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Mini Review

Marginal Integrity Of 3D Printed Provisional Restorations.

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ABSTRACT

A fixed dental prosthesis is used for restoring oral function and aesthetics when replacing missing teeth. This allows the preservation and improvement of the patient's appearance, comfort, physical and mental health. Numerous variables can influence the precision and marginal adaptation of an FDP, including the precision of the impression, the fabrication of the master cast, and the method of fabrication of the prosthesis. These variable methods of fabrication can be broadly classified into conventional and digital methods. The conventional method had demonstrated remarkable success; however, this procedure is unfavorable for patients. An alternative was needed to minimize the laboratory variables and the human factor generated by the inconsistency of the dimensional changes of different materials used and also to reduce patient discomfort. Therefore, digital techniques, known as CAD/CAM systems, that were recently introduced have gained great popularity. Although even in a digital workflow, it is necessary to create a functional model in order to determine and correct the restoration's fit. The manufacturing step of digital technology can be categorized as subtractive (milling) and additive (3D printing). Additive manufacturing produces precise accurate prosthesis by minimal materials and less cost. Additionally, multiple restorations can be fabricated simultaneously.

Keywords: marginal integrity, 3D printing, provisional restoration.

Introduction

Any dental prosthesis's marginal integrity is crucial to both its longevity and success. Restorations that fit poorly are thought to be harmful to the periodontium and the teeth that borders them. Oral bacterial adhesion is facilitated by ill-fitting restorations, and this can be linked to traumatic gingival irritation and/or subsequent caries (1).

From the start of tooth preparation until the final cementation, the provisionalization of restorations is an essential stage in any fixed prosthodontic therapy. A successful final restoration depends on a temporary restoration that is manufactured correctly (2).

With the increasing popularity of 3D printing, a variety of resins are being utilised. One method of additive manufacturing is 3D printing (layer upon layer). It can produce accurate prostheses with little wastage of materials. It is thought of more rapid and less expensive than subtractive milling. In addition, it is force-free, passive, and capable of producing finer features like anatomical details and undercuts. Fused Deposition Modelling (FDM), Digital Light Processing (DLP), Selective Laser Sintering (SLS), and Stereolithography (SLA) are some of the 3D printing techniques (3).

Provisional restoration materials:

The type of material plays a significant role in the overall fracture strength outcome; numerous studies reported that bis-acryl resins are stronger than conventional PMMA and PEMA resins (4). The clinician must take into account a number of factors when selecting a provisional restoration material, including flexural strength, surface hardness, wear resistance, dimensional stability, polymerization shrinkage, colour stability, handling properties, repair capacity, and cost.

No provisional material has been found to be universally useful in all clinical situations, according to Haselton et al. (2005). As a result, it's critical to understand the characteristics of the provisional materials in order to understand the indications and contraindications for their clinical use for prolonged periods of time (5).

Based on the fact that certain bis-acryl groups exhibited high mean fracture force while others performed poorly, even when compared to PMMA resins (6), Haselton et al. (2002)

concluded that the fracture property relied on each material individually rather than the material category.

Fabrication techniques of interim restorations:

The fabrication process of provisional restorations has been greatly impacted recently by the availability of CAD/CAM technology in the dentistry field. CAD/CAM technology falls into two categories: additive manufacturing, also known as three-dimensional (3D) printing, involves layer by layer addition of small sections of the material, while subtractive manufacturing, also known as milling, is accomplished by removing undesirable portions from a block of solid material. The mechanical qualities of previously utilised chemically cured resins may be improved by using high density and pre-polymerized polymer, which is made possible by the CAD/CAM milling process. According to a number of investigations, CAD/CAM-milled PMMA, with or without thermocycling, exhibited greater strength than auto-polymerized PMMA and traditional bis-acrylic based materials (7).

According to Jivanescu et al. (2016), the mechanical and physical characteristics of direct provisional restorations are negatively impacted by the unfavourable circumstances in which resin-based materials are manufactured and polymerized. Due to their propensity for inhomogeneity, porosity, they run the risk of discolouration, bacterial adherence, and a marked decline on biocompatibility and long-term stability. In order to overcome the drawbacks of the traditional procedure, new, modern technologies are introduced to create indirect provisional restorations (8).

