The Study of Tooth Preparation Technique Influence on the Quality of Formed Shoulder, Accuracy of Prosthesis Manufacture, and Condition of Supporting Teeth Parodontium after Prosthetics

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Abstract

Purpose: The purpose is to study the quality of a shoulder, the condition of the supporting teeth paradontium and the accuracy of non-removable metal-ceramic structure manufacture after prosthetics, depending on the preparation technique. **Materials and Methods:** A total of 78 porcelain fused metal crowns were made for 64 patients. The total number of patients was randomly divided into two equivalent groups of 32 people. In the first group (Group A), tooth preparation was performed according to the traditional method. The preparation of teeth in the second group (Group B) was performed using the developed algorithm. The marginal abutment of the crowns was measured after the obtaining of digital photographs with a calibrated microscope. The quality of the shoulder was estimated using the author's technique, which presupposes three-dimensional scanning and color staining of the tooth stump model. Periodontal status was assessed by the amount of gingival fluid measured by the area of filter paper strip impregnation immersed in the gingival sulcus after obtaining the digital photographs. **Results:** The average values obtained for each group were the following ones: The shoulder quality - Group A = 67.27% (standard deviation [SD]: 4.64%) and Group B = 74.96 (SD: 5.83%), fitting accuracy - Group A = 78, 18 μm (SD: 6.83 μm) and Group B = 69.58 μm (SD: 6.83 μm), and the amount of gingival fluid - Group A = 0.621 mm^2 (SD: 0.04 mm^2) and Group B = 0.598 mm^2 (SD: 0.05 mm^2). Pearson's statistical analysis showed a significant difference in shoulder quality and the accuracy of crown fitting in Groups A and B ($P < 0.05$). An insignificant relationship was shown for the criterion of gingival fluid volume in the Groups A and B ($P > 0.05$). **Conclusion:** The use of the developed algorithm of the tooth preparation for permanent orthopedic constructions allows to obtain a statistically significant increase of the shoulder quality and the accuracy of crown fitting in comparison with the traditional preparation method.

Key words: Crevicular fluids, crown margins, gum crest, ledge, marginal fit, sulcus, three-dimensional scanning

INTRODUCTION

Metal-ceramic crowns and bridges remain the most popular type of fixed orthopedic structures.[1] The quality of orthopedic dental treatment is determined by many components, including the accuracy of prosthesis manufacture and the complications due to medical intervention.[2] is the fundamental factor affecting the result of treatment. The level of tooth preparation technical implementation largely determines the esthetic qualities of the manufactured prosthesis, the conditions for prosthesis retention, and the degree of marginal periodontal disease irritation or injury.[3-5] Despite the progress in

dentistry, the problem of qualitative preparation of teeth remains unsolved. This largely explains the significant proportion of complications after orthopedic treatment.[2,6-9] To improve the quality of treatment, it is necessary to focus on quantitative and qualitative assessments. The qualitative manufacture of a dental prosthesis requires an accurate edge fit of crowns, which reduces the accumulation of plaque along the edge of crowns and the risk of secondary caries development, and also has a beneficial effect on the condition of marginal periodontal disease.[10-12]

At present, odontopreparation is the most widely used in Russia according to the national guidelines.[13] Previous studies have shown that clinicians make the deviations from the recommended preparation methodology.[14] In our opinion, the easiest way to influence the quality of treatment with non-removable orthopedic structures is the optimization of tooth preparation. We developed a modified algorithm of tooth preparation for crowns, based on laboratory data. This approach does not require a significant restructuring of the material base and can give an excellent result at low costs.

The purpose of this study was to compare the influence of tooth preparation technique under crowns on the shoulder quality, the accuracy of crown fitting, and the condition of the periodontal supporting teeth. The null hypothesis was that a significant difference in treatment quality will be found depending on the applied tooth preparation algorithm.

MATERIALS AND METHODS

Orthopedic treatment was performed for 64 patients with the pathology of hard tooth tissues. 1–3 metal-ceramic crowns for premolars and molars were made for each patient. The inclusion criteria in the study were the following ones:
- Favorable general health;
- The absence of mucous membrane disease signs in the oral cavity and periodontium;
- Physiological bite;
- First-time or metal-ceramic constructions;

The absence of the need for surgical interventions on the marginal periodontium before prosthetics;·
- The absence of defects in dental curves;
- KPU index is not more than 12 (average caries intensity), pressurized mating adapter index is not more than 20%, and the hygienic index of IG is not more than 2.2 (good and average level of hygiene).

The total volume of patients was arbitrarily divided into two equivalent groups. The preparation of teeth for the patients from the first group was carried out according to the traditional method, using galvanic burs of all necessary shapes and sizes. For the second group of patients, tooth preparation was performed using the developed preparation algorithm [Figure 1].

An essential difference of the proposed algorithm is the use of whole drills for a finishing shoulder processing since they make it possible to achieve the smoothest surface with the roughness of 0.437 μm. Furthermore, it is used a rigid standardization of the applied tool shapes and sizes for marking and an abrasive surface treatment of a stump. The preparation of teeth according to the proposed algorithm is carried out using a specially designed set of drills.[15]

Traditional orthopedic treatment was carried out, including the preparation of teeth, the production of temporary crowns, the making of impressions, the fit of crowns, and the fixation on cement. Temporary crowns were made of "protemp-4" material (3M-ESPE, USA), the working impressions were obtained using "speedex" (Coltene, Swiss) and chemical-mechanical retraction, and the crowns were fixed on the cement "Fuji-1" (GC, Japan). The technical stages of crown making were the same in all cases, and the lost-wax casting technique was used.

The shoulder quality evaluation was performed on a flat image of the prepared tooth (occlusal norm) after the color map change. The test image was obtained as follows:
1. Three-dimensional (3D) scanning of the tooth plaster model was performed;
2. The file with tooth information was sent to the 3D graphic editor;
3. They positioned the 3D model in the editor according to the occlusal rate;
4. They fixed a black and white image of the occlusal norm using the screenshot command;
5. They replaced the color map of the resulting image.

The 3D graphic editor CAD assistant (OPEN CASCADE SAS, France) was used. The replacement of the color map of the received black and white image was carried out by the processing in the graphical editor GIMP2 (ver. 2.8.16, GNOME Foundation, USA), by activating "Palette change" function and the changing of the color gradation "from black to white" to the gradation "from red to green." This color transformation made it possible to visualize the shoulder geometry [Figure 2].

The measurement of the shoulder parameters was performed at eight equidistant control points on the shoulder surface.

The quality of the shoulder was assessed according to six criteria: The presence of a shoulder, an estimate of the shoulder width uniformity, stability of the shoulder geometry, the clarity of the preparation margin, surface defects, and sufficient shoulder width. The coefficients below are determined by the method of expert estimates.

The presence of a shoulder was determined in each of eight control points on the resulting color image of a tooth. To
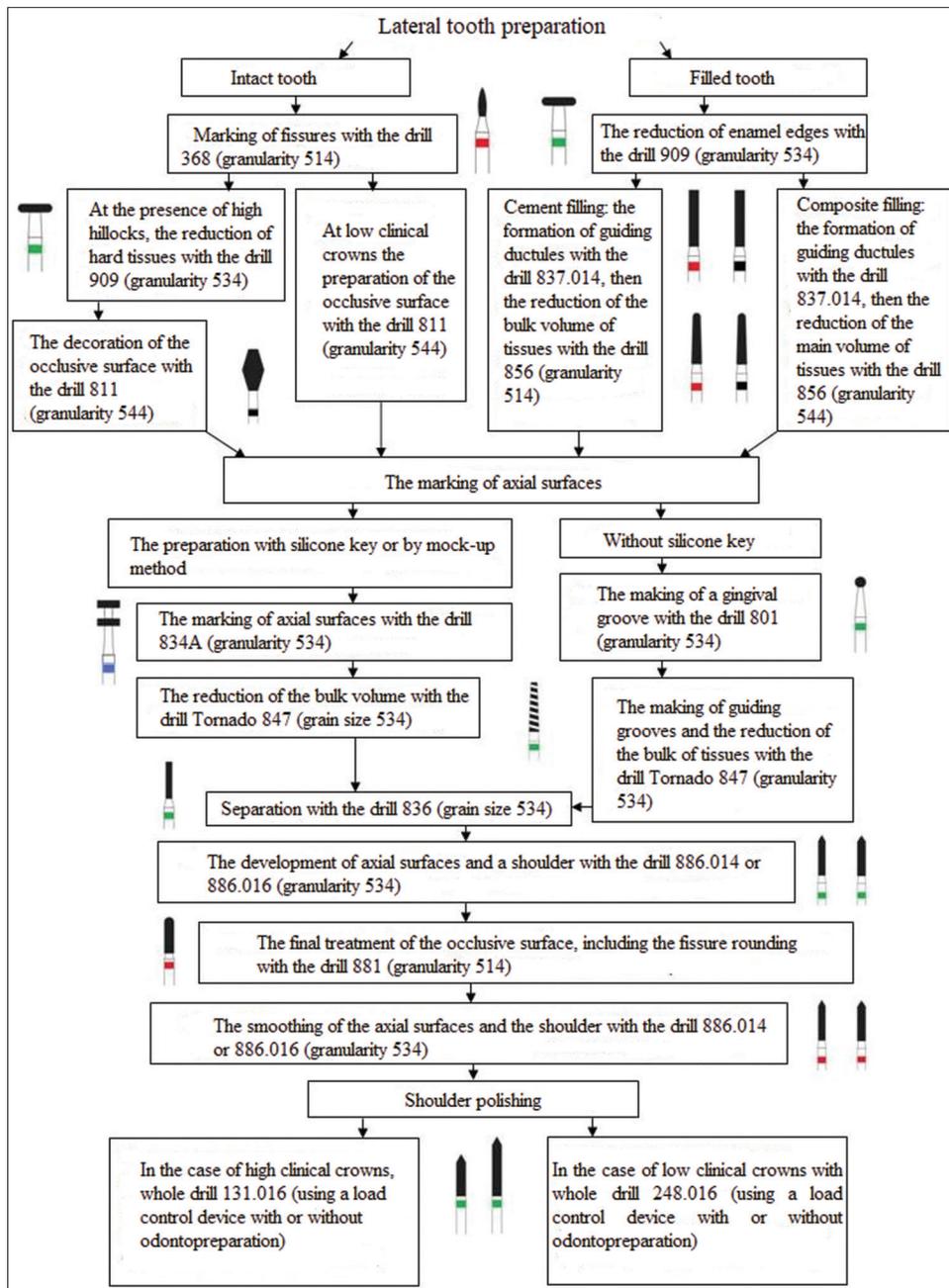
Figure 1: The developed algorithm for a lateral tooth preparation under a crown

obtain an estimate by the criterion "Shoulder presence," the number of points in which the presence of the shoulder was recorded was multiplied by the factor of 3.375.

To evaluate according to the criterion "the uniformity of the shoulder width," the ratio of the maximum-to-minimum shoulder width was calculated. For the evaluation according to the criterion "shoulder geometry stability," the uniformity of the color was evaluated in the shoulder zone on the color image. To evaluate the criterion "preparation boundary sharpness," the ratio of the maximum width of the yellow zone was calculated along the outer contour of the shoulder on the color image to its average width. The numerical value of these estimates was obtained using Table 1.

The criterion "surface defects" was assessed by the presence of contrast zones with smooth, distinct boundaries lying within the boundaries of the shoulder zone on the tooth color image. The tooth without defects was awarded 8 points and 0 points if the defects were present by this criterion.

To evaluate a tooth by the criterion "sufficient shoulder width," the smallest width of the shoulder was measured along eight points of the image. At the result of 0.6 mm and more, the tooth was awarded 7 points, with the values <0.6 mm - 0 points.

The integral score, obtained by adding the estimates according to all listed criteria, can vary from 0 to 100 points. The higher it is, the higher the studied tooth shoulder quality.
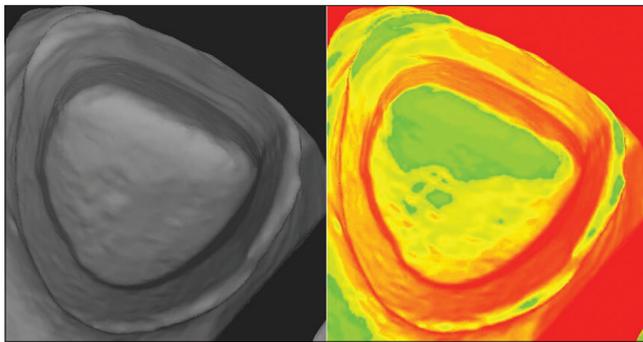
Figure 2: Black and white image of the occlusal norm (left). The color image obtained by the replacement of the color map of the black and white image (on the right)

Table 1: The numerical value of estimates by individual criteria at shoulder quality evaluation

Indicators	Points
The ratio of the maximum width of the shoulder to the minimum one	
1–1.1	12
1.1–1.5	9
1.5–1.9	6
1.9–2.2	3
2.2 and more	0
The description of the shoulder color on the color image	
The shoulder along the entire perimeter is represented by a continuous yellow or green zone	15
The shoulder has 1-2 color transitions of green zones into yellow ones	8
The shoulder is interrupted, has red zones	0
The ratio of the maximum width of the yellow zone to the average width of the shoulder	
0–0.05	31
0.05–0.1	24
0.1–0.15	18
0.15–0.2	12
0.2–0.25	6
0.25 and more	0

A standard method was used to determine the amount of gingival fluid in the area of the supporting teeth (Barer and Lemetskoy, 1980). To obtain the gingival fluid, the standard strips of filter paper (4 mm × 15 mm) with a pointed end were used. The area to be examined was cleared of plaque, isolated with cotton swabs, and dried; then, a strip of filter paper was introduced into the dentogingric groove for 3 min. After the extraction, a strip of filter paper was stained with 0.2% solution of ninhydrin, while the impregnation zone with gingival fluid acquired a blue color.[16] The impregnation area

in square millimeters was measured in the ImageJ2 program (National Institutes of Health, USA) using the photos taken with a ×1000 microscope (GAOSUO, China). 2 mm × 2 mm square marks were applied to filter paper strips for convenience [Figure 3].

If a patient had several crowns, the average value of gingival fluid (KJ) amount was calculated.

The silicone template was used to measure the accuracy of the crown fit. The fitted crown was filled with a correcting mass of A-silicone with a low viscosity and was placed on a supporting tooth. After polymerization, the crown was removed together with the resulting silicone film and was filled with a silicone mass of contrasting color and normal viscosity. Then, the resulting template was removed from the crown and was cut into eight equal parts. After that, the thickness of the silicone film was measured with a graduated digital microscope after the obtaining of digital photographs [Figure 4].

RESULTS

Shoulder quality

The values of the shoulder quality varied from 54.625% to 90%; the mean total in the two groups was 71.11% (standard deviation [SD]: 6.51%). The intergroup comparison using the Chi-square Pearson's test showed a statistically significant difference between Groups A and B ($P = 0.045$).

Fit accuracy measurement. When you perform the measurement of crown making accuracy, it was found that the thickness of the silicone film is in the range of 65.1–113.8 µm. The total average value of the silicone film thickness was 73.88 µm (SD: 7.37 µm). Using the Chi-square Pearson's test, a statistically significant difference was found between Groups A and B ($P = 0.0004$).

Concentrated growth factor (CGF) measurements

According to the selection criteria, the marginal periodontitis of supporting teeth of all patients corresponded to healthy mucosa. The amount of gingival fluid (mean values) before the start of treatment is as follows: Group A = 0.489 mm² (SD: 0.02 mm²) and Group B = 0.505 mm² (SD: 0.02 mm²). 1 month after the fixation of the crowns, the parameter values were determined in the Group A = 0.621 mm² (SD: 0.04 mm²) and Group B = 0.598 mm² (SD: 0.05 mm²). The statistical significance of gingival fluid amount increase compared to the initial one was confirmed by McNemar's test within the Groups A and B ($P = 0.034$ and $P = 0.047$, respectively); there was no statistically significant difference between the groups [Table 2].

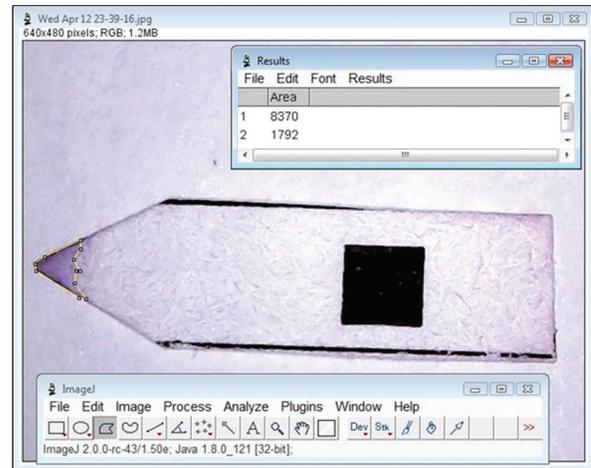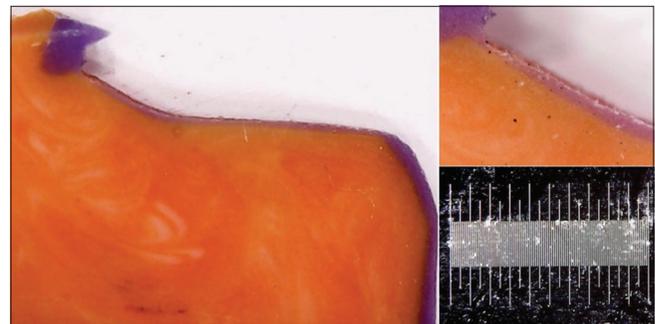| Table 2: The data of shoulder quality measurements, the fit accuracy and CGF in Group A and B		
Indicator	**Group A**	**Group B**
Shoulder quality, %*	Mean 67.27	Mean 74.96
	SD 4.64	SD 5.83
	Minimum 54.625	Minimum 61.625
	Max 70	Max 90
Silicone film thickness, µm*	Mean 78.18	Mean 69.58
	SD 6.83	SD 5.06
	Minimum 72.8	Minimum 65.1
	Maximum 113.8	Maximum 90.5
CGF, mm^2	Before treatment	
	Mean 0.489	Mean 0.505
	SD 0.02	SD 0.02
	Minimum 0.402	Minimum 0.394
	Maximum 0.52	Maximum 0.535
	1 month after fixation**	
	Mean 0.621	Mean 0.598
	SD 0.04	SD 0.05
	Minimum 0.558	Minimum 0.505
	Maximum 0.734	Maximum 0.74

*The difference between Group A and B with the significance level of $P<0.05$. **The difference within the Group A and B at different stages of treatment with the significance level $P<0.05$. SD: Standard deviation, CGF: Concentrated growth factor

Figure 3: ImageJ2 working window (explanation in the text)

Figure 4: Microphotography of the silicone model cut (explanatifgcon in the text)

DISCUSSION

The purpose of this study was to evaluate the effect of the preparation technique on the outcome of orthopedic treatment with non-removable denture designs. The results of the study confirmed the null hypothesis that there is a significant difference in the shoulder quality and the marginal fit of the crowns between the experimental groups of patients. The significance of the tooth preparation algorithm for crowns was demonstrated convincingly.

The preparation of teeth with various techniques has a statistically significant effect on the shoulder quality and the marginal fit of crowns ($P < 0.05$). Previous studies show that the marginal fit of the crowns is influenced by many facts, including the size of teeth.[10] This was the reason for the selection of patients with lateral teeth. The mean accuracy of fit, obtained during the study in Groups A and B, corresponds to generally accepted acceptable values.[17] At the same time, a significant reduction of the cement film thickness in Group B indicates a greater accuracy in the manufacture of crowns. This fact will contribute to the manufacture of esthetic structures, the reduction of plaque accumulation of at the crown/root boundary, the prevention of caries, and complications from the marginal periodontium. Using the technique of shoulder quality evaluation, regular changes in tooth preparation quality were revealed successfully with the use of the developed preparation algorithm.

For CGF measurements, there was no statistically significant difference between two patient groups ($P > 0.05$) in our study although the mean values in Group A were higher than in Group B. A more significant increase of CGF in Group A after prosthetics indicates a gentler attitude to the tissues of marginal parodontium if we use the developed preparation algorithm.

The main limitation of this study is that only molars and premolars were examined. The application of a new technique for a shoulder quality evaluation can be regarded as a limitation. Furthermore, it should be noted that obtaining results in the long term after the prosthesis was not the part of the research task.

CONCLUSION

Thus, taking into account the limitations of this study, the best indices of marginal fit and the shoulder quality were found in Group B. Both considered preparation methods provide acceptable results and can be applied in practice. At the same time, due to the more sparing attitude toward

marginal periodontium, a higher preparation quality, and crown fit accuracy, the developed preparation algorithm can be recommended for single metal-ceramic crowns.

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