ABSTRACT

INTRODUCTION: Nowadays, the improvement of intraoral scanning systems aims to overcome some limitations of the conventional methods and to eliminate the mistakes that can be made during the production technology and to achieve a more precise design of prosthetic restorations [7].

AIM: The aim of the present study is to evaluate and compare the marginal adaptation and the internal fit of zirconium dioxide fixed partial dentures, made by direct and indirect digital approach.

MATERIALS AND METHODS: To perform the in vitro study, a model-sample of the upper jaw was used, on which two artificial plastic teeth 24 and 26 were prepared and tooth 25 was removed. 30 virtual models were created from the prepared model. To obtain the virtual models in the first group (CIS group), 10 conventional impressions (n = 10) were taken with additive silicone impression material using a two-stage two-phase impression technique with a standard metal impression tray. For the second group (PCS group) the conventional impressions were casted with IV class high quality hard plaster. The ten digital impressions from the third group (ISG group) were obtained using an intraoral TRIOS scanner.

RESULTS: The highest mean value in P1 was measured in the CIS group (155.1 ± 69.96 µm), followed by the PCS group (135.62 ± 78.7 µm). The highest mean value in P2 was obtained in the CIS group (138.32 ± 63.08 µm), followed by the ISG group (117.2 ± 32.48 µm). The highest mean value in point P3 was found in the CIS group (94.525 ± 23.03 µm), while the highest mean value in point P4 was measured in the PCS group (86.34 ± 26.99 µm).

CONCLUSION: The obtained mean values regarding the marginal adaptation in all studied groups are within the clinically acceptable range. The highest values in terms of the marginal adaptation indicator were obtained in the PCS group, and the lowest - in the ISG group.

Key words: Digital impression, conventional impression, fixed partial denture, marginal adaptation, internal fit, comparison

INTRODUCTION:

Over the last three decades, CAD / CAM (computer-aided design and computer-aided manufacturing) technology has entered rapidly and gained great popularity, providing better working conditions and increasing the comfort of both dentists and their patients.. Each CAD / CAM system consists of three main parts: 1. a unit with which data is collected from the prosthetic field, after which they are turned into a virtual impression; 2. software, with the help of which the prosthetic restoration is virtually created on a three-dimensional virtual model; and 3. a production unit, by means of which the prosthetic restoration is physically created. Two types of technologies are used in this process: subtractive and additive. The first two elements are part of the CAD module, and the third - of the CAM module.

The first commercial CAD / CAM system was developed and introduced by Mormann in collaboration with Marco Brandestini in 1985. They succeeded in creating the first inlay made on site using a combination of an optical scanner and a milling machine. This device is called CEREC, short for Chairside Economic Restoration for Esthetic Ceramics [1]. In the 80's, several different CAD / CAM systems were introduced - Andersson developed the Procera system (NobelProcera, Nobel Biocare), which makes high-precision crowns. He is also working on the possibility
of using titanium instead of conventional chromium-nickel alloys due to evidence of allergies to them. Andersson used CAD/ CAM for the first time to make composite veneers. Rekow et al. work on a CAD / CAM system for dental use, using photos, a high-resolution scanner and a milling machine [2,3].

In essence, the optical impression, also called digital, is a virtual three-dimensional copy of the prosthetic field. It is obtained with the help of so-called intraoral scanning systems (ISS). The information obtained from the scan is processed by special software and a 3D model is compiled in real time, which can be seen and evaluated by the dentist directly on a computer screen. The difference between digital and conventional impressions is that the latter produces a negative copy of the prosthetic field. To obtain a working model, it is necessary for the conventional impression to be casted from plaster with certain physical properties [4,5,6]. The development of ISS aims to overcome some limitations of conventional methods, such as volume changes of impression materials, the expansion of plaster during the casting of working models, as well as errors that can be made during the production technology during the manufacture process of prosthetic restorations [7].

With the creation and introduction of CAD / CAM technology, the aim was to solve three main challenges in dental medicine - to ensure sufficient strength of restorations, especially in the distal area, to create restorations with a more natural appearance and to facilitate and shorten the process of making these restorations, which would also increase their accuracy [5].

**AIM:**

The aim of the present study is to evaluate and compare the marginal adaptation and the internal fit of zirconia fixed partial dentures (FPD), made by direct and indirect digital approach.

