ORIGINAL ARTICLE

MONOLITHIC ZIRCONIA – THE MODERN SOLUTION FOR PROSTHETIC RESTORATIONS USING CAD/CAM TECHNOLOGY

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Abstract: *Aim of the study.* This study aimed to highlight the treatment possibilities of partial edentulism in a group of patients based on Kennedy classification and to establish correlations between the prevalence of partial edentulism and gender, age, residence medium. We followed the presence or absence of previous prosthetic treatments, but also their type, fixed or removable. Material and method. The study involved 98 patients, of both genders, from both rural and urban areas, aged between 21 and 70 years. Results. The majority of patients were females, the age group 41-50 years being the most consistently represented. Most patients presented edentation in both arches and had previous prosthetic treatments. Conclusions. The highest prevalence of the edentulism class, both in the maxillary and mandibular arches, is represented by Kennedy class III. More than half of the patients in our study had benefited from previous prosthetic treatments - two thirds of these were treated fixed, and one third were treated removable.

Keywords: monolithic zirconia, prosthetic restorations, cad /cam

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1. Introduction

In recent years, the use of zirconia as a biomaterial for implants and prosthetic restorations has increased significantly in dentistry, due to the superior mechanical properties of zirconia, such as high mechanical strength, biocompatibility, as well as very high wear and friction resistance. [1,2].

Increasing patient demands for esthetics have led to the search for alternatives to metal-ceramic restorations. Due to the high success rates of 93.8% at 5 years and 89.2% at 10 years, it was considered the gold standard for fixed partial prosthetic restorations [3]. All new materials should provide results comparable to those obtained with metal-ceramic restorations [3-10]. The introduction of new materials and production methods have offered various possibilities for eliminating the metal support from metal-ceramic restorations.

Zirconia prosthetic restorations have gained significant popularity due to their esthetic qualities, durability, biocompatibility, and ease of fabrication using digital technologies.

When esthetics were a priority, all-ceramic restorations were the first choice as an alternative to metal-ceramic restorations, due to their natural appearance [11]. Mechanical properties are an important factor in choosing a material for use in a fixed prosthetic restoration. The main problem associated with all-ceramic restorations is their lower fracture resistance [3, 12-14].

Zirconia has demonstrated excellent mechanical properties [15,16]. It was initially a promising alternative for prosthetic restorations in the lateral areas, where an average masticatory force of 700 N can be recorded, with a maximum of approximately 900 N [17-22]. However, the main problem associated with first-generation zirconia restorations was milling of the material, with a higher fracture rate than that of metal-ceramic restorations [3]. Several factors were involved in milling zirconia restorations, such as compressive forces and thermal expansion resulting from the sintering process and differences in the modulus of elasticity between zirconia and veneering ceramic [23,24], alteration of the crystalline structure of zirconia during its surface treatments, which induced cracks [3] an increase in temperature and a change in the coefficient of expansion [3,25]. Milling was also associated with inadequate thickness of the layering ceramic and therefore an anatomical structure design was recommended [26, 27].

Therefore, to overcome these complications, prosthetic zirconia restorations have begun to be made with a monolithic design, in which the entire restoration is produced from zirconia without ceramic layering [28,29].

Currently, zirconia restorations can be produced through workflows involving conventional or digital impressions. In the conventional workflow, the prosthetic field is analogically imprinted, and the generated plaster working model is scanned with a laboratory scanner. The digital workflow is based on optical scanning of the prepared teeth with an intraoral scanner (IOS) to directly obtain a virtual image of the teeth to be restored [30-32].

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The virtual image of both workflows is used to design a zirconia restoration that can be subsequently produced by milling. Numerous studies have confirmed the validity of the 2 workflows for the production of zirconia restorations [33-35].

