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Evaluating Aesthetic Outcomes of Provisional Restoration Fabrication Techniques in Full Mouth Rehabilitation: An Updated Review

Amrutha Shenoy[1], Vinay Sivaswamy[2], Subhabrata Maiti[3*], Deepak Nallaswamy[4]

[1]Department of Prosthodontics and Implantology, Saveetha Dental College And Hospitals, Saveetha Institute Of Medical And Technical Sciences, Saveetha University, Chennai-600077

[2]Reader, Department of Prosthodontics and Implantology, Saveetha Dental College And Hospitals, Saveetha Institute Of Medical And Technical Sciences, Saveetha University, Chennai-600077

[3]Reader, Department of Prosthodontics and Implantology, Saveetha Dental College And Hospitals, Saveetha Institute Of Medical And Technical Sciences, Saveetha University, Chennai-600077,Tamilnadu,India

[4]Professor, Department of Prosthodontics, Saveetha Dental college and hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-600077,TamilNadu ,India.

*Corresponding author: Subhabrata Maiti, Reader, Department of Prosthodontics and Implantology, Saveetha Dental College And Hospitals, Saveetha Institute Of Medical And Technical Sciences, Saveetha University, Chennai-600077,Tamilnadu,India, Email: drsubhoprostho@gmail.com

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ABSTRACT

Statement of problem: Provisional restoration fabrication techniques are critical in Full Mouth Rehabilitation (FMR) procedures. Traditional techniques are widely used to fabricate provisional restorations for FMR. However, newer techniques such as intraoral scanners and cone beam computed tomography (CBCT) have been introduced for data acquisition as alternatives to traditional methods. The effectiveness of these newer techniques in producing aesthetically pleasing provisional restorations for FMR remains unclear.

Aim: This review article aims to evaluate the aesthetic outcomes of provisional restoration fabrication techniques such as traditional conventional methods and newer ones like using intraoral scanners and CBCT for crown and bridge fabrication for Full Mouth Rehabilitation.

Materials and methods: A literature search was conducted using electronic databases, including PubMed, Embase, and Cochrane Library, from inception to April 2023. Studies that reported the aesthetic outcomes of provisional restoration fabrication techniques were included in the review. A clinical protocol was set up with the current available literature.

Results: The majority of the studies evaluating the aesthetic outcomes of traditional techniques reported satisfactory results. However, studies evaluating newer techniques such as intraoral scanners and CBCT were limited.

Conclusion: The use of newer techniques such as intraoral scanners and CBCT as data acquisition methods is gaining popularity, and the available studies suggest that they produce comparable or superior aesthetic outcomes. Further research is needed to confirm these findings and determine the optimal technique for provisional restoration fabrication in FMR.

Keywords: *Cone beam computed tomography, intraoral scanners, digital dentistry, full mouth rehabilitation*

INTRODUCTION

Full mouth rehabilitation is a comprehensive approach to improving a patient's oral health, function, and appearance. It involves rehabilitating most or all of the teeth in both the upper and lower jaws to achieve optimal oral health, function, and esthetics. Common indications for full mouth rehabilitation include dental decay or damage, missing teeth, worn or broken teeth, bite problems, jaw joint disorders, and esthetic concerns. Advances in dental technology and materials have made full mouth rehabilitation more precise, efficient, and esthetically pleasing. The procedure involves a combination of restorative and cosmetic dental procedures such as dental crowns, bridges, implants, veneers, orthodontics, and periodontal therapy, and it may take several weeks or months to complete.

Temporary crowns and bridges are crucial for full mouth rehabilitation as they provide a temporary solution for the patient while permanent restorations are being fabricated. In cases where the patient's teeth are badly damaged or decayed, temporary restorations help maintain the function and esthetics of the patient's smile, protect the underlying teeth and gums, and prevent further damage or infection. Polymethylmethacrylate (PMMA) is a popular material used for temporary crown and bridge restorations, known for its strength, biocompatibility, and natural tooth-like appearance. CAD/CAM technology can quickly and easily produce milled PMMA restorations, making it an ideal option for immediate restoration.

There has been a significant shift towards digital dentistry, which utilizes new technologies such as intraoral scanners (IOS) and cone-beam computed tomography (CBCT) as data acquisition units. The use of IOS eliminates the need for physical impressions, reducing the discomfort and gag reflexes associated with conventional impression techniques. Moreover, IOS allows for real-time visualization of the teeth and gums, enabling the clinician to adjust the impressions as needed to ensure accuracy. The use of Digital Imaging and Communications in Medicine (DICOM) images obtained from CBCT to create Standard tessellation language(STL) file formats to create a 3d model for fabricating prostheses is also simplified, thanks to advances in medical engineering, imaging engineering, and the decreasing costs of hardware and software.The review will provide an overview of the available literature on the aesthetic outcomes of these techniques and identify their strengths and weaknesses.Our team has extensive knowledge and research experience that has translate into high quality publications1–6, that made us to do multiple research.

Objectives

The aim of this paper was to present a detailed workflow for fabrication of provisional restorations using advanced dental technologies like Cone beam computed tomography and intraoral scanners to obtain satisfactory esthetics in patients undergoing full mouth rehabilitation,

Full mouth rehabilitation

Full mouth rehabilitation (FMR) is a customized treatment that aims to reconstruct and restore the entire dentition to optimize oral health. The objective of FMR is to achieve both functional and biological efficiency, allowing the teeth, periodontal structures, muscles of mastication, and temporomandibular joint (TMJ) mechanisms to function in harmony 7. By converting unfavorable forces on teeth into favorable ones, FMR can prevent or treat periodontal disease and promote normal function and healthy conditions 8,9. This requires a range of procedures to achieve a healthy, aesthetically pleasing, and self-sustaining masticatory function. FMR is a challenging procedure that requires a multidisciplinary approach, and its success depends on accurate diagnosis, the underlying cause of the problem, and the scientific approach used in rehabilitation 10.

A.1.a. Conditions requiring full mouth rehabilitation

Occlusal rehabilitation is performed to restore multiple teeth that may be missing, worn, decayed, or broken down, and to replace poorly designed or executed crown and bridge work. In some cases, it may also be required to treat temporomandibular disorders, but caution is advised. The primary goal of any treatment should be to achieve oral health, function, esthetics, and comfort, and the treatment plan should revolve around these factors, rather than just technical possibilities. To achieve these goals, several biological considerations must be taken into account when planning and executing occlusal rehabilitation, such as the indications for reorganizing the occlusion, selecting an appropriate occlusal scheme, determining the occlusal vertical dimension, deciding whether to replace missing teeth, and considering the effects of the materials used on occlusal stability and control of parafunction and TMD. 7,11–13.

A.1.b. Tooth wear

Tooth wear is a natural process that occurs over time. It can be considered a physiological process, and normal ranges for tooth wear have been reported for specific populations14. However, when this normal rate of tooth wear is accelerated by unusual factors, such as endogenous or exogenous factors, it can lead to pathologic wear. Severe tooth wear is often multifactorial and variable, making it difficult to diagnose the underlying cause.

There are four types of surface loss that have been identified, each with differing causes. Attrition refers to mechanical wear caused by mastication or parafunction, and is limited to the contacting surfaces of teeth 15. Abrasion, on the other hand, is the wearing away of tooth structure through some unusual or abnormal mechanical process other than tooth-to-tooth contact 16. Erosion, meanwhile, is the progressive loss of tooth structure through chemical processes that do not involve bacterial action 17. Finally, abfraction refers to the pathologic loss of tooth structure attributed to mechanical loading and results in wedge-shaped defects in cervical areas 16,18,19.

It is essential to diagnose the underlying cause of abnormal tooth wear to prevent further pathologic changes. However, identifying the factors responsible for severe tooth wear can often present a clinical challenge. Understanding the different types of surface loss and their causes is critical to determining the appropriate treatment and preventing further damage to the teeth.

A.1.b.i. Epidemiology of tooth wear

Epidemiological studies on tooth wear have reported a wide range of prevalence rates depending on the population studied and the definition and criteria used to diagnose tooth wear. In general, tooth wear appears to be a common finding in all age groups, with studies reporting prevalence rates ranging from 17% to 97% in different populations 20,21.

Studies have also reported differences in the patterns and severity of tooth wear between age groups and genders. For example, studies have reported that tooth wear is more prevalent and severe in older individuals and males 20,21. Johansson and co-workers 17,22–24 examined 59 high-wear patients and found that men showed significantly more wear than women. Increased bite force was also positively correlated with increased wear. Analysis of saliva showed that a low buffering capacity and a diminished rate of secretion also were related to high wear rates. Other studies have found no gender differences in tooth wear prevalence or severity 25,26.

Geographical and cultural factors may also influence the prevalence and patterns of tooth wear. For example, studies have reported higher prevalence rates of tooth wear in rural areas compared to urban areas, possibly due to differences in dietary habits and access to dental care 27. Additionally, studies have reported higher prevalence rates of tooth wear in certain cultural groups that practice habits such as betel nut chewing or tobacco use 28.

Overall, tooth wear is a common finding in populations worldwide, and its prevalence and patterns may be influenced by various demographic, behavioral, and cultural factors.

A.1.b.ii. Etiology of tooth wear

Tooth wear can be classified into three categories: mechanical loss, chemical loss, and abfraction. Mechanical loss involves attrition and abrasion, while chemical loss involves erosion. Abfraction is a controversial category that is attributed to tooth flexure. Surface loss is usually multifactorial, and the location of the loss cannot reliably indicate its cause 17,22. However, population studies have attempted to identify factors associated with high-wear groups 17,22,23.

A diagnostic approach involves determining whether the cause of the surface loss is chemical or mechanical, or a combination of both (fig.1). The location of the loss and the accompanying signs and symptoms can guide the differential diagnostic process. Additionally, hereditary dysplasias 8,, such as amelogenesis imperfecta and dentinogenesis imperfecta, can compromise the wear resistance of teeth and predispose them to accelerated surface loss from mechanical or chemical causes. Amelogenesis imperfecta affects the quantity of enamel or the quality of calcification, resulting in thinner and more friable enamel, which is more susceptible to chemical erosion and mechanical wear. Dentinogenesis imperfecta affects the dentin and results in teeth with a characteristic gray or brown opalescent appearance 29. The weak enamel-to-dentin bond in dentinogenesis imperfecta results in the early loss of enamel, rapid attrition, and increased susceptibility to caries.

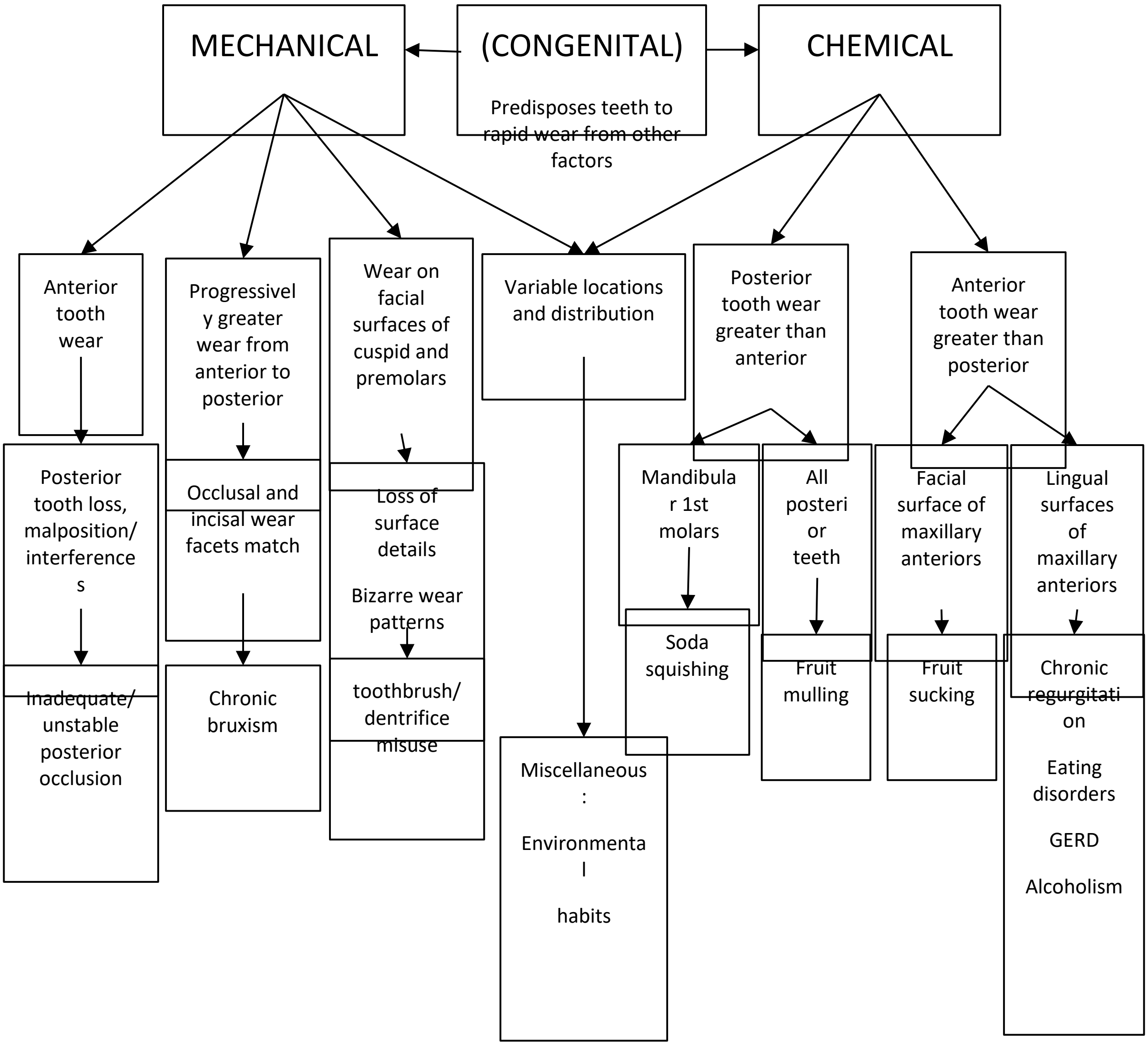

FIG 1. The diagnostic decision tree can be combined to provide a methodical framework for analyzing an extremely worn dentition.30

A.1.b.iii. Classification for tooth wear

Several classifications have been proposed to assess tooth wear and teeth restoration in FMR, including those by Jones, Turner and Missirlian, and Dawson31. Among these, Turner and Missirilian's classification is commonly used for its simplicity in application 32.

This classification divides patients with occlusal wear into three categories:

Category-1: Excessive wear with loss of vertical dimension of occlusion (VDO)

Patients in this category have a speaking space of more than 1 mm and an interocclusal space of more than 4 mm. They also exhibit some loss of facial contour and drooping of the corners of the mouth. In such cases, all teeth in one arch must be prepared in a single sitting to achieve a gradual increase in VDO and better control of esthetics.

Category-2: Excessive wear without loss of VDO but with space available

Patients in this category typically have a long history of gradual wear caused by bruxism, oral habits, or environmental factors, but their occlusal vertical dimension (OVD) is maintained by continuous eruption. However, it may be difficult to achieve retention and resistance form due to shorter crown length, and gingivoplasty may be necessary. Enameloplasty of opposing posterior teeth may also be used to provide space for the restorative material.

Category-3: Excessive wear without loss of VDO but with limited space

Patients in this category have excessive wear of anterior teeth over a long period, but minimal wear of the posterior teeth. Centric relation and centric occlusion are coincidental with a closest speaking space of 1 mm and an interocclusal distance of 2-3 mm. In such cases, vertical space must be obtained for restorative materials. This can be achieved through orthodontic movement, restorative repositioning, surgical repositioning of segments, or programmed OVD modification.

Before beginning the reconstruction procedure, the clinician must evaluate and classify the patient's existing clinical situation and decide on the occlusal approach and an appropriate occlusal scheme.

A.1.c. Treatment approaches for full mouth rehabilitation

Full mouth rehabilitation (FMR) involves various aspects, with occlusal rehabilitation being a major topic discussed in the literature33. Occlusal rehabilitation can be classified into two approaches: conformative and reorganized.

The conformative approach mainly involves the removal of occlusal interferences, deflective contacts, and tall cusps of opposing teeth 33,34. The reorganized approach is followed when there are changes required in vertical dimension, failed restorations, bruxism, severe attrition, constraints in the interocclusal space, occlusal trauma, temporomandibular disorder, and disorder in functions and esthetics.

The reorganized approach involves the fundamental process of establishing centric and eccentric occlusal relationships 10,31,35.

With the present understanding of traumatic occlusion and its deleterious effect upon the supporting structures, the procedure known as "bite raising" has shifted in emphasis and broadened in scope and is now designated by a term that describes it accurately. Full mouth reconstruction, as of now includes therapy which will, by improving the relationship of the teeth, improve the condition and health of the supporting structures. It should be kept in mind that although the operations of all mouth rehabilitation procedures are performed on tooth units, they have one basic objective: the equalization of the forces directed against the supporting structures.

The FMR procedure typically begins with diagnosis, treatment planning, and mock wax up. There are variations in the techniques and applications used in FMR. While many reports provide details on procedures, management of difficulties is less explained in the literature (36. Occlusal concepts in FMR are widely discussed in the literature 37,38, but studies are needed to determine the influence of tooth/implant support, partially-edentulous span length, and the influence of restorative materials on occlusal rehabilitation 38,39.

Few studies 40 have examined the influence of CAD-CAM restorations on FMR, but the use of this technology could simplify procedures and aid in the establishment of accurate occlusal contacts.

A.1.d. Need for establishing ideal Centric relation and Vertical dimension

Centric relation

Can be defined as a maxillomandibular relationship, independent of tooth contact, in which the condyles articulate in the anterior-superior position against the posterior slopes of the articular eminences; in this position, the mandible is restricted to a purely rotary movement; from this un- strained, physiologic, maxillomandibular relationship, the patient can make vertical, lateral or protrusive movements; it is a clinically useful, repeatable reference position17.

Determination of Centric relation

The determination of centric relation involves identifying the position of the condyle-disc assembly in the temporomandibular joint. This can be done using various methods 41–43, including the Ash 1998 technique and the Ackee and Piper classification.

The Ash technique: also known as the "short rest technique," is a method used to record the position of the mandible in centric relation (CR)44. The technique involves placing the mandible in a position of maximum retrusion and then seating the mandibular teeth against the anterior teeth of the maxilla, creating a "short rest" position. This position is then recorded using a wax or silicone material, which is used to create an occlusal registration. The registration is then used to mount the study casts on an articulator to simulate the patient's occlusion in CR.

The Ackee and Piper classification: It is a method of classifying centric relation, which is the most retruded position of the mandible that can be reproducibly achieved45. The classification is based on the relationship between the condyles and the articular eminences of the temporomandibular joint (TMJ) in centric relation. According to the Ackee and Piper classification, there are three types of centric relation:

Type I: The condyles are in the most superior position on the articular eminences, with the discs interposed between the condyles and the eminences.

Type II: The condyles are in a slightly inferior position on the articular eminences, with the discs still interposed between the condyles and the eminences.

Type III: The condyles are in a significantly inferior position on the articular eminences, with the discs displaced anteriorly or medially.

It is important to note that theAsh technique and the Ackee and Piper classification are few of many methods used to classify centric relation, and different clinicians and researchers may prefer different classification systems. Additionally, centric relation is often difficult to determine precisely and reproducibly, and its significance in clinical practice remains a matter of debate.

Vertical dimension of occlusion (VDO)

Can be defined as the distance between two selected anatomic or marked points (usually one on the tip of the nose and the other on the chin) when in maximal intercuspal position17.

The establishment of a proper vertical dimension of occlusion is crucial in achieving successful restorative outcomes and patient satisfaction 46. A loss of vertical dimension due to excessive tooth wear or occlusal trauma can result in various problems such as facial collapse, reduced lip support, and compromised esthetics .

Furthermore, a decreased vertical dimension can lead to temporomandibular joint (TMJ) disorders, muscle pain, and other functional problems 47,48. Therefore, it is important to establish and maintain the correct vertical dimension of occlusion to ensure proper function, esthetics, and overall oral health.

A.1.e. Re-establishing the VDO in Provisional/ Prototype stage

Restoring the vertical dimension of occlusion (VDO) can be achieved using various methods. A thorough clinical examination of the patient's occlusion, including tooth wear, mobility, and occlusal discrepancies, is the first step in determining the best approach. In addition, a detailed history of the patient's symptoms and past dental treatment is crucial. One common method for increasing the VDO is through the use of a mockup or dental wax-up49, which involves building up the teeth with wax to their ideal occlusal position (fig.2). The wax-up can be used to evaluate the esthetics and function of the proposed restoration before any irreversible procedures are performed 50,51. Provisional restorations, such as PMMA temporary crowns and bridges, can also be used to increase the VDO and evaluate the patient's ability to adapt to the new occlusal position 52–54. This can help in determining the final VDO and selecting the appropriate restorative materials, such as composite resin or ceramic, which can be used to increase the VDO through the placement of direct or indirect restorations. A temporary partial denture may also be used55. In some cases, orthodontic treatment may be necessary to restore the VDO by moving the teeth to their ideal position56. Another option is the use of occlusal appliances like splints or night guards 57,58,59, which can help increase the VDO and evaluate the patient's ability to adapt to the new occlusal position. Finally, the regeneration of the dentition through dental implants or other methods can also help restore the VDO. The choice of method depends on the specific needs of each patient and should be determined in consultation with a dental professional.

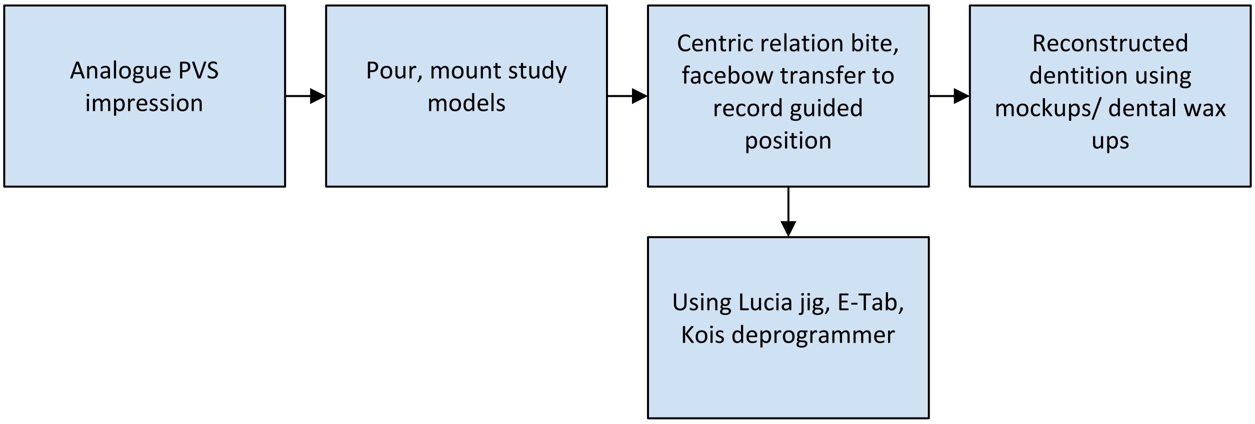

FIG.2 : Traditional methods of re-establishing the CR and VDO (Courtesy: Dawson et al, 1995)

A.2. Interim prosthesis for full mouth rehabilitation

Interim prosthesis, also known as provisional or temporary prosthesis, is a temporary restoration used to maintain the function, esthetics, and comfort of the patient during the time period between the preparation of the teeth and the fabrication of the final prosthesis 60,61. It serves as a blueprint for the definitive prosthesis as it allows the clinician to evaluate the fit, function, and esthetics of the proposed prosthesis before it is fabricated62.

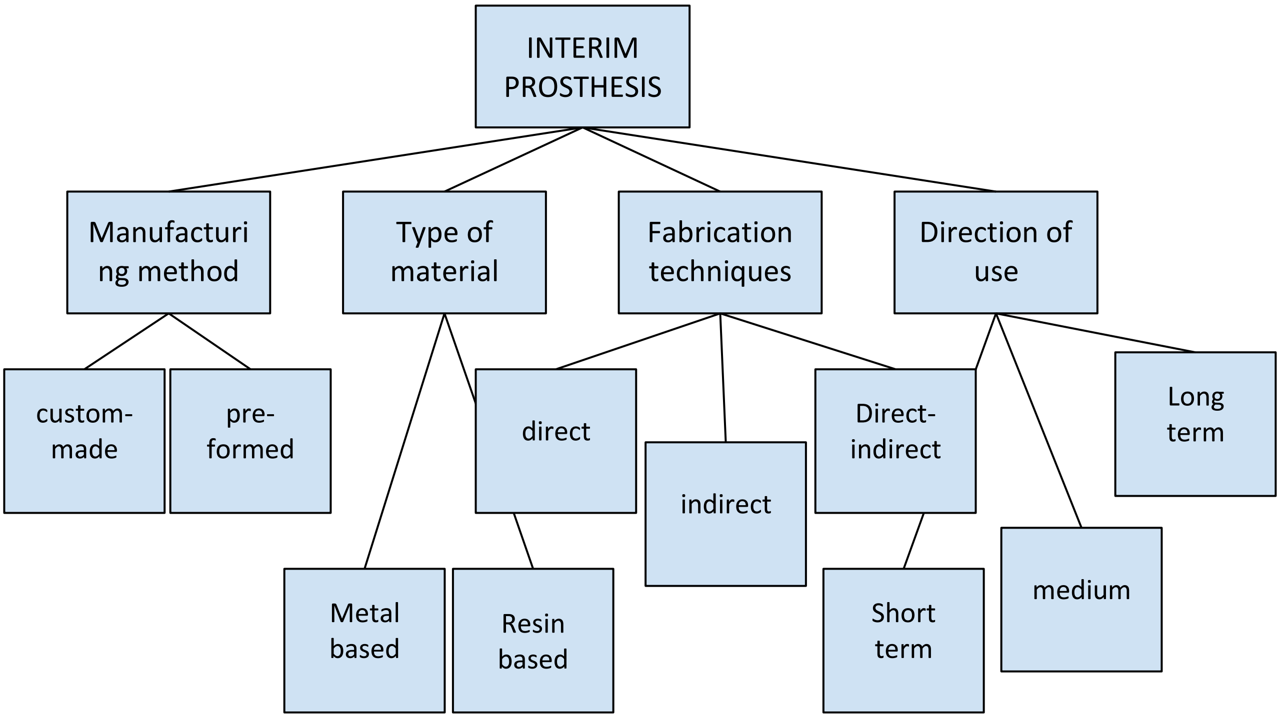

FIG 3 : Classification of Interim prostheses

A.2.a. Method of Fabrication:

Based on the method of fabrication of provisionals, they may be classified as indirect, direct and direct- indirect methods.

Direct Technique

The direct method of temporary prosthesis introduction involves the creation of an interim restoration directly in the patient's mouth, without the need for a diagnostic cast or laboratory procedures. This method is typically used when time or resources are limited, and a quick solution is required. Although it may not provide the same level of precision and accuracy as indirect methods, the direct method offers several advantages, including the ability to test the fit of the restoration in the mouth and make adjustments as necessary. Additionally, it allows for immediate restoration of function and aesthetics, which can be particularly beneficial in cases where the patient has undergone extensive tooth preparation or requires multiple restorations. However, the direct method also has some limitations, including the potential for polymerization shrinkage and lack of durability compared to laboratory-fabricated restorations.

Indirect Technique

The creation of interim restorations outside the oral cavity has become a popular technique among dental practitioners. To achieve this, a diagnostic cast is made, and an acrylic tooth is placed on the missing tooth region, followed by occlusal adjustments and sealing with carding wax. A silicone putty index is created to encompass at least one tooth on either side of the abutment teeth. After preparing the patient's teeth to receive the prosthesis, a sectional impression is taken, and a check cast is made. To create the interim restoration, the check cast is lubricated, and provisional restorative material is placed on the tissue surface of the index before seating it on the cast. The preformed restoration is then tested for fit on the cast and intra-orally, followed by realignment to ensure a proper internal fit. Finally, the restoration is finished, polished, and cemented. This technique has proven successful and has been adopted widely in dental practice.

Direct- Indirect Technique

The indirect-direct technique for creating an interim restoration involves several steps. Firstly, a pre-treatment diagnostic cast is created from an impression of the unprepared teeth, and for FPDs, a pontic is waxed into the edentulous area. Next, an impression is made using a high-viscosity elastomeric material involving at least one tooth beyond the abutment teeth. The acrylic tooth is then removed, and the abutments are prepared on mounted diagnostic casts. After lubricating the prepared diagnostic cast, provisional restorative material is mixed and placed in the tissue surface of the index and reseated on the diagnostic casts. Once the acrylic resin has polymerized, the restoration is finished. The patient's teeth are then prepared, and the preformed restoration is tried in and relined if necessary to perfect the internal fit. Finally, the restoration is finished, polished, and cemented in place. Advantages of this technique include reduced chair time and decreased heat generation and chemical exposure. However, there is a potential need for a laboratory phase before tooth preparation, and adjustments may be required to seat the shell completely on the prepared tooth.

A.2.b. Materials used for fabrication

Interim restorations can be fabricated using a variety of materials 63–65, including polymethyl methacrylate (PMMA), bis-acrylic resins, and composite resins. Each material has its own advantages and disadvantages, and the choice of material depends on factors such as the clinical situation, patient preferences, and the expected longevity of the restoration.

Polymethyl methacrylate (PMMA) is a thermoplastic material that is easy to work with and has good mechanical properties 66. PMMA can be used to fabricate interim restorations using both direct and indirect techniques. Direct techniques involve the fabrication of the restoration directly in the patient's mouth, while indirect techniques involve the use of an impression to create a model of the prepared teeth and surrounding tissues. PMMA interim restorations can be used for short-term or long-term use depending on the specific case.

Bis-acrylic resins are also commonly used for the fabrication of interim restorations 66,67. They are stronger and more wear-resistant than PMMA, making them suitable for longer-term use. Bis-acrylic resins are typically used for indirect fabrication techniques.

Composite resins can be used to fabricate both direct and indirect interim restorations 54,65. Composite resins are tooth-colored and can be customized to match the patient's natural teeth. Composite resin interim restorations are typically used for short-term use only.

Resin-bonded interim restorations are a type of provisional restoration that is bonded to the prepared teeth using an adhesive resin68. Resin-bonded restorations can be made using any of the materials mentioned above, but are typically made using composite resin. The restoration is bonded to the tooth surface, providing stability and preventing displacement.

Bis-acryl composite and conventional PMMA are two of the most commonly used materials for fabricating interim prostheses. Here is a comparison of these materials in terms of several factors:

Flexural strength: Bis-acryl composite materials typically have higher flexural strength compared to PMMA 69–71.

Thermal damage: Both materials can be affected by thermal damage during fabrication, but PMMA is generally more susceptible to thermal damage 72,73.

Irritant to oral mucosa: Both materials have the potential to irritate the oral mucosa, but bis-acryl composite materials may be less irritating due to their lower exothermic reaction during polymerization 74,75.

Polymerization shrinkage: Bis-acryl composite materials typically have lower polymerization shrinkage compared to PMMA 76,77.

Microbial adhesion: PMMA has been found to have higher microbial adhesion compared to bis-acryl composite materials 78,79

Marginal accuracy: Both materials can produce accurate margins, but bis-acryl composite materials may have better marginal accuracy due to their lower polymerization shrinkage 80,81.

Color stability: Bis-acryl composite materials are generally more color stable compared to PMMA 82–86

Furthermore, studies have been done comparing bis-acryl composite to CAD/CAM milled PMMA to overcome the drawbacks of conventional PMMA.

A previous study (87,88) compared the clinical performance of milled PMMA and Protemp materials for fabricating temporary crowns. The study found that the milled PMMA material had significantly better retention and marginal adaptation than the Protemp material.

Another study published earlier 89 compared the marginal adaptation and surface roughness of milled PMMA and bis-acryl composite materials for fabricating temporary crowns. The study found that the milled PMMA material had better marginal adaptation and lower surface roughness than the bis-acryl composite material.

A further study 90 compared the surface roughness and color stability of milled PMMA and Protemp materials. The study found that the milled PMMA material had significantly lower surface roughness and better color stability than the Protemp material.

While these studies suggest that milled PMMA may offer some advantages over the bis-acryl composite materials, the choice of material should depend on several factors such as the specific clinical scenario, the preferences of the clinician, and the availability and cost of materials.

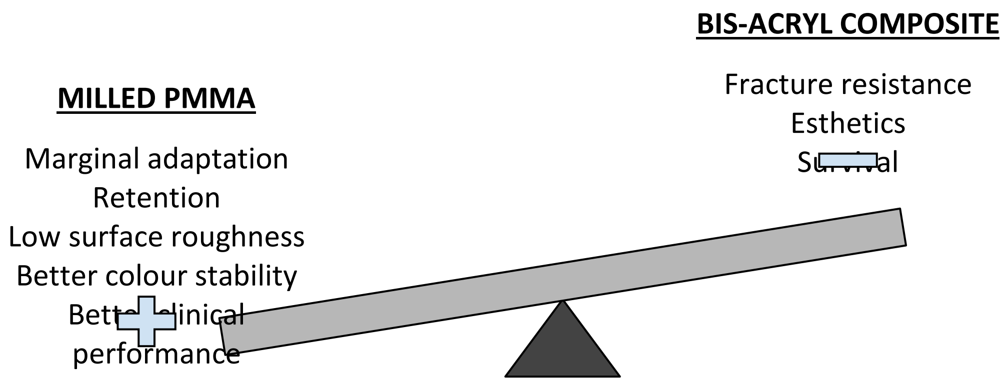

FIG 4 : Pros and Cons of using Milled PMMA for fabricating temporary crown and bridge prostheses.

A.2.c. Polymethylmethacrylate

Polymethyl methacrylate (PMMA) is a commonly used material for interim prosthesis due to its several advantages over other materials 91. Some of the benefits of PMMA include:

Strength and durability: PMMA has good mechanical strength and is resistant to fracture and wear, making it ideal for interim prosthesis 92,93.

Easy to fabricate: PMMA can be easily fabricated using both direct and indirect techniques, allowing for fast and efficient fabrication of interim prostheses 94.

Biocompatibility: PMMA is considered biocompatible and has low allergenic potential, making it less likely to cause adverse reactions in patients.

Stain resistance: PMMA is relatively stain-resistant, which helps to maintain the esthetics of the interim prosthesis over time 78,82.

Cost-effective: PMMA is a relatively low-cost material, making it a cost-effective option for interim prostheses.

Overall, PMMA is a versatile and reliable material for interim prostheses, making it a popular choice among most dental professionals.

A.3. Fabrication of PMMA provisionals using CAD/CAM technology

The history of CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) in dentistry can be traced back to the 1970s when the first computer systems were used for designing and manufacturing dental restorations. However, it wasn't until the 1980s that CAD/CAM technology began to gain wider acceptance in the dental field.

In 1985, the first commercially available CAD/CAM system for dental applications, called CEREC (CEramic REConstruction), was introduced by Sirona Dental Systems. This system used a chairside scanner and a milling machine to produce ceramic inlays, onlays, and crowns in a single visit.

Over the next few decades, CAD/CAM technology continued to evolve and improve, with advancements in software, hardware, and materials. In the 1990s, 3D printing technology began to emerge, which allowed for the production of more complex and intricate dental restorations.

In recent years, CAD/CAM technology has become increasingly popular in dentistry, with many dentists and dental laboratories incorporating it into their workflow as it allows for faster, more accurate, and more predictable fabrication of dental restorations, reducing the need for traditional dental impressions and improving patient outcomes.

Polymethylmethacrylate (PMMA) provisional restorations can benefit from CAD/CAM technology in various ways. The use of digital scanning and 3D modeling in CAD/CAM technology enables highly accurate and precise fabrication of PMMA provisional restorations 95,96. Studies have demonstrated that CAD/CAM-fabricated PMMA provisional restorations have superior marginal adaptation and fit compared to those made with traditional methods 89,97. The process of fabricating PMMA provisional restorations with CAD/CAM technology is also more efficient and faster, allowing for the entire process to be completed in a single visit. The computer-controlled milling process of CAD/CAM technology ensures predictability and consistency, which reduces the risk of errors and ensures that each restoration meets the required standards. Additionally, CAD/CAM technology enables customization of PMMA provisional restorations to meet the individual needs and preferences of the patient, resulting in restorations with excellent esthetics and function89,95,97 that closely resemble the patient's natural teeth.

3D printing and milling are two popular techniques used in the CAD/CAM (computer-aided design and computer-aided manufacturing) process for fabricating PMMA (polymethylmethacrylate) provisional restorations. Here are some more details on each technique:

A.3.a. 3D Printing

3D printing involves creating a physical object from a digital model by depositing successive layers of material 96,98. In the case of PMMA provisional restorations, 3D printing can be used to create restorations using a PMMA resin. The 3D printing process involves slicing the virtual 3D model of the restoration into thin layers, which are then printed layer-by-layer using a 3D printer. The 3D printer typically uses a photo-polymerization process, in which a light source is used to cure the resin in the desired shape.

A.3.b. Milling

Milling involves cutting away material from a block of PMMA using a milling machine, guided by a digital model of the restoration. The milling machine typically uses a high-speed rotating tool to remove material from the PMMA block until the desired shape is achieved 87,88. The milling process is computer-controlled, which ensures that the restoration is accurately and consistently fabricated to the design specifications.

Studies have compared the two techniques for fabricating PMMA provisional restorations. While 3D printing is a relatively new technology in the field of dentistry, some studies have shown that 3D-printed PMMA provisional restorations have similar clinical performance and marginal adaptation compared to milled PMMA restorations90. However, milling has been the gold standard technique for fabricating PMMA provisional restorations for many years, and numerous studies have demonstrated its accuracy, precision, and consistency89. While 3D printing technology offers advantages such as reduced material waste and increased design flexibility, milling has the advantage of being a well-established and widely used technique with a high level of accuracy and consistency99.

B. Cone beam computed tomography

CBCT (cone beam computed tomography) is a relatively new imaging technology that has transformed dental and maxillofacial imaging. In the past, medical CT (computed tomography) technology was adapted for dental use, but its high radiation dose and cost limited its use in dentistry. In the late 1990s and early 2000s, the first dental CBCT systems were introduced. These systems used a cone-shaped X-ray beam to acquire 3D images with lower radiation dose and cost compared to medical CT. The first commercially available dental CBCT system was introduced in 2001, and since then, numerous other CBCT systems have been introduced by various manufacturers worldwide, with varying specifications, imaging capabilities, and applications. CBCT has become widely used in dentistry and maxillofacial surgery for various applications such as implant planning, orthodontic treatment planning, evaluation of impacted teeth, assessment of jaw lesions, and evaluation of the temporomandibular joint. The development of CBCT has also led to the emergence of new software tools for image processing, analysis, and simulation, enabling clinicians to perform more accurate and personalized treatment planning.

B.1. Application of CBCT in prosthodontics

CBCT (cone beam computed tomography) technology is a powerful imaging tool that has revolutionized dentistry, particularly in the field of prosthodontics 100. CBCT can be used to generate 3D models in STL format using specialized software101. These 3D models are extremely valuable in various applications in prosthodontics. Here are some examples:

Implant planning: 3D models generated from CBCT images can be used to plan implant placement, allowing clinicians to visualize the placement of the implant and plan accordingly for the best outcome.

Crown and bridge restorations: CBCT-derived 3D models can be used to plan and design restorations such as crowns and bridges, allowing for more accurate fit and improved aesthetics 100,102.

Orthodontic treatment planning: 3D models can be used to plan and design orthodontic appliances such as braces and aligners, allowing for more precise tooth movement and more efficient treatment 103.

Temporomandibular joint (TMJ) disorders: 3D models can be used to assess and diagnose TMJ disorders, allowing clinicians to plan and execute treatment more accurately.

Endodontic treatment: 3D models can aid in the diagnosis and treatment of complex root canal anatomy, allowing for more accurate and successful treatment 104.

The use of CBCT-derived 3D models in prosthodontics allows for more accurate diagnosis, treatment planning, and execution of various procedures, leading to improved patient outcomes.

B.2. Provisionals fabricated using CBCT

Using CBCT to generate STL files is an exciting development in prosthodontics that has the potential to improve patient outcomes and streamline the restorative workflow 105. These 3D models can then be used to virtually prepare teeth for provisional restorations, and the resulting virtual tooth preparations can be used to fabricate provisional crowns using a variety of methods such as 3D printing or milling. The advantages of using CBCT to generate STL files for virtual tooth preparation workflows 106 to create provisional crowns include:

Increased accuracy and precision: CBCT imaging allows for more accurate and precise virtual tooth preparation, resulting in better-fitting provisional crowns.

Improved aesthetics: Precise virtual tooth preparation enables the creation of provisional crowns that have improved aesthetics and blend in better with the patient's natural dentition.

Reduced need for physical impressions: The use of CBCT eliminates the need for physical impressions, which can be uncomfortable for patients and can introduce errors into the workflow.

Faster turnaround times: The entire process of creating provisional crowns can be completed digitally, reducing the time required for manufacturing and fabrication.

Improved patient comfort: The use of digital workflows eliminates the need for multiple appointments and reduces patient discomfort associated with traditional methods. However, only in-vitro studies are done so far and more high level evidence and clinical research is required to fill the lacunae in the existing literature.

B.3. Risks of CBCT

Although Cone Beam Computed Tomography (CBCT) is a safe and valuable diagnostic tool, there are still some potential risks associated with its use 107. These risks include:

Radiation exposure: CBCT scans expose patients to ionizing radiation, which can increase the risk of developing cancer 108. However, the radiation dose of CBCT scans is much lower than that of conventional CT scans, and the risks can be minimized by following appropriate guidelines for imaging protocols and patient selection.

Allergic reactions: Some patients may be allergic to the contrast agents used in CBCT imaging, which can lead to an allergic reaction 109. However, the incidence of allergic reactions is rare, and pre-medication can be used to prevent adverse reactions.

Psychological effects: Some patients may experience anxiety or stress related to the scanning process or the potential outcomes of the scan 110. This can be mitigated by providing patients with clear information and support throughout the process.

Artifact formation: CBCT scans may produce image artifacts, which can interfere with the accuracy of the diagnosis 111. This can be caused by patient movement, metal restorations, or other factors 112. However, newer CBCT machines and software are designed to minimize these artifacts.

It is important for clinicians to carefully evaluate the risks and benefits of CBCT scans for each individual patient and to use appropriate imaging protocols and techniques to minimize the risks 101. Additionally, patients should be informed about the potential risks and benefits of CBCT imaging and provided with clear information and support to ensure a safe and successful imaging experience.

C. Intraoral scanners

Intraoral scanners are devices used in modern dentistry to capture digital impressions of teeth and surrounding oral structures. The technology has its roots in the 1980s when digital imaging systems were introduced in dentistry113. Since then, with the advent of computer-aided design/computer-aided manufacturing (CAD/CAM) systems, intraoral scanners have become a crucial component in the fabrication of dental restorations114.

Intraoral scanners can be divided into two categories, open and closed systems. Open systems allow for compatibility with various CAD/CAM systems, whereas closed systems are proprietary and only work with specific software115. Closed systems tend to be more affordable and straightforward to use, but may lack compatibility with certain types of restorations or software. On the other hand, open systems offer greater flexibility and choice, enabling clinicians to select software and materials based on their needs116.

C.1. Principles of intraoral scanners

Intraoral scanners use various principles to capture images of the teeth and surrounding oral structures. These principles include triangulation, confocal imaging, active wavefront sampling, and stereophotogrammetry 117.

Triangulation: It is the most common method used in intraoral scanners. It involves projecting a laser light onto the surface of the teeth and measuring the angle and distance of the reflected light. The scanner then uses this information to create a 3D image of the teeth and surrounding oral structures 118.

Confocal imaging: It involves using a narrow beam of light to illuminate a specific area of the teeth and surrounding oral structures. The scanner then measures the reflected light and creates a 3D image of the illuminated area. This method is particularly useful for capturing detailed images of small or difficult-to-reach areas.

Active wavefront sampling: It involves projecting a light onto the surface of the teeth and measuring the distortion of the light as it travels through the tooth structure. This method is particularly useful for capturing detailed images of the internal structure of the teeth.

Stereophotogrammetry: It involves using multiple cameras to capture images of the teeth and surrounding oral structures from different angles. The scanner then combines these images to create a 3D image of the teeth and surrounding oral structures. This method is particularly useful for capturing detailed images of the occlusal surfaces of the teeth.

Each of these principles has its own strengths and weaknesses, and different intraoral scanners may use different combinations of these principles to capture images. Overall, the goal of intraoral scanners is to capture accurate and detailed images of the teeth and surrounding oral structures, which can be used to create digital models for the design and fabrication of dental restorations.

C.2. Pros and Cons using an intraoral scanner

Intraoral scanners offer several benefits over conventional impression-taking techniques42. Traditional impressions are often uncomfortable and can cause anxiety and discomfort for the patient. With an intraoral scanner, the process is much quicker and less invasive, eliminating the need for messy impression materials that are often uncomfortable for the patient. Additionally, intraoral scanners provide real-time feedback, which can be very useful for identifying problems and correcting them immediately.

When compared to extraoral laboratory scanners, intraoral scanners have several advantages. Extraoral laboratory scanners rely on casts of the patient's teeth that are created using traditional impression techniques. These casts may be less accurate due to distortion during the manufacturing process. In contrast, intraoral scanners capture images directly from the patient's mouth, eliminating the need for impression materials and reducing the risk of distortion. Additionally, intraoral scanners provide real-time feedback, allowing clinicians to make adjustments as needed 119,120.

In conclusion, intraoral scanners are a valuable tool in modern dentistry, enabling clinicians to capture accurate and detailed digital impressions of the patient's teeth and surrounding structures. These devices offer several advantages over traditional impression techniques, including increased accuracy, improved patient comfort, and real-time feedback. Intraoral scanners can be used in a wide range of applications, from the design and fabrication of dental restorations to orthodontics and implant placement. As technology continues to advance, intraoral scanners are expected to become even more prevalent in dental practice.

Intraoral scanners are digital devices used in dentistry to capture accurate images of a patient's teeth, gums, and other intraoral structures 121,122. They have replaced traditional impression materials and techniques for dental restorations, such as crowns, bridges, and implants. Intraoral scanners use optical or laser technology to create a 3D digital model of the patient's mouth, which can be used for diagnosis, treatment planning, and fabrication of restorations. The digital model can be viewed on a computer screen, manipulated and edited using specialized software, and sent electronically to a dental laboratory for fabrication of the final restoration. Intraoral scanners offer many advantages over traditional impression methods, including increased accuracy, faster processing times, and improved patient comfort102. They have become an increasingly popular tool in modern dentistry, enabling dentists to provide high-quality restorations with greater precision and efficiency.

D. Esthetic outcomes

In restorative dentistry, evaluating the esthetic and functional outcomes of prosthetic restorations is essential for ensuring patient satisfaction and optimal treatment success. There are several types of evaluations that can be used to assess prosthetic restorations, including subjective evaluations by the dentist and patient, objective measurements, and digital imaging technologies.

Subjective evaluations involve the dentist and patient discussing the patient's expectations and goals for the restoration, and then evaluating the outcome based on those goals123. This approach is heavily reliant on individual perception and subjective opinion and may be influenced by factors such as lighting conditions and mood. The dentist may use a visual analog scale (VAS) or a modified VAS to evaluate the overall satisfaction of the patient with the restoration. The modified VAS includes different domains, such as color, shape, size, and texture, allowing the dentist to evaluate each aspect of the restoration separately124.

Objective measurements involve using standardized techniques to measure specific parameters of the restoration, such as tooth shade, contour, and symmetry. These techniques may include digital photography, spectrophotometry, and visual shade matching. Digital photography is commonly used to document the preoperative and postoperative conditions of the restoration and to evaluate the symmetry, shape, and contour of the restoration. Spectrophotometry is a technique that measures the color of the teeth and restorations, and it can provide objective data on the color matching and shade selection of the restoration. Visual shade matching is a technique where the dentist evaluates the shade of the restoration under different lighting conditions and against a shade guide to ensure a match with the natural teeth.

Digital imaging technologies, such as intraoral scanners and computer simulations, provide a visual representation of the expected outcome and can help predict the final esthetic outcome. Computer-aided design and computer-aided manufacturing (CAD/CAM) software can be used to design and fabricate prosthetic restorations with a high degree of accuracy and precision. The use of digital technologies allows for virtual try-in of the restoration, providing the patient with a preview of the final outcome and allowing for modifications to be made prior to fabrication. In addition, digital imaging technologies can be used to create digital wax-ups, which can serve as a guide for the fabrication of provisional restorations.

In summary, the evaluation of prosthetic restorations involves a combination of subjective and objective measures, including visual analog scales, digital photography, spectrophotometry, visual shade matching, intraoral scanners, computer simulations, and CAD/CAM software. By using these techniques, dentists can assess the esthetic and functional outcomes of prosthetic restorations, ensure patient satisfaction, and achieve the highest possible treatment success. Some of the most commonly used indices are as follows:

The Pink Esthetic Score (PES) and White Esthetic Score (WES) are two quantitative tools used to evaluate the esthetic outcomes of restorative treatments on natural teeth 125,126. The PES is used to assess the esthetic outcome of the soft tissue surrounding a restored tooth, while the WES evaluates the esthetic outcome of the restored tooth itself. The PES score ranges from 0 to 2 and takes into account several factors, such as the contour of the soft tissue, the level of the gingival margin, and the color and texture of the mucosa. A score of 0 indicates poor esthetics, while a score of 2 indicates excellent esthetics. The WES score ranges from 0 to 2 and takes into account the color, shape, texture, translucency, and surface characteristics of the restored tooth. A score of 0 indicates poor esthetics, while a score of 2 indicates excellent esthetics.

Both PES and WES scores are commonly used by dentists and researchers to assess the success of restorative treatments and to guide treatment planning 127,128.

Modified USPHS (United States Public Health Service) criteria: The USPHS criteria were developed to evaluate the clinical performance of dental restorations. The modified criteria assess restoration survival, marginal adaptation, anatomic form, color match, and secondary caries 129,130. The scores range from Alpha (excellent), Bravo (good), Charlie (satisfactory), Delta (unsatisfactory) to Echo (failure).

Oral Health Impact Profile - Aesthetic component (OHIP-AES): OHIP-AES is a questionnaire that measures the impact of oral health on an individual's quality of life 125131,132. It includes questions related to the esthetic appearance of the teeth, and the scores range from 0 to 60, with higher scores indicating greater dissatisfaction with esthetics.

Orofacial Esthetic Index (OES): OES is a clinical index that evaluates the orofacial esthetics of an individual. It assesses facial and dental esthetics using a series of measurements, including lip position, smile line, tooth color, and alignment 133. The scores range from 0 to 10, with higher scores indicating greater esthetic impairment.

Overall, a combination of subjective and objective evaluation methods is recommended to assess the esthetic and functional outcomes of prosthetic restorations thoroughly. These evaluation methods can help ensure patient satisfaction and optimize treatment success.

CONCLUSION

Provisional restoration fabrication is critical in FMR procedures, and their aesthetics are essential for patient satisfaction. While traditional techniques have been widely used and have demonstrated satisfactory outcomes, the use of newer techniques such as intraoral scanners and CBCT is gaining popularity and may produce better results. Further research is needed to confirm these findings and determine the optimal technique for provisional restoration fabrication in FMR.

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