**MATERIALS AND METHODS:**

An in vitro study was performed comparing the accuracy of fixed zirconia bridges without ceramic veneering made by direct and indirect digital approach. The "Replica technique" was used to carry out this laboratory experiment. (RT) [8,9,10]. It was used to compare and evaluate the distance and the discrepancies between the retainers and the abutments of each prosthetic restoration.

To perform the study, a model of the upper jaw (Ivoclar Vivadent, Fixed Prosthetics) was used, on which two artificial plastic teeth (24 and 26) were prepared and tooth 25 was removed. The place of tooth 25 was filled with Teflon and a thin layer of wax. The two abutment teeth were prepared with a horizontal preparation margin with a rounded inner angle and a width of 0.8 mm at the level of the gingiva, circumferential reduction of the axial walls - 1.5 mm, occlusal reduction - 2 mm and total inclination of the axial walls - 6°. To control the axial and occlusal reduction, a silicone key was made before the preparation of the two artificial teeth (Fig. 1).

The preparation was done using a high speed contraangle 1:5 (Ti-Max X95L, NSK, Japan) and diamond burs with coarse (OkoDent diamond bur, REF 881 012SC, REF 811 037SC и REF 368 018SC), medium (OkoDent diamond bur, REF 881 012C) and fine (OkoDent diamond bur, REF 881 012F, REF 881 014F и REF 368 018F) abrasiveness with a suitable workpiece shape to achieve the desired marginal design.

From the prepared model, 30 virtual models (.STL files) were created in three different ways based on the process used to obtain these .STL files. They were divided into three test groups (n = 10): 1. conventional impression scanning group (indirect digital method) - CIS; 2. scanning of plaster models (plaster cast
scanning group) (indirect digital method) - PCS; 3. intraoral scanner group (direct digital method) - ISG.

To obtain the virtual models in the first group (CIS group), 10 conventional impressions (n = 10) with additive silicone impression material (Variotime 2 putty and light body, Kulzer GmbH, Germany) were taken using a two-stage two-phase impression technique with a standard metal impression tray at room temperature. All impressions are left on the model three times longer than the time recommended by the manufacturer to ensure adequate polymerization of the impression material at room temperature. The impressions were sent to the dental laboratory, where they were scanned directly with a laboratory scanner (Up360 + Desktop Scanner, Up3D, China) to obtain ten .STL files.

For the second group (PCS group) the conventional impressions were casted from class IV high-quality hard plaster (GC Fujirock, EP; GC Europe, N.V., Leuven, Belgium) using a vacuum stirrer, following the manufacturer's instructions. Each plaster model was digitized with the same laboratory scanner, thus generating 10 virtual 3D models, which were converted to .STL format (n = 10).

The ten digital impressions from the third group (ISG group) were obtained using an intraoral scanner TRIOS (Trios 3, 3Shape A / S, Denmark) (n = 10). The scan of the sample model was performed in the sequence recommended by the manufacturer.

From the received .STL files from each group, 10 zirconia FPDs were made (total number of structures = 30). The virtual design of the restorations was done by the same dental technician using specialized CAD software (Tizian Creative RT CAD Software, Schütz Dental, Germany). All test sites are designed with the same parameters: distance of 15 µm for the cementing layer in the area of the preparation margin and 60 µm for the axial walls and in the area of the occlusal surface and for the transition point between the axial and occlusal surface; 1.5 mm thickness of the axial walls and 2 mm of the occlusal surfaces. After completing the CAD design, the structures are milled from pre-sintered zirconia discs (NOVAZir ® Fusion Float ML) into a 5-axis milling machine (Tizian Cut 5.2, Schütz Dental, Germany). The milled FPDs were sintered according to the manufacturer's instructions in a special furnace (Vario S 400, Züblin, Germany).

We evaluated the marginal adaptation and the internal fit using the replica technique without any adjustments done on the restorations by the dental technician after the completion of the sintering process. The internal surface of the retainers of each FPD was dried and a special VPES material (Fit checker Advanced Blue, GC, America) was placed in them. The restoration was then placed on the prepared teeth on the sample model by applying finger pressure in the apical direction. To standardize the study in all restorations, a maximum pressure for 5 seconds was initially applied to simulate a clinical trial, after which they were held with constant vertical pressure until the polymerization of the material was completed. After it has hardened, the restoration was removed from the model with the creamy silicone remaining on the inner surface of the retainers. The thin layer of VPES material was stabilized by injecting an additive transparent silicone material with high hardness according to Shore A (Memosil 2, Heraus Kulzer GmbH, Germany) into the inner surface of the retainers. After completion of the polymerization of the transparent silicone, the two bonded materials were carefully removed from each retainer. The replica of each retainer was sectioned mesio-distally and bucco-lingually to obtain 4 equal pieces of each abutment.

