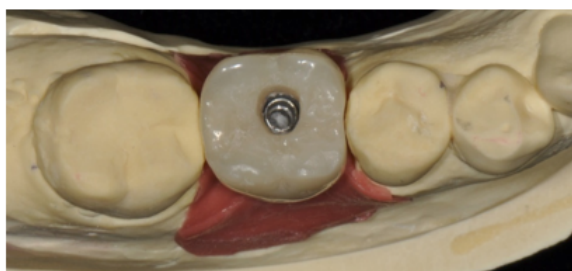


Fig. 5. Long-term temporary screw-retained crown on model.



Fig. 6. Adequate adaptation of long-term temporary screw-retained to implant abutment.



Fig. 7. Long-term temporary screw-retained crown in the oral cavity

The outcome of temporary crown made of PMMA disk using CAD/CAM technique for long-term temporary restorations on dental implants was evaluated following two factors: temporary crown and periimplant gingival tissue.

Criteria for crown evaluation are: anatomic configuration, marginal adaptation, physiognomic aspect, discoloration, surface texture.

Criterion 1: restoration with anatomical contour and relief in harmony with neighbouring teeth and gingival tissues.

Criterion 2: continuity between crown and implant.

Criterion 3: restoration has the colour of neighbouring teeth.

Criterion 4: there is no discolouration of temporary crown.

Criterion 5: crown has a smooth surface.

Clinical parameters were used for evaluating the periimplant marginal soft tissue and included: Mombelli plaque index (mPI) and Mombelli gingival index (mGI).

Mombelli and co-workers [19] modified the original Plaque Index (PI) introduced by Silness and Loe to assess biofilm formation in the marginal area around implants as follows:

- score 0 - no detection of plaque,
- score 1 - plaque only recognized by running a probe across the smooth marginal surface of the implant,
- score 2 - plaque can be seen by the naked eye,
- score 3 - abundance of soft matter.

They also introduced an index used to assess marginal mucosal conditions around oral implants, Mombelli gingival index (mGI):

- score 0 - no bleeding when a periodontal probe is passed along the mucosal margin adjacent to the implant,
- score 1 - isolated bleeding spots visible,
- score 2 - blood forms a confluent red line on mucosal margin,
- score 3 - heavy or profuse bleeding.

16 subjects enrolled in this study. All subjects received screw-retained temporary crown for implants replacing single missing teeth. Patients were instructed about maintaining a good oral hygiene and after fixing temporary crown they are evaluated at one week, 12 weeks and 18 weeks. After 18 weeks periimplant soft tissue is mature and final restoration can be fabricated.

Table 1
ASSESSMENT OF LONG-TERM TEMPORARY CAD/CAM CROWN

Criterion Subject	Anatomic configuration			Marginal adaptation			Physiognomic aspect			Discoloration			Surface texture		
	1 W	12 W	18 W	1 W	12 W	18 W	1 W	12 W	18 W	1 W	12 W	18 W	1 W	12 W	18 W
1.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
4.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
5.	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+
6.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
7.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
9.	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+
10.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
12.	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+
13.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
14.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
15.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
16.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Results and discussions

The results are presented in table 1 and 2. All long-term temporary crowns performed well considering criteria 1, 2, 3, and 5. Three subject (18.75%) presented discoloration (criterion 4) after 18 weeks and two (12.5%) after 12 weeks. Discoloration was extrinsic and disappeared after polishing.

Regardless of their chemical composition, dental resins tend to absorb liquids and as a result discoloration may occur over time especially in relationship with coffee, tea, red wine, or chlorhexidine mouthwashes [20, 21]. Also, the degree of discoloration is be influenced by oral hygiene or surface roughness of the restoration [22]. In this study majority of subject demonstrated adequate oral hygiene, only two subjects (12.5%) displayed plaque when running a probe across the smooth marginal surface of the implant after 18 weeks. Crosslinked polymers do not absorb liquid as readily as linear polymer [23] and are more resistant to discolouration in comparison with linear ones.

Regarding marginal mucosal conditions around oral implants, all subjects shown no bleeding when a periodontal probe is passed along the mucosal margin adjacent to the implant. Consequently, after 18 weeks after placing long-term temporary crown, periimplant soft tissue permits fabrication of final restorations.

Telio CAD is a cross-linked PMMA block for the fabrication of long-term temporaries (up to one year) by means of the CAD/CAM technique. It is used for long-term provisional restorations, from single-tooth restorations up to 4-unit fixed dental prosthesis including restorations on implants [10]. The use of a high density, highly filled acrylic industrially fabricated in blocks offers significant advantages in fabrication of temporary restorations. In contrast to conventional temporary materials, the industrially produced blocks offer the advantage of a constant high quality, because fluctuations due to the mixing of components cannot occur [24]. The CAD/CAM polymer blocks are free of porosity and voids, exhibit higher homogeneity by less infiltration of pollutants and bubbles, have higher fracture resistance, and enhanced colour stability [25]. Another advantage is the fact that stains and/or layering materials can be used to apply final aesthetic optimizations.

Because these materials are milled to desired shape, there is no volumetric change in size of the material due to polymerization shrinkage during fabrication and due to high homogeneity surface present high polishability and therefore, smoothness. And a smooth surface inhibits bacterial adherence.

According to ISO standard for polymer-based crown and bridges materials [26] flexural strength should at least

Parameter Subject	Mombelli Plaque Index (mPI)			Mombelli Gingival Index (mGI)		
	1	12	18	1	12	18
	W	W	W	W	W	W
1.	0	0	0	1	1	1
2.	0	0	0	1	1	1
3.	0	0	0	1	1	1
4.	0	0	0	1	1	1
5.	0	0	1	1	1	1
6.	0	0	0	1	1	1
7.	0	0	0	1	1	1
8.	0	0	0	1	1	1
9.	0	0	0	1	1	1
10.	0	0	0	1	1	1
11.	0	0	0	1	1	1
12.	0	0	1	1	1	1
13.	0	0	0	1	1	1
14.	0	0	0	1	1	1
15.	0	0	0	1	1	1
16.	0	0	0	1	1	1

Table 2
ASSESSMENT OF PERIIMPLANT TISSUE

50 MPa, water sorption no more than $40 \mu\text{g}/\text{mm}^3$ and solubility less than $7.5 \mu\text{g}/\text{mm}^3$. The flexural strength of PMMA-resin blocks is high enough and because is coupled with a good modulus of elasticity, they do not fracture easily under functional loads. Telio CAD showed high flexural strength [27], more than 100 MPa and flexural modulus around 3250 MPa [28]. Resistance to fracture is 950 N in the Zwick universal testing machine [28]. *In vitro* study shown that aging did not influence the fracture load of PMMA-resin block, including Telio CAD [29].

Due to the continued growth of the implant request, the demand for long-term temporary restoration has been constantly rising. An exceptional characteristic of CAD/CAM technology is the ability to replicate the poured model after scanning and milled temporary restorations. This technology and utilization of high-density polymer discs avoids the disadvantages of traditional indirect temporary restorations.

Conclusions

Long-term temporary restoration with high-density polymer CAD/CAM showed no fracture or periimplant soft tissue bleeding during survey. Anatomic configuration, marginal adaptation, physiognomic aspect, surface texture was well preserved during 6 months.

With the limitations of this study, it can be concluded that progressive bone loading with high-density polymer CAD/CAM interim crown is a highly predictable technique.

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