Monolithic zirconia restorations can be produced entirely through a digital workflow, without dental technician intervention and without a physical model [36,37]. However, the disadvantage of monolithic zirconia restorations is the lack of color customization for special aesthetic requirements. To alleviate this limitation, minimal veneering can be applied to the vestibular surface of a monolithic zirconia restoration to improve its aesthetics. However, minimal veneering consequently requires a physical model to ensure the accuracy of the marginal adaptation of the prosthetic restoration and the interproximal contacts. The model can be made of class four plaster for the conventional workflow or of a specific resin in the case of a 3D printed model using the digital workflow. However, the veneering process and the use of a conventional physical model increase the fabrication steps and may affect the adaptation of the prosthetic zirconia restoration [38-42].

In recent years, multilayer zirconia has been introduced, with different intensities of pigmentation of each layer, which has led to the simulation of the typical color gradient of a natural tooth.

Zirconia discs contain 4 or 6 layers in different pigmentations with different translucencies [43]. This aspect has led to the solution of the aesthetic problem of the past, currently the individualization of the monolithic zirconia dental restoration is completed through a simple process of applying stains and glazes [44,45].

Therefore, the purpose of this study was to highlight the technological stages of obtaining monolithic zirconia restorations using exclusively digital flow and the importance of making provisional prosthetic restorations.

2. Materials and method

The study was conducted between 01.10.2023 and 01.05.2024 and included a group of 25 patients with different types of partial edentations in the frontal or lateral area, aged between 30 and 75 years. The patients in the study group presented with coronal destruction and reduced or extensive edentations. Before treatment, the patients were informed about the objectives of the study, the clinical procedure, the materials used, the risks and benefits of zirconia restorations and therapeutic alternatives. All patients signed an informed consent to participate in the study. Ethics Committee Opinion, 65/29.01.2024

The two maxillary arches as well as the occlusion of the patients were scanned using the Medit i700 intraoral scanner and Medit Link v.3.2.1 software (Medit, Seoul, Republic of South Korea). The intraoral scanner was calibrated according to the manufacturer's instructions. The scans were performed for the complete dental arches by the dentist.

The Exocad v3.2 Elefsina design software (Darmstadt, Germany) was used to design the future prosthetic restorations and virtual models. The models were printed using the Elegoo Saturn S 3D printer (Elegoo, Shenzhen, China) with specific resin, and the zirconia milling was performed

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with the Imes-iCore 150i Dry milling machine (imes-icore GmbH, Hessen, Germany). The zirconia discs used were from the manufacturer Kerox Dental (Kerox 3DML, Kerox LTD, Soskut, Hungary).

Cabinet stages

The patient files were completed in the Medit Link application version 3.2.1 (Figure 1 A) and consisted of patient data, the type of total physiognomic prosthetic restorations, the material and the chosen color, then the two dental arches were scanned with the preparations and interocclusal relationships (Figure 1 B).

After the scan was performed, the conformity of the digital impression was checked so that there were no missing scans, the arches did not interpenetrate and the line of the package was well expressed.

After the digital impressions were validated by the dentist, they were sent via the common Medit Link application. So, via the internet, the digital impression immediately reaches the dental laboratory.

Laboratory steps

Before starting the laboratory stages, which involve part 3D design and part production, the dental technician checks the integrity of the digital impression in the Medit application and if there are no errors, creates an electronic patient file where they store each patient's impression, as well as other data about them, such as photographs, radiographs or CBCT data.

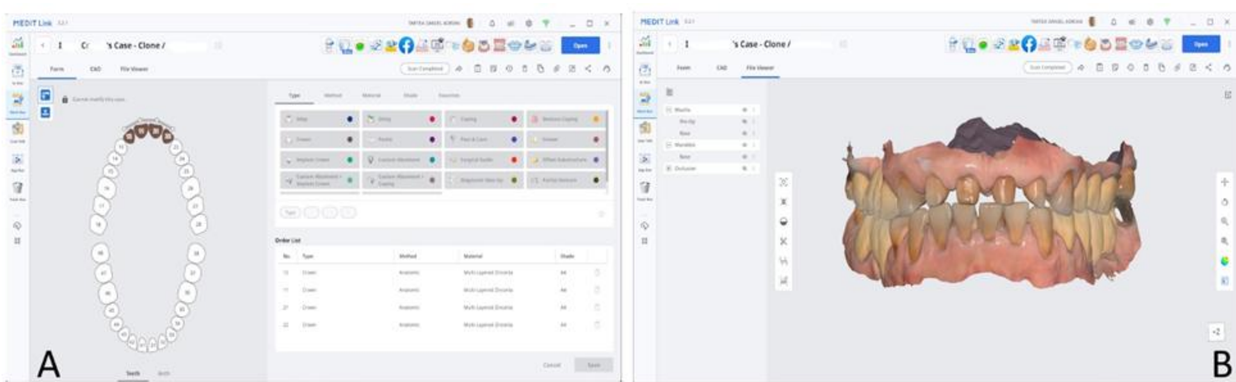

Figure 1. Example of Patient Record (A) and Digital impression in Interocclusal Relationship (B).

Figure 2. Example of Patient Record (A) and Digital impression in Interocclusal Relationship (B).

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The Exocad 3D design application has two working interfaces. The first DentalDB interface, the one with which the 3D design stages begin, represents a database with Worksheets (Figure 2A) where a series of data about the office with which one collaborates, the patient's case is entered specifying the future dental restoration, its type and the material from which it will be made (Figure 2B).

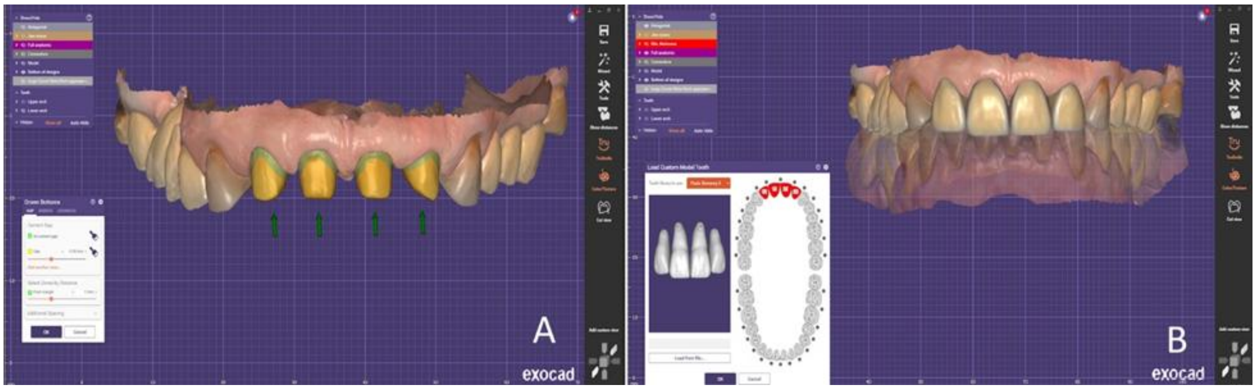

Figure 3. DentalCAD with digital impression (A) and design model of a dental restoration (B).

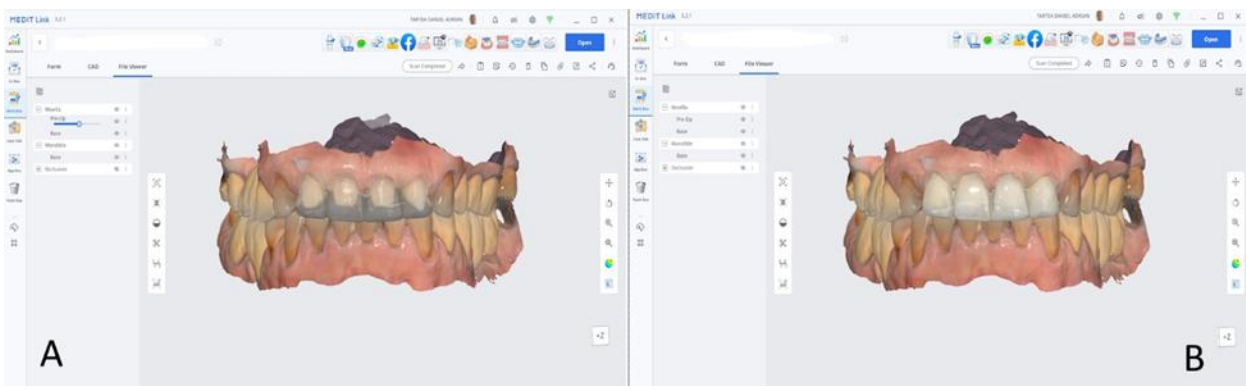

Figure 4. Distribution of female patients according to the edentulous arch.

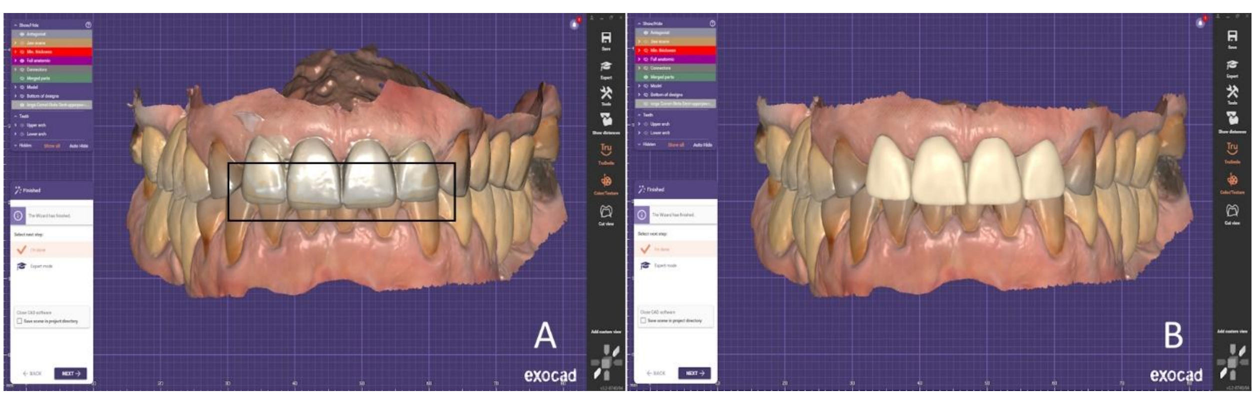

Figure 5. Distribution of male patients according to the edentulous arch.

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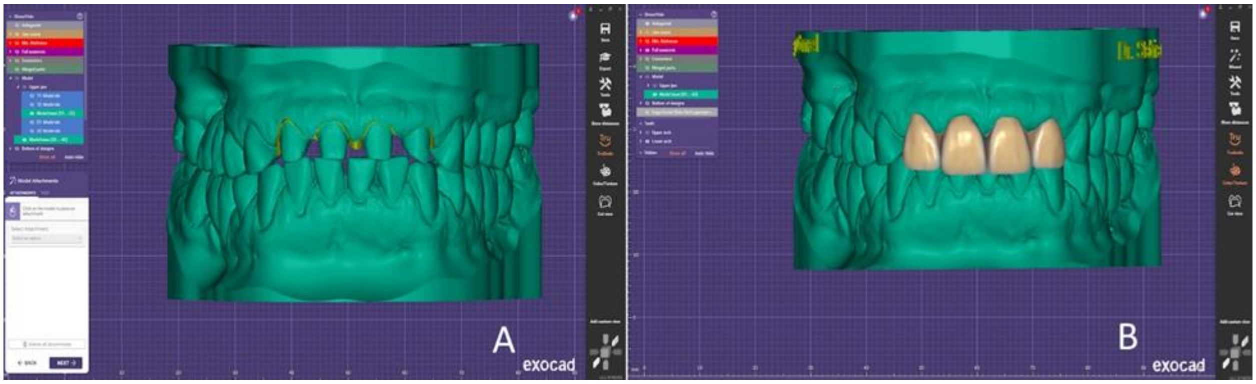

Figure 6. 3D printing model design (A) and final shape of monolithic zirconia (B).

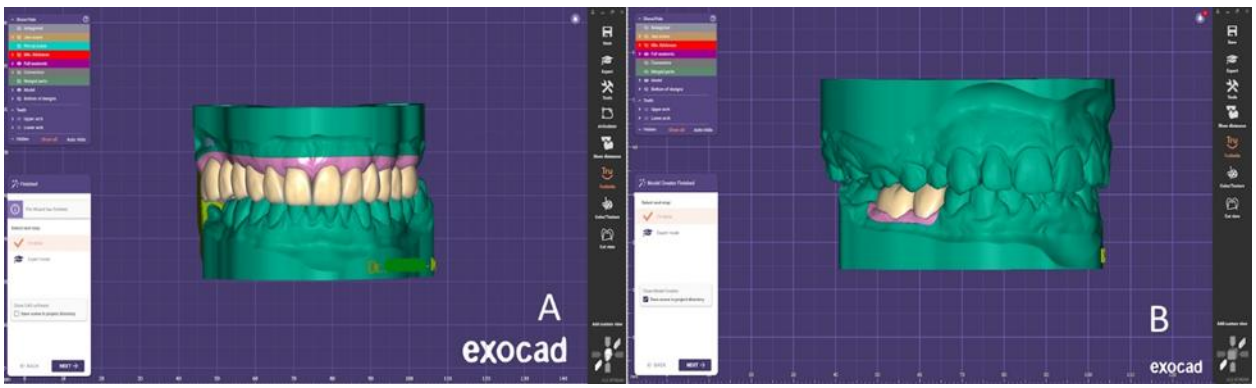

Figure 7. Full maxillary rehabilitation (A) and lateral mandibular area rehabilitation (B).

The parameters chosen in DentalDB will represent the design working stages in the second interface of the DentalCAD application (Figure 3A) with the help of which the design of the dental restoration will be made (Figure 3B).

One of the most important steps in the digital workflow for monolithic zirconia restorations is the in-office try-in with a PMMA provisional restoration. This step validates the preliminary marginal adaptation, proximal and occlusal contacts, and their esthetics through the achieved shape.

Validation of the provisional restoration in the office is achieved both by recording what is to be modified, but especially by intraoral scanning of the provisional (Figure 4 A and B) after its adaptation in the oral cavity has been verified.

The next step was to load the new pre-op digital impression into dentalCAD. This impression was superimposed on the impression from which the provisional restoration design was made, where it was determined what was to be modified (Figure 5 A). The modification found in the office was followed so that the final design could be sent to the production of the final monolithic zirconia dental restoration (Figure 5 B).

The final restoration will be fabricated by milling, sintering the zirconia, and then final individualization by applying stains and glaze. In the last stage of the morphology

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restoration process using CAD-CAM technology, the working model will be designed and then 3D printed.

The figures below show details about the alignment of the model and the particularities of the abutments (Figure 6 A) and the final form in which we have the working model and the definitive prosthetic restoration in Zirconia (Figure 6 B).

The monolithic zirconia restorations performed for the 25 patients in the study consisted of various types of complex rehabilitations of the maxillary arches (Figure 7 A), the maxillary frontal area and the mandibular lateral area (Figure 7 B).

3. Results

The 25 patients included in the study received prosthetic zirconia restorations, 8 women and 17 men (Table 1).

Of the 8 women, 7 had coronal destruction and only one woman had edentulism requiring prosthetic restoration. Of the 17 men, 5 had coronal destruction and 12 had edentulism (Figure 8).

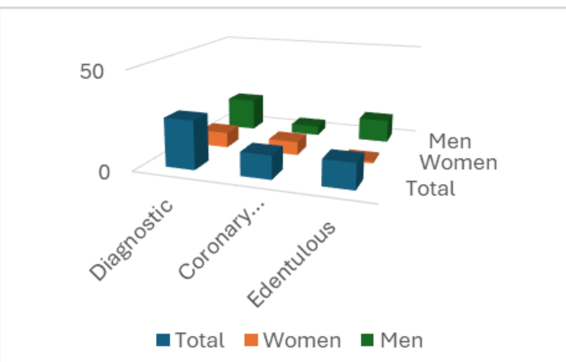

Figure 8. Patient-diagnosis correlation.

The restored arch was in both women and men, in a higher percentage, the maxillary one (6 cases in women and 9 cases in men) (Figure 9), and the area of the dental arch restored in a higher percentage was the lateral one (7 women and 10 men) (Figure 10).

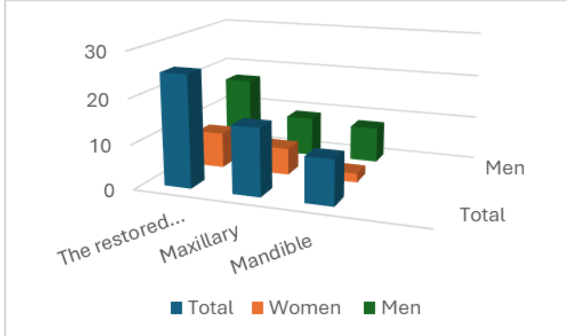

Figure 9. Patient correlation – restored arch.

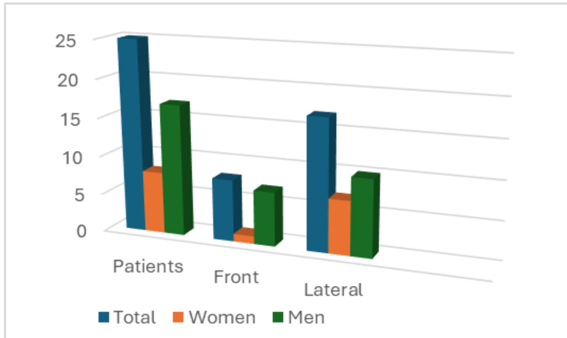

Figure 10. Patient – restored area correlation.

Following verification of the zirconia restorations in the oral cavity, prior to the application of stains and glazing, 6 cases required adaptation to the occlusal surface in the lateral movement, however, marginal integrity was assessed as excellent in all restorations when verified both on the model and upon insertion into the oral cavity (Table 2).

Regarding the correspondence between the color of the restoration in the patient's file and the color of the restoration in the oral cavity, for 2 cases it was necessary to modify the intensity of the stains according to the reality of the color in the patient's oral cavity (Table 2)

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Table 1. Patient data, diagnosis, arch and restored area.

Patients		Total	Women	Men
		25 (100%) (n%)	**8 (32%)**	**17 (68%)**
Diagnostic	Coronary destruction	12(48%)	7(87,5%)	5 (29,41%)
	Edentulous	13(52%)	1(12,5%)	12 (70,59%)
The restored arcade	Maxillary	15(60%)	6 (75%)	9(52,94%)
	Mandible	10(40%)	2(25%)	8(47,06%)
Restored area	Front	8(32%)	1(12,5%)	7(41,18%)
	Lateral	17(68%)	7(87,5%)	10(58,82%)

Table 2. Results obtained from the evaluation of dental restorations.

25 cases	Adjustment after trial n/ %	Remade after the trial n/%	Not require any changes n/%
Color	2(8%)	0(0%)	23(92%)
Marginal fit	0(0%)	0(0%)	25(100%)
Occlusal adaptation	6(24%)	0(0%)	19(76%)

4. Discussion

Zirconia is a bioceramic that was first investigated by German chemist Martin Heinrich Klaproth in 1789 [46]. The first research paper on the use of ZrO2 as a biomaterial was published by Helmer and Driskel in 1969 [47].

The minimum material thickness in our study was the manufacturer's recommended minimum for monolithic zirconia of 0.6–0.8 mm, with an axial reduction of 1 mm and an occlusal reduction of 1.5 mm. Adequate preparation of the smaller abutment is an advantage for monolithic restorations, as the lack of adequate interocclusal space can lead to the failure of these restorations, as Miura S et al. found in a similar study [48].

The results of the study showed that none of the prosthetic works required marginal adaptation, 92% of the prosthetic works did not require color changes and only 24% required occlusal adaptation. Thus, the time lost in the office with the adjustment of a prosthetic work made of monolithic zirconia is much shorter than with metal-ceramic works, where three fitting sessions are required (frame fitting, ceramic-color fitting and the last final fitting session and cementation). With monolithic zirconia there can be only one final fitting session and cementation.

The introduction of digital technology has allowed the fabrication of dental restorations to become more automated, time-efficient, and precise. The digital workflow has shown results comparable to those obtained with conventional techniques. One of the parameters associated with the success of restorations is marginal adaptation, along with fracture resistance, and studies have shown excellent results for prosthetic restorations made with a digital workflow [49-51]. However, there are several factors that can affect the accuracy of prosthetic restorations, such as the experience of the doctor and dental technician, the software version, and the adjustment parameters. The good results observed in this study may also be due to the

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good control of bacterial plaque, the good marginal adaptation of monolithic zirconia prosthetic restorations and the excellent biocompatibility of zirconia, an aspect that was also highlighted by Morsy N et al. [52].

According to the specialized literature, referring specifically to the study conducted by Holmes et al., the points that we considered for analysis were: marginal, axial, axio-occlusal and occlusal [53].

Marginal and internal adaptation can be affected by the fabrication technique as well as the impression technique [54].

For all restorations made, the same impression techniques were used, the same zirconia material and the same milling technique were used, by designing them in their own design programs, without modifying the scanner data in special formats, to avoid any bias in the production process and to avoid data loss, as also mentioned by Erozan C et al. in their own study [55].

Regarding the aspect of the greater marginal adaptation accuracy of dental restorations in the case of intraoral scanning impressions or even superior to restorations produced with laboratory scanners, debates continue among clinicians [56-58]. Marginal adaptation is considered to be one of the most important criteria in the evaluation of fixed prosthetic restorations [59]. The greater the lack of marginal adaptation, the greater the plaque index and retention loss, and the greater the exposure of the cementing material to the oral environment [60]. The internal fit of a ceramic crown is another critical factor. An improper internal fit can cause low strength of the restoration and reduce fracture resistance [60,61]. According to the study by McLean and von Fraunhofer, a marginal discrepancy of 120 μm is clinically acceptable. However, different values of marginal discrepancy have been reported, including 100 μm [62,63] and 75 μm [64]. However, there is no consensus on the clinically acceptable value of marginal adaptation.

The digital workflow helps us to obtain much more accurate and faster provisional restorations with optical impression and digital design in the first stage. This also leads to a reduction in working time and the number of clinical and laboratory sessions.

Regarding PMMA provisional restorations, they were designed to improve esthetics, function, and to evaluate the efficacy of a specific treatment plan [65]. Most clinical cases require a provisional stage, not only those using immediate loading for implants, but also those for fixed dental restorations on prepared teeth [66,67]. The basic requirements for provisional restorations can be divided into biological, biomechanical and aesthetic requirements [68]. They must be biocompatible, non-irritating, have a pleasant smell and taste and provide a highly polished surface [65].

Recently, dental doctors and technicians have increasingly started to use provisional restorations made using the 3D printing technique, as an alternative to conventionally made and milled ones, with very promising results even for long-lasting crowns and bridges [69].

5. Conclusions

Use of new materials - CAD/CAM technology has enabled the efficient processing of new materials, such as high-

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strength multilayer zirconia, which is used in the construction of fixed dental restorations.

Time efficiency - The use of CAD/CAM technology allows for a reduction in the time required to manufacture dental crowns and bridges. Thus, patients benefit from faster and more efficient treatment. Quality control - The use of CAD/CAM technology ensures precision and superior quality in the manufacture of dental prosthetic components. This allows for better and more durable results for patients.

Comfort for patients - CAD/CAM technology allows for more comfortable and esthetic dental restorations.

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