The thickness of the silicone, representing the mismatch between the retainers and the abutments, was measured using a light microscope (Olympus SZ51 Stereo Microscope) at x40 magnification and a digital microscope camera (Ucmos microscope camera). The pieces were prepared for observation under an optical microscope after their horizontal fixation of the silicone matrix in order to obtain a parallel orientation to the plate of the microscope. Measurements were made at the following four points of each section in mesio-distal and bucco-lingual direction:

- P1: occlusal surface
- P2: transition between occlusal and axial surface.
- P3: middle of the axial wall
- P4: area of the preparation margin

Point P1 represents the distance between the inner surface of the retainer and the occlusal surface of the abutment, measured in the central part of the latter. At point P2, the distance between the inner surface of the structure and the prepared tooth in the area of the transition between the occlusal surface and the axial wall was measured. Point P3 represents the distance between the inner surface of the retainer and the axial wall of the tooth in its middle part. Point P4 is defined as the perpendicular distance between the inner surface of the restoration and that of the abutment in the area of the preparation margin. The measurements from P4 gave information about the marginal adaptation, and those from P1, P2 and P3 - about the internal fit. (Figure 2)
The image of each test point was digitized using a microscope camera, and the measurements were made with image processing software (ImageJ, National Institutes of Health, Bethesda, USA) after setting the correct scale. Marginal adaptation and internal fit were calculated for each FPD and compared between the three groups. The whole experiment was performed at room temperature (23 °C).

The statistical analysis was performed with a specialized statistical software (SPSS Statistics v.20 IBM Corp.)

**RESULTS:**

When calculating the average values of the two abutments of each fixed partial denture of the three groups, we obtained the following results:

1. the highest average value in P1 was measured in the CIS group (155.1 ± 69.96 µm), followed by the PCS group (135.62 ± 78.7 µm) and the ISG group (102.02 ± 28.21µm). The comparative analysis between the obtained results showed significantly less distance between the retainers and the prepared teeth in the area of the occlusal surface in the ISG group compared to the other two groups (p <0.01). In addition, the average value in P1 of the PCS group was significantly lower than that of the CIS group (p <0.01), but significantly higher than that in the ISG group (p <0.01).

2. the highest average value in P2 was obtained in the CIS group (138.32 ± 63.08 µm), followed by the ISG group (117.2 ± 32.48 µm) and PCS (115.38 ± 38.45 µm). From the performed comparative analysis it is clear that no statistically significant difference in the obtained results was found between the PCS and ISG groups (p> 0.05), but such was found between the CIS group in comparison with the other two groups (p <0.05).

3. the highest average value in P3 was found in the CIS group (94.525 ± 23.03 µm), followed by the ISG group (82.525 ± 22.64 µm) and the PCS group (78.56 ± 26.87 µm). The obtained results do not show a statistically significant difference between the PCS and ISG groups (p >0.05). This was found when comparing the values between the CIS group and the other two groups (p <0.01).

4. the highest average value in P4 was measured in the PCS group (86.34 ± 26.99 µm), followed by the CIS group (68.57 ± 33.20 µm) and the ISG group (50.7 ± 19.88 µm). The performed comparative analysis shows that the average distance in the marginal area of the restorations from the PCS group is significantly greater compared to the CIS and ISG groups (p <0.01). There was also a statistically significant difference between the average values in item P4 between the bridges of the CIS and PCS group (p <0.05), as well as between those of the PCS and ISG group (p <0.01).

Fig. 3 shows the average values from the measurement of the distance between the retainers and the prepared artificial teeth (tooth 24 and tooth 26) in P1: occlusal surface. Although no significant difference was found in the results when measuring the premolar and molar in the studied groups, lower values were observed in the premolar. The lowest results are reported in the ISG group.
Fig. 4 presents a comparative analysis of the distance between the retainers and the prepared artificial teeth (tooth 24 and tooth 26) in P2: transition between occlusal and axial surface. There was a significant difference in the values measured in all three groups (p < 0.05). In premolars, lower results were observed in all three studied groups.