CAD/CAM resin blocks for temporary restorations:

The market offers a range of CAD/CAM resin blocks that can be used for temporary restorations. The TelioCAD, VitaCAD, Artbloc, Premio, and DC temperatures are a few of these. According to Stawarczyk et al. (2012), CAD/CAM resin blocks undergo industrial polymerization at high temperatures and pressures using standardised conditions. This ensures that the resin blocks' mechanical properties and microstructure maintain a consistent quality. As a result, industrially produced resin blocks offer both superior optical and mechanical qualities as compared to conventional ones (9).

Guth et al. (2012) discovered that there are major benefits to fabricating temporary restorations utilising high density, highly filled acrylic blocks that are manufactured industrially. Because fluctuations resulting from component mixing are removed, industrially made blocks offer a steady and constant high quality, in contrast to conventional provisional materials. The CAD/CAM polymer blocks had improved colour stability, greater fracture resistance, reduced infiltration of contaminants and bubbles, and no porosity or voids (10).

CAD/CAM technology for interim restorations:

In recent times, interim crowns have been fabricated using CAD/CAM technology. The majority of dental CAD/CAM systems that are sold commercially employ the milling approach, which involves employing a cutting bur to mechanically create interim crowns from a resin block. The strength and precision of the interim crown are superior when created using the milling process as opposed to the traditional direct procedure because the resin block is polymerized with a high degree of conversion (11, 12).

Every CAD/CAM system consists of three parts. The first component is a digitization tool or scanner, which converts physical data into digital data so that a computer and software can process it. The second component is a computer and software, which process and analyse data so that the product can be manufactured. In addition to the third part, which uses a milling machine to convert the data set into the required result (11, 12). Chairside, laboratory, and centralised are the three CAD/CAM ideas. The chairside idea places all of the CAD/CAM system's components in a dental clinic. Therefore, chairside fabrication of dental restorations is possible without the need for laboratory processes. In contrast, the dentist using the laboratory approach makes a traditional impression, mails it to the laboratory, and the lab fabricates a master cast, digitises it using an extraoral scanner, and completes the remaining steps to constructs the restoration. Regarding the centralised model, restorations are manufactured in production centres using CAD/CAM devices, and the production is carried out in a milling centre where data are transmitted by an internet-based dental lab (13).

Limitations of CAD/CAM technology:

The primary disadvantage of certain intraoral scanner systems is that the tooth surface must first be covered in a layer of powder before scanning. This results in the creation of a thicker layer ranging from 13 to 85 micrometres, which could potentially negatively impact the

precision of restorations. Furthermore, regardless of the digitising mode used, it is challenging to accurately recognise the border of an abutment due to constrained scanning conditions in the mouth, which include the presence of neighbouring teeth, gingiva, blood, saliva, and/or movement of the patient. This has proven to be a significant drawback of several techniques when it comes to creating an accurate final restoration. Powderless scanning is now possible thanks to freshly developed intraoral scanners.

Furthermore, surface cracks and subsurface defects could be created by the CAD/CAM milling processes, which could have a negative impact on the restoration's strength. Strength can be increased through the use of glazing and polishing together. Finally, the object's intricacy, the cutting tool's size, and the block material's characteristics all have an impact on how accurate milled restorations can be (7,13).

3D Printing Technologies:

Charles Hull printed a three-dimensional item for the first time in 1983 with the first 3D printer. For use in dentistry and medicine, a wide range of 3D printing technologies are available, such as digital light projection (DLP), powder bed fusion (PBF), polyjet or inkjet printing, fused deposition modelling (FDM), and stereolithography (SLA). The materials utilised and the order in which the layers are deposited to form the three-dimensional object are the primary distinctions between these methods. Depending on the type of material being used, 3D printing technologies can be divided into three categories: liquid-based, powder-based, and solid-based. Regarding precision, speed, and material cost, each process has pros and cons of its own.

Stereolithography (SLA):

It is a type of photopolymerization in which liquid materials are solidified using an ultraviolet (UV) light or laser, forming solid components in multiple layers. SLA systems are made up of a building platform, an ultraviolet (UV) light or laser, and a bath of photosensitive liquid polymer monomers (such as acrylates and epoxy monomers). Items are constructed in a 50–200μm layer-by-layer fashion. The platform lowers or raises while the UV light cures and hardens a thin layer of polymer on predetermined locations determined by the CAD data at each layer. Meanwhile, the UV light cures and attaches the subsequent layer to the preceding one. The procedure keeps on until the entire object is finished (3).

Digital Light Processing (DLP):

The concept of DLP is almost the same as that of stereolithography; digital micromirrors reflect a digital light projection to form a light mask that cures the photosensitive polymer. Thousands of micromirrors make up the digital micromirrors gadget, which moves each one separately to regulate the light path. Every micromirror is in charge of producing a single pixel from the picture. In contrast to SLA, where the laser beam must travel to cure each layer, this method exposes the entire layer simultaneously and shortens the manufacturing time (3).

The speed is one of the main distinctions between SLA and DLP. Because of the highly localised nature of its polymerization technique, SLA is known to be fairly sluggish. SLA 3D printers sweep through an object's interior sections more quickly than its outside shells in order to lessen this restriction. Although UV curing as a post-processing step is frequently recommended to establish greater mechanical integrity of an object, this can speed up the printing process. DLP's primary benefit is its ability to simultaneously cure a layer's whole surface. There is no distinction between the inner and exterior regions, therefore post-curing is not as necessary. In this way, printing a 30-minute document on a DLP printer could take four hours on a SLA printer for the same STL file (3).

Even though DLP 3D printing is quicker, surface polish and resolution considerations must be made. This is so that volumetric pixels, or voxels, can be created in the resin by the digital light projector’s pixel-by-pixel light delivery. This eventually leads to a pixelated form that makes clean edges impossible (14).

Digital workflow of 3D printing technology:

The steps involved in creating a temporary restoration using a 3D printer are as follows: data collection, data processing, and manufacturing processes. Digitization processes are a part of data capture, and extraoral or intraoral scanning devices are typically used for this. Either the patient's mouth or the working casts—which are transformed into a standard tessellation language (STL) file—are used for this procedure. With the use of specialised CAD software, data processing entails the virtual design of the temporary restoration. The thickness of the digital design can be fully controlled with the tools available in CAD software.

For the purpose of maintaining the structural integrity of the printed product, it is crucial to take this parameter into account when processing digital model data. After the object has been designed, the build variables and settings for slicing and adding support structures are described in the STL file that is exported to the printer.

The type of 3D printer and the additive manufacturing technology determine the printer parameters. Using the file on the 3D printer, manufacturing methods adhere to the layer-by-layer buildup technique. To ensure consistency and accuracy, these delicate devices need to be calibrated not just when 3D printers are calibrated on a regular basis but also whenever room conditions or printer locations change (3,14).

It is crucial that the operator maintain control over the printing parameters throughout the operation. These consist of the object's size, colour, and buildup substance. It can be necessary to use a different printing angle when printing resilient materials, or it might be necessary to adjust the ratios and placement of the supporting structures (14).

Advantages of 3D printed interim restorations:

According to Digholkar et al., provisional crowns created via 3D printing have a higher microhardness than crowns created using traditional techniques. Additionally, a number of studies have shown that superior internal fit is obtained when the provisional crown is made via an indirect method as opposed to a direct one (15).

According to Christopher Tollefors and Arthur Meland (2016), the 3D printing technique has certain advantages over direct methods because it avoids the release of residual monomers and eliminates the majority of clinical and laboratory procedures, such as traditional waxing procedures. It also overcomes the material's exothermic heat phase. (16).

The benefits of traditional restorations and 3D printed restorations were compared by Zaharia et al. (2017). The comparison was quite favourable to restorations made using 3D printing. They offer the potential for rapid and simple production of high-quality restorations.(17)

Mai et al. (2017) discovered that due to a number of limiting variables, including bur size, milling bur tolerance, and the cutting device's motion range, 3D printed restorations were more accurate than restorations made by milling techniques. In contrast, methods for additive

manufacturing enable the creation of intricate designs with less time and material, making them a more cost-effective manufacturing technique than milling (18).

Limitations of 3D printing technology in dental field:

According to Zaharia et al. (2017), the drawbacks of digital light processing (DLP) and stereolithography (SLA) are limited to light curable liquid polymers and need the removal of the supporting structure. Besides being filthy, resin can irritate skin and induce inflammation by inhalation and touch (17).

According to Srinivasa Prasad's (2018) research, the advantages of high material utilisation may occasionally be outweighed by the disadvantages brought on by the prolonged post-processing time. The occurrence of the staircase effect (caused by multilayer deposition), uneven reproduction, and need for support materials are further drawbacks. Moreover, because of the significant porosity created during creation, ceramics—one of the most often used materials in dentistry—cannot be 3D printed (19).

León et al. (2019) have discussed the issue of overexposure that arises from fabricating a clear or transparent object because light that polymerizes additional layers can reach the beginning layers of the fabrication through recently formed material. Nevertheless, materials that absorb light more readily do not face this issue. Since light also passes through the resin tray, an object's geometry and the orientation in which the print is chosen can result in a distortion similar to this. Consequently, while choosing print orientation, a precise plan should be followed in order to reduce the possibility of overexposure when utilising specific materials and printing specific geometries (20).

According to Taormina et al. (2018), any material that is treated by 3D printing has some restrictions and issues. The resin's viscosity needs to be less than 5 Pa/s. Higher viscosities cause the resin to flow more slowly, which lengthens the fabrication process and makes it more difficult to recoat (after each layer is polymerized, fresh liquid monomer should be able to flow and recoat the reacted surface). The resin also needs to have the right curing depth and be curable. Enough transparency must exist to let a whole layer to cure. An additional troublesome feature is over-curing. A post-curing procedure is required each time there is unreacted or partially reacted resin in order to completely harden the product and enhance its mechanical

qualities. However, completing the procedure over an extended period of time may cause over-curing and the ensuing deterioration of the attributes (21).

Marginal integrity and internal fit:

One of the key elements of a successful prosthodontic restoration is the marginal fit of a fixed prosthesis. A healthy periodontium is maintained and cement dissolution is avoided with an optimal marginal fill. The marginal integrity of a prosthesis has been the subject of numerous studies aimed at assessing its prognosis. (22).

Marginal integrity:

The amount of space between the planned abutment completion line and the restoration margin indicates the margin's integrity. Marginal spaces may create an ideal environment for the deposition of biofilm, which can lead to the development of periodontal and secondary caries. Regardless matter the type of cement, large gaps exacerbate its wear. Much less cement disintegration and gingival discomfort result from ideal marginal adaptation. (23).

Marginal gap measurement:

Any fixed dental restoration's marginal fit is a crucial factor in determining how well it performs over time. Microleakage and both chemical and physical gingival irritation are associated with poorly fitting restorations. Inflammation of the pulp tissue may result from microleakage into the pulp chamber via the dentinal tubules. Furthermore, a poor margin may have an impact on the restoration itself since a poorly fitted restoration may result in stress concentrations that weaken the restoration and lower its long-term viability (24).

Five criteria were suggested by Shillingburg as the foundation for tooth preparation: marginal integrity, retention and resistance, structural durability, periodontium preservation, and structure preservation. Long-term clinical performance for restorations is influenced by these qualitative and quantitative concepts in concert (25).

The clinically acceptable marginal gap following cementation, according to Fransson et al., McLean, and von Fraunhofer, should be less than 150μm and 120μm, respectively. Furthermore, McLean and von Fraunhofer found that it is challenging to identify a marginal gap smaller than 80μm in clinical settings after looking at the marginal fit of 1000 fixed restorations

over the course of five years. The "misfit" that is measured at different locations between the restoration surface and the tooth best describes how well a restoration fits (26).

According to Holmes et al., the internal gap is the distance measured between the internal surface of the casting and the prepared tooth's axial wall; the same distance measured at the periphery is referred to as the "marginal gap."

Moreover, the "absolute marginal discrepancy," which precisely indicates the linear distance from the preparation's surface finish line to the restoration's margin, is an angular combination of the marginal gap and extension error. Since it always has the biggest inaccuracy at the margin and captures the entire crown misfit there, both vertically and horizontally, it is regarded as the best alternative measurement.

The two primary categories of measuring procedures are invasive and noninvasive, which are represented by sectioning and direct-view techniques, respectively. Experimental configurations can vary depending on the fit testing stage, such as before or after cementation, and incorporate additional factors (such as sample size and measurements per specimen) (27).

Ttherapeutically acceptable marginal deviations that are invisible to the unaided eye and imperceptible to a skilled explorer have been the subject of several authors' attempts to ascertain. According to Christensen et al., the range of clinically acceptable marginal gaps for subgingival margins is 34-119μm, while for supragingival margins it is 2-51μm. (24, 26).

Nevertheless, McLean and von Fraunhofer used an in vivo method to study the cement film thickness and concluded that the clinically acceptable limit should be a marginal difference of 120μm. A restoration's lifespan may be shortened by unacceptable or insufficient marginal fittings, which are usually broader than 120μm, because they increase cement film exposure. (24, 26).

According to the current definition, marginal integrity is thought to be the "the exact vertical distance between a veneer's manufactured margins and the prepared tooth's finish line." Consequently, long-term durability is determined by the permissible level of marginal exposure between a restorative veneer and its target tooth (24, 26).

The type of finish line, the geometry of tooth preparation, the relief of the internal crown surface (die spacer), the crown material, the fabrication technique, porcelain veneering, cement types, cementation techniques, and ageing are some of the variables that can affect the marginal adaptation of a dental crown. Marginal accuracy has been evaluated using a range of techniques

and testing parameters, namely direct view, cross-sectional view, and impression replica technique. The two primary approaches to measuring procedures are non-invasive and invasive, which are represented by sectioning and direct-view techniques, respectively (24, 26).

Marginal Gap Measurements techniques:

Under a microscope, the internal fit (cement thickness) and marginal gap in both the vertical and horizontal planes can be directly measured using the cross-sectioning method (28).

A non-destructive technique that allows for precise focus is profilometry, which uses a profile projector to display the die and specimen views in the same focal plane on a monitor (28, 29). Micro-computed tomography, or micro-CT, has been used to analyse restorations non-destructively. This method enables the analysis of marginal and internal gaps in the range of a few micrometres in two dimensions (2D) and three dimensions (3D) at several sites and directions (sagittal and coronal for four distinct regions). (Coronal mesial, coronal distal, sagittal buccal, and sagittal lingual) (29).

The primary purpose of a digital micrometre is to measure the variation in marginal adaption between cementation and non-cementation. Measurements can be taken while the crown is seated against its die. Following cementation, the crown is fixed to the die, measured once more, and the disparity between the measurements is computed (28–30).

Direct view, or exterior microscopic examination, uses a microscope at various magnifications to measure the gap between the die and crown at their edge rather than within. It is the approach that produces repeatable results the most frequently. In comparison to other techniques, it is thought to be less expensive, take less time, and have a lower possibility of errors occurring as a result of many procedures. Because direct assessment of the marginal gap under high power microscopy is necessary for this technique's precision, it can only be employed in vitro.

It has been noted that for assessing the marginal gap of class II CAD/CAM inlays, scanning electron microscopy (SEM) imaging performed better than light microscopy. Still, The accuracy of the two methods was not significantly different, according to Groten et al., but SEM was able to produce more appropriate and realistic findings than light microscopy, particularly with complex repair margin morphologies. The more measurements there are for each specimen, the more accurate the analysis is.

In a study examining the marginal fit of fixed dental restorations, Groten et al. found that a higher number of measurements per sample can offset a lower sample size. Whether the measurement sites are chosen randomly or systematically, he found that 50 measurements are necessary to obtain clinically meaningful information about gap size. It is significantly more than the in vitro investigations that are being conducted now. Depending on the necessary degree of precision, at least 20 to 25 measurements per crown could be allowed (28–30).

Replica technique, also known as the internal replica approach, is a widely employed non-destructive technique. Low viscosity light body silicone material is applied to the crown's fitting surface, and the crown is then seated on a die that replicates the cementation process. The thin light body film is stabilised inside the crown by injecting heavy body silicone, which is then carefully withdrawn from the die when the silicone substance has set. After that, the light body silicone layer can be divided into sections and measured at various locations (31).

Conflict of Interest

All authors declare that they have no conflicts of interest.

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