![Fig. 4 Comparative analysis of the distance between the retainers and the prepared artificial teeth (tooth 24 and tooth 26) in P2: transition between occlusal and axial surface](image)

Fig. 5 presents the results of the comparative analysis of the distance between the retainers and the prepared artificial teeth (tooth 24 and tooth 26) in P3: middle of the axial wall. In the CIS and PCS groups significantly lower premolar values were found, while in the ISG group the lower values in the measurement were in molars.

![Fig. 5 Comparative analysis of the distance between the retainers and the prepared artificial teeth (tooth 24 and tooth 26) in P3: middle of the axial wall](image)

Fig. 6 presents the comparative analysis of the distance between the bridge retainers and the prepared artificial teeth (tooth 24 and tooth 26) in P4: area of the preparation margin. In the CIS group, significantly lower values were found in the measurement of the molar compared to the premolar, while in the ISG group the lower values were found in the measurement of the premolar.

![Fig. 6 Comparative analysis of the distance between the bridge retainers and the prepared artificial teeth (tooth 24 and tooth 26) in P4: area of the preparation margin](image)
DISCUSSION:
A number of clinical studies have been found in the available literature that prove the importance of the accuracy of prosthetic restorations in order to accept a prosthetic treatment as successful [11,12,13]. Two of the main parameters that describe the concept of “accuracy” of the fixed partial dentures are the marginal adaptation and the internal fit of the restorations. Together with the high mechanical strength of the material and the good adhesion of the luting cements, these factors are extremely important for the long-term success of the treatment. Unsatisfactory accuracy of structures can cause plaque accumulation in the marginal area, leading to the appearance of a local inflammatory process, hypersensitivity, thicker cement layer, dissolving part of the cement, micro-leakage and the appearance of secondary caries [11,12,14,15]. Based on the analysis of the studied literature, the following factors can be systematized, which can have a negative impact on the accuracy of prosthetic restorations: the impression technique (conventional and digital), the type of restoration and the used material, the design of the preparation margin, the preparation of the model (gypsum or virtual 3D), the used production technology, the adjustment and the used cementing technique [15,16,17,18,19]. Based on studies, it has been established that the maximum allowable distance between the preparation margin and the prosthetic restoration, at which clinical success can be achieved, is not more than 120 μm [20,21,22,23].

A number of studies in the available literature compare the accuracy and clinical success of fixed prosthetic structures made by digital impressions compared to conventional methods. Kouliyvand et al. compare marginal accuracy using replica technique with a microscope with a magnification of x50. The results show better accuracy of constructions made by the digital impression technique [24]. Similar results were reached by Haddadi et al. in their 2019 study [25]. The replica technique was also used in a study by Banic et al. from 2018, comparing the discrepancies in 4 areas of frameworks of zirconium dioxide, made using the digital method, compared to those of metal alloy, made with the conventional method. The results show the same or better marginal accuracy in the first test group [26]. The authors of three other independent studies demonstrated that no statistically significant difference was found in the marginal accuracy of single zirconia crowns or lithium disilicate crowns made by digital or conventional PVS impression techniques [27,28,29]. Ahrberg et al. and Zaraus et al. conclude that digital impression designs show significantly better marginal accuracy than conventional impression techniques. The marginal discrepancies in the two test groups are within the clinically acceptable difference [21,30]. According to Boeddinghaus et al. the digital impression technique with a subsequent digital approach in the manufacture of prosthetic restorations can be an alternative to conventional impressions, provided that the preparation margin is clearly visible and the prosthetic field can be adequately dried by blood, saliva and gingival fluid [31].

CONCLUSION:
Within the limitations of this in vitro study, the following conclusions can be drawn:
1. The obtained average values with respect to marginal adaptation in all studied groups are within the clinically acceptable values
2. The highest values in terms of the marginal adaptation indicator were obtained in the PCS group, and the lowest - in the ISG group
3. The average values at points P1, P2 and P3, which give information about the internal fit, are the lowest in the ISG group
4. Deviations from the clinically acceptable value of 120 micrometers can be established only in point P1 and point P2 for both retainers.
5. The largest deviations are observed in point P1 and point P4.

LITERATURE: