

Article

Influence of the Operator's Experience, Working Time, and Working Position on the Quality of the Margin Width: In Vitro Study

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Abstract: *Background and Objectives:* Appropriate tooth preparation is mandatory to obtain a perfect marginal fit of fixed restorations. The heavy chamfer is the most commonly used finish line, especially for minimally invasive tooth preparation. The aim of the study was to compare the width of the finish line obtained during tooth preparation performed by experienced (university lecturers) and inexperienced persons (dental students) in different working times and positions. *Materials and Methods:* Forty left upper-second molars were prepared on the simulator by each participant, totaling 160 prepared teeth. A new round-end tapered diamond was used to obtain the 0.5 mm width of the heavy chamfer. The prepared teeth were photographed using a Canon D5300 camera with a macro lens attached to a tripod. The measurements were made with the Image-Pro Insight software selecting the same eight reference points. From these points, perpendicular lines were drawn above the finish line to the axial walls and the distance between the chamfer's outer edge and the axial wall's inner edge was measured. GraphPad Instat and NCSS Dowson Edition software were used. The statistical significance was set at $p < 0.05$. The mean (M) and standard deviation (SD) were calculated. The used tests: one sample t-test, ANOVA test, and Tukey–Kramer Multiple Comparisons Test. *Results:* Statistically significant differences were obtained according to the experience of the participant, preparation time, patient's position, and the chamfer width on the prepared tooth different surfaces. *Conclusions:* Daytime or weeklong tiredness and patient position do not affect the width of the heavy chamfer prepared by experienced and inexperienced persons. The experience and the operator's working position influence the width of the prepared finish line.



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Keywords: heavy chamfer; tooth preparation; prosthodontics

1. Introduction

Proper tooth preparation is mandatory for the perfect marginal fit of fixed restorations. Inadequate preparation seems responsible for early failures such as caries, endodontic and periodontal complications [1]. This is due to the accumulation of the bacterial plaque at the microscopic opening at margins of the crowns [2]. The accuracy of clinical procedures during the tooth preparation and the manufacturing techniques of the restorations can condition the dimension of the marginal gap [3]. According to McLean and Von Fraunhofer, the clinically acceptable marginal gap is under 120 µm [4]. Aminian and Brunton have developed indications about the finish line preparation to avoid stress, improve the aesthetics, minimize the surface roughness, and eliminate the stress zones at this level [5]. The chamfer and the heavy chamfer have different indications; the recommended finish line for metal crowns is chamfer, for full ceramic crowns is heavy chamfer [6,7]. No scientific studies approve that the chamfer finish line is better than other finish lines [8]. For aesthetic ceramic

restorations, the performed preparation should be minimally invasive. A ceramic thickness of at least 0.5 mm and preparation without exposing dentine are advantageous for adhesive cementation [9,10]. Enamel thickness varies at the different levels of teeth's clinical crown surface: 0.3–0.5 mm cervical, 0.6–1 mm in the middle third, and 1.0–2.1 mm in the incisal third [11], and the minimally invasive preparations must be performed respecting these standards.

The study aimed to compare the width of the heavy chamfer prepared by experienced and inexperienced persons at different working times (different days of the week, various stages of the day) and the patient's position (sitting and supine position).

Hypothesis: Daytime or weeklong tiredness and patient position do not affect the width of the chamfer prepared by experienced or inexperienced persons. There are no statistically significant differences between the width of the finish line and half the diameter of the diamond bur used for its preparation.

2. Materials and Methods

Two dental students from last year, t1 (female) and t2 (male), and two university lecturers from the University of Medicine and Pharmacy Targu Mures G. E. Palade, Faculty of Dental Medicine, Department of Fixed Prosthodontics, T1 and T2 (females), performed the preparations. Student t1 was trained by lecturer T1, and student t2 was trained by lecturer T2. The two instructors did the theoretical training of the participants following the same rules regarding the principles of tooth preparation with a heavy chamfer finish line. The participants learned about the techniques and instruments used during the preparation sessions and the ergonomic working positions for the sitting and supine patient positions. The practical training was carried out over a week. On the first and second days of the practical training, the students prepared an upper left second molar in the sitting position of the patient, similar to a study conducted by Won et al. [12], in which the preparations were performed on upper left premolars and upper left second molars in a random position and home position with ergonomically stable posture. T1 and t2 learned how to: prepare the occlusal surface morphologically by placing orientation grooves; avoid undercuts by maintaining the diamond bur parallel to the tooth axis; obtain a minimal taper close to 6°; to place equigingival the finish line. They prepared another molar in the supine patient position in the following two days. The preparations were conducted in both patient positions on the last training day. Each participant performed the tooth preparations with high-speed handpieces.

The sample size was calculated based on the standard deviation (SD) and mean (M) from a similar study by Lee and Choi [13] using a web-based sample size calculator. In their study [13], a total of one hundred prepared teeth by five operators were assessed regarding the chamfer width. Parameters: SD was 0.0908, M was 0.6283, the alpha level was set at 0.05, and the power of the test was set at 0.8. Based on the parameters, an estimated sample size of 58 teeth was obtained. An average value of the number of teeth prepared during one week of clinical activity of the two experienced persons was calculated, resulting 38 prepared teeth. Dividing the obtained value by working days resulted in eight prepared teeth/day/operator.

The desired finish line for the preparations was the equigingival heavy chamfer, which is used currently for minimally invasive preparations in the case of ceramic restorations. The preparation depth was adjusted to the minimum wall thickness of the ceramics in the lateral area (0.5 mm) [11]. According to Kasem et al. and Nakamura et al., the 0.5 mm margin width can be considered the ideal conservative thickness for zirconia and zirconia-reinforced glass-ceramic systems. Their recorded fracture resistance values of these crowns were superior to the maximum mastication force of humans (850 N) [14,15].

The artificial teeth were fixed in standardized positions in Planmeca simulators (Planmeca Oy, Helsinki, Finland) in the Simulation Center of the University of Medicine and Pharmacy Targu Mures G. E. Palade, Faculty of Dental Medicine. All the participants in this study prepared four teeth with the patient in a sitting position and four in a supine

position every day of the week at the same time: Monday morning, Tuesday evening, Wednesday morning, Thursday evening, and Friday morning. A total number of 160 teeth were prepared. The preparations were performed from the operators sitting positions, in the 9–11 o'clock area according to ISO Standard 11226: "Ergonomics-Evaluation of static working postures".

A new round-end tapered 016 diamond with a standard 3° taper was used to perform the preparations and obtain the 0.5 mm width of the heavy chamfer finish line. The active end of the diamond had a diameter of 1.1 mm. Each diamond bur was only used for one preparation. Only one half the diameter of the diamond bur was used to prepare the chamfer's proper width to prevent unsupported enamel being left at the margins. Precise control and correct orientation of the diamond bur are mandatory to obtain the desired shape and width of the finish line and the proper taper. For this purpose, the diamond bur was maintained parallel to the tooth axis as well. Tilting away from the tooth will create undercuts (opposing axial preparation walls will diverge in an occlusal direction), and tilting towards the tooth will result in an excessive convergence angle of the preparation.

The prepared teeth were removed and labeled after each preparation. They were divided into groups based on the operator, the working time, and patient position (sitting and supine). New unprepared teeth were positioned into the same spots. After every participant finished, the preparations and the casts supporting the artificial teeth were removed from the simulators. A cast with an unprepared second upper molar was placed on a survey table. The adjacent teeth (first upper molar and third upper molar) were removed from the cast. The prosthetic equator was marked with a black pencil at the maximum convexity of the tooth. The survey table was adjusted until the black line was visible from the occlusal view on the axial surfaces (Figure 1a). The survey table position was recorded as the reference position. The unprepared molar with the black line was removed from the cast. All the prepared teeth were placed in the reference position (the spot of the marked unprepared molar) and photographed twice using a Canon D5300 camera with a macro lens attached to a tripod. A ruler was placed parallel to the survey table, at the cervical area of the prepared tooth, at the same level as the finish line to calibrate the digital measurements (Figure 1b).

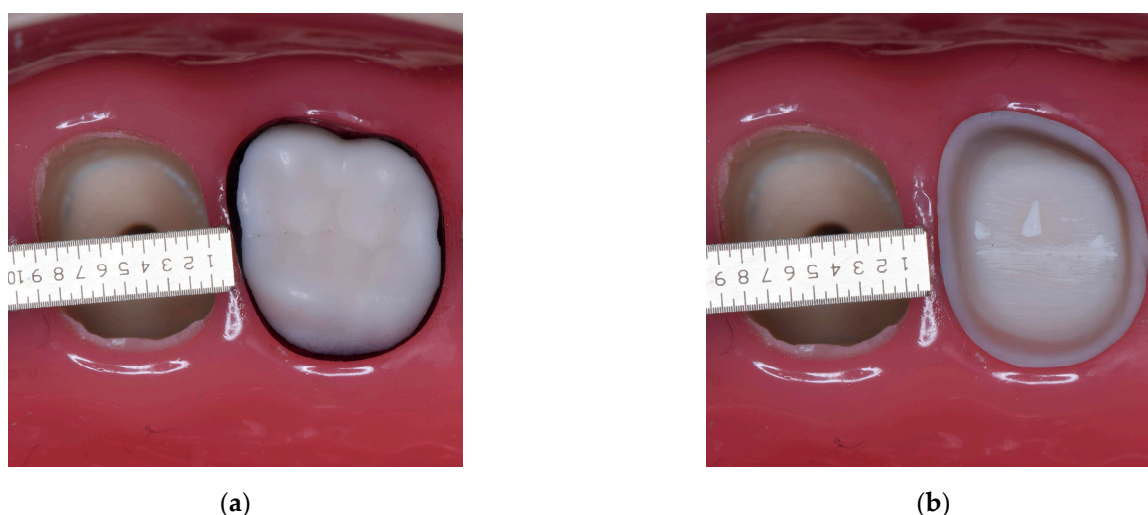


Figure 1. The upper second molar on the cast (a) The prosthetic equator, marked with a black pencil; (b) The calibration of the digital measurements.

The photographs were selected and imported in the Image-Pro Insight software which was used for the measurements.

Eight reference points were selected (Figure 2a), and from these points perpendicular lines were drawn above the finish line to the axial walls. The distances between the

chamfer's outer edge and the axial wall's inner edge were measured (Figure 2b) three times for each preparation by the same operator.



Figure 2. The measurements with the Image-Pro Insight software: (a) The eight reference points; (b) Measurements of the width of the chamfer at the reference points.

For statistical analysis of the data, GraphPad Instat and NCSS Dowson Edition software were used. The statistical significance was set at $p < 0.05$. The mean (M) and standard deviation (SD) were calculated. The used tests: one sample t-test, ANOVA test, and Tukey–Kramer Multiple Comparisons Test.

In a pilot study, the axial wall's convergence was examined [16], considering the first preparations of each operator/day/patient position. The obtained values were considerably higher than the ideal values in the literature. Furthermore, the study concluded that the total convergence of the axial wall is independent of the operators' experience or education level.

3. Results

The mean values (M) of the width of the daily prepared heavy chamfer and the standard deviation (SD) are represented in Table 1.

Table 1. Descriptive statistics of the obtained values.

		Position	Mean	Standard Deviation	Minimum	Maximum
1 Day	t 1	Sitting	0.4175	0.1062006	0.3000	0.6000
		Supine	0.4375	0.1410927	0.2500	0.6600
	T 1	Sitting	0.57625	9.999107E-02	0.4400	0.7000
		Supine	0.565	0.1393864	0.3200	0.7300
	t 2	Sitting	0.765	0.2173214	0.4000	0.9700
		Supine	0.90875	0.3267344	0.5000	1.550
	T 2	Sitting	0.6625	0.1263499	0.5500	0.8400
		Supine	0.6675	8.172253E-02	0.5200	0.8100
2 Day	t 1	Sitting	0.4675	8.972179E-02	0.3600	0.5800
		Supine	0.41125	0.1664278	0.1500	0.6400
	T 1	Sitting	0.6175	0.2141928	0.3200	0.9400
		Supine	0.63625	0.1340509	0.4200	0.8000
	t 2	Sitting	0.68125	0.2269322	0.3500	0.9700
		Supine	0.745	0.3009034	0.3100	1.200
	T 2	Sitting	0.7025	0.1248714	0.4800	0.8700
		Supine	0.78375	0.1863896	0.4300	0.9600

Table 1. Cont.

		Position	Mean	Standard Deviation	Minimum	Maximum
3 Day	t 1	Sitting	0.425	0.155747	0.2500	0.7000
		Supine	0.495	0.1247855	0.3400	0.6900
	T 1	Sitting	0.50125	0.1341042	0.2600	0.6500
		Supine	0.5225	0.1492601	0.2300	0.6800
	t 2	Sitting	0.83625	0.277434	0.3500	1.210
		Supine	0.855	0.2514529	0.5300	1.240
	T 2	Sitting	0.8825	0.1805349	0.6000	1.170
		Supine	0.79375	0.1204678	0.6200	0.9400
4 Day	t 1	Sitting	0.46625	0.1100568	0.2400	0.5800
		Supine	0.385	0.1404076	0.1200	0.5200
	T 1	Sitting	0.65875	0.1582437	0.4300	0.9800
		Supine	0.525	7.111359E-02	0.4600	0.6600
	t 2	Sitting	0.81	0.2532644	0.5300	1.310
		Supine	1.09	0.2751104	0.7800	1.500
	T 2	Sitting	0.89875	0.1462324	0.7200	1.170
		Supine	0.725	0.1457983	0.5000	0.9200
5 Day	t 1	Sitting	0.52125	0.2118246	0.1900	0.7900
		Supine	0.48125	0.1988134	0.1500	0.7600
	T 1	Sitting	0.5375	0.1239528	0.4100	0.7800
		Supine	0.45875	0.122991	0.3100	0.6800
	t 2	Sitting	0.83125	0.2511367	0.5300	1.220
		Supine	0.8825	0.3702027	0.4100	1.550
	T 2	Sitting	0.94625	0.2178425	0.3100	0.6800
		Supine	0.9	0.2200649	0.5700	1.210

The values obtained at the reference points by each participant in sitting and supine patient positions and workdays are represented in Figures 3–7.

The mean values of the width of the chamfer prepared by all participants during the week are represented in Table 2.

Table 2. Mean values of the width of the prepared chamfer.

Participants	Width of the Chamfer (Mean Values)	Differences
t 1	0.450000	-
t 2	0.840500	+
T 1	0.559125	+
T 2	0.79625	+

The ANOVA test, $p < 0.0001$, showed an extremely significant variation among column means. The statistically significant results obtained by applying the Tukey–Kramer multiple comparison test are represented in Table 3.

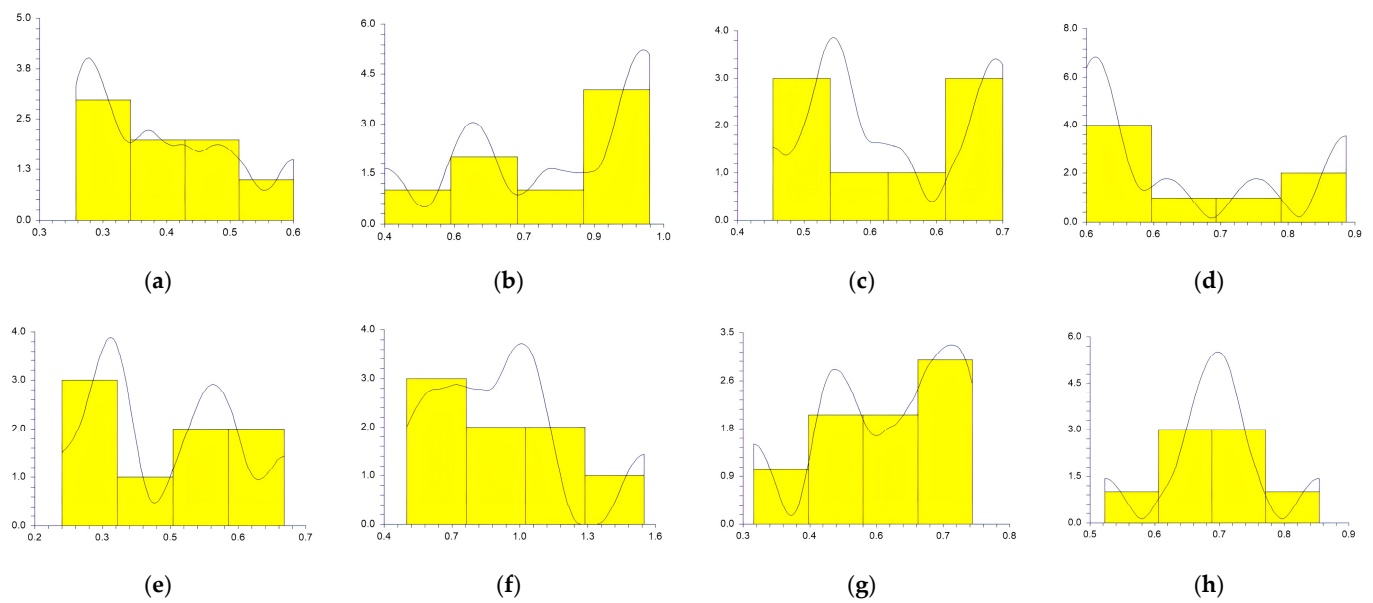


Figure 3. The chamfer width obtained at the reference points by all the participants Monday: (a) t1 sitting position; (b) t2 sitting position; (c) T1 sitting position; (d) T2 sitting position; (e) t1 supine position; (f) t2 supine position; (g) T1 supine position; (h) and T2 supine position.

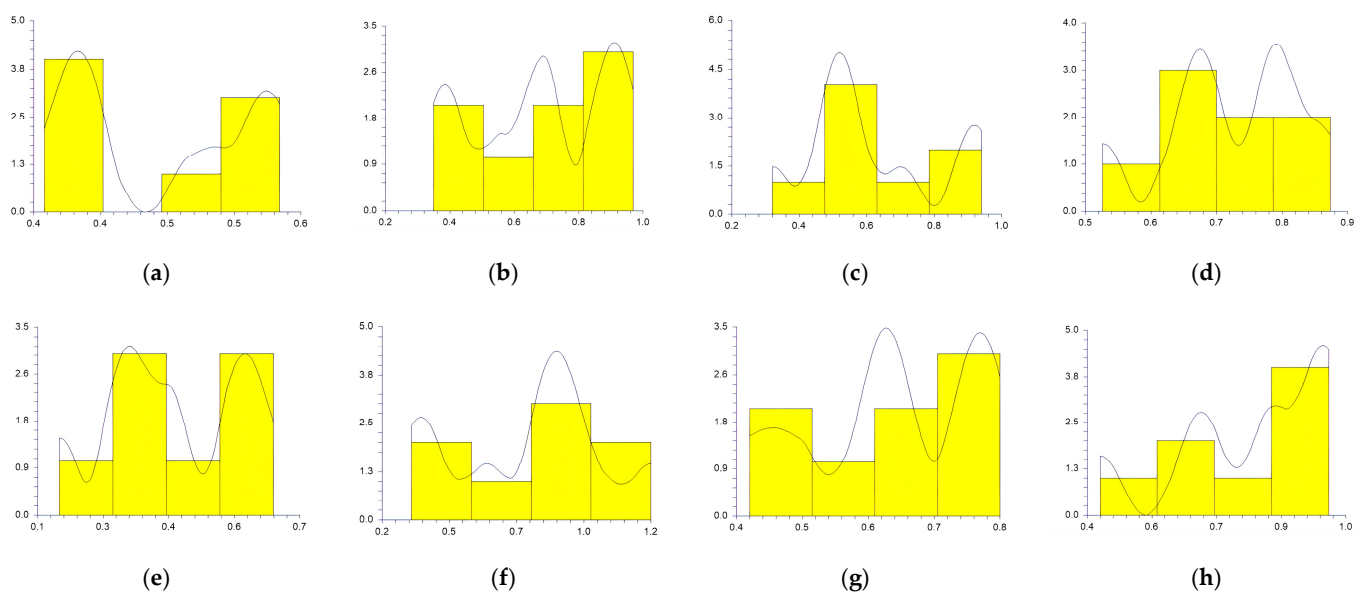


Figure 4. The chamfer width obtained at the reference points by all the participants Tuesday: (a) t1 sitting position; (b) t2 sitting position; (c) T1 sitting position; (d) T2 sitting position; (e) t1 supine position; (f) t2 supine position; (g) T1 supine position; (h) and T2 supine position.

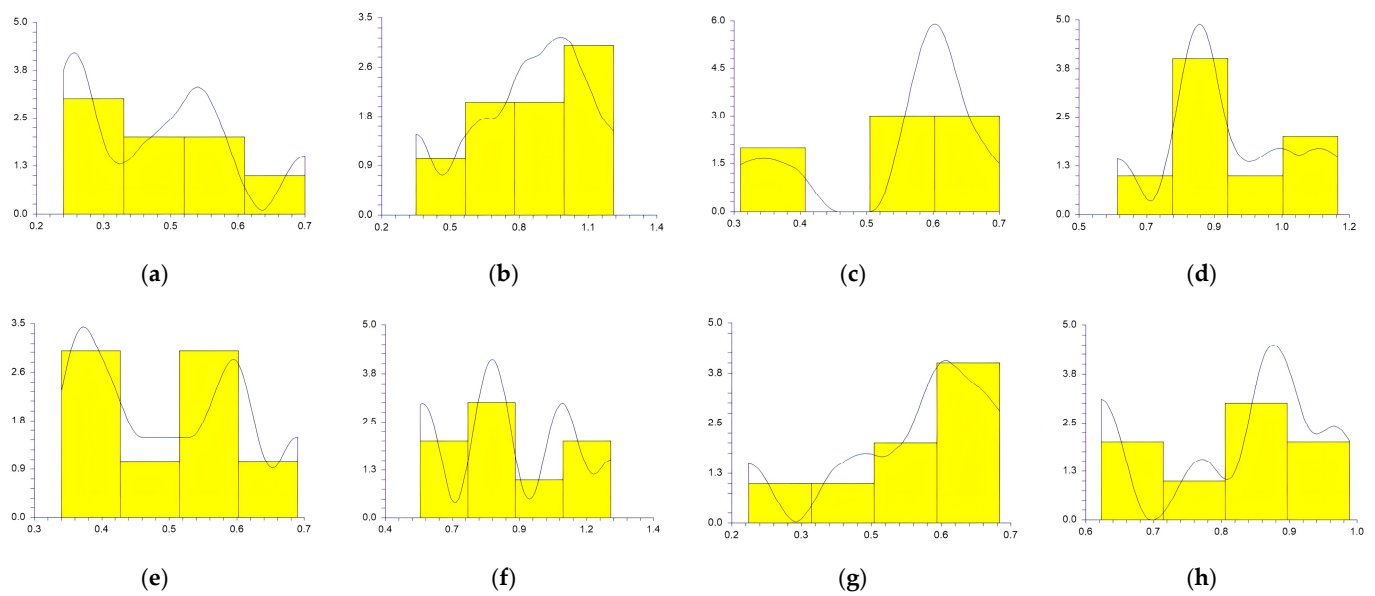


Figure 5. The chamfer width obtained at the reference points by all the participants Wednesday: (a) t1 sitting position; (b) t2 sitting position; (c) T1 sitting position; (d) T2 sitting position; (e) t1 supine position; (f) t2 supine position; (g) T1 supine position; (h) and T2 supine position.

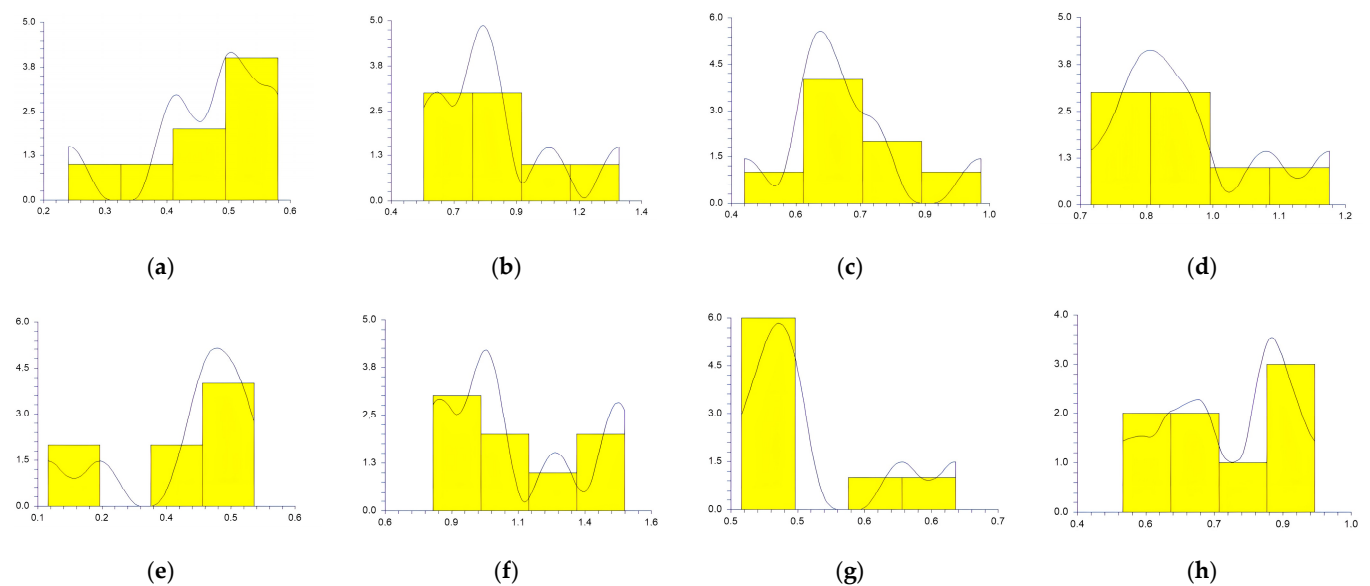


Figure 6. The chamfer width obtained at the reference points by all the participants Thursday: (a) t1 sitting position; (b) t2 sitting position; (c) T1 sitting position; (d) T2 sitting position; (e) t1 supine position; (f) t2 supine position; (g) T1 supine position; (h) and T2 supine position.

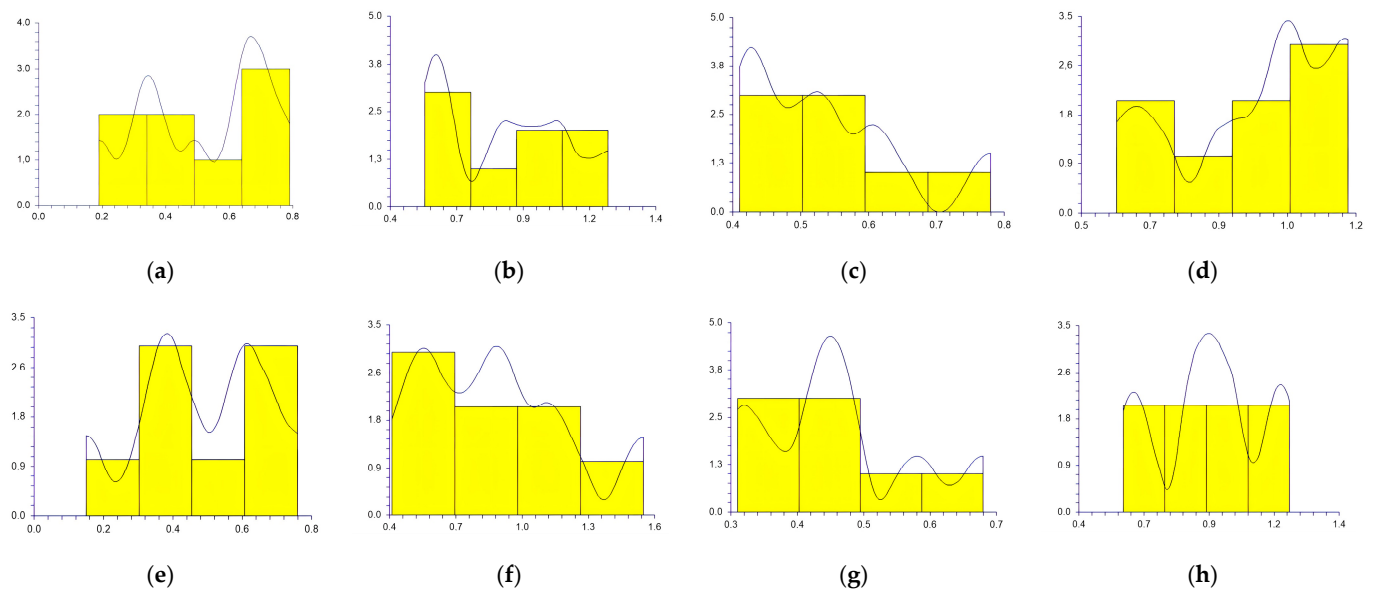


Figure 7. The chamfer width obtained at the reference points by all the participants Friday: (a) t1 sitting position; (b) t2 sitting position; (c) T1 sitting position; (d) T2 sitting position; (e) t1 supine position; (f) t2 supine position; (g) T1 supine position; (h) and T2 supine position.

Table 3. Tukey–Kramer multiple comparison test—extremely significant differences.

Day	Operator	Position	Operator	Position	Difference
1	t 1	Sitting	t 2	Supine	−0.4913 ***
	t 1	Supine	t 2	Supine	−0.4713 **
3	t 1	Sitting	T 2	Sitting	−0.4575 **
	t 1	Sitting	t 2	Supine	−0.4300 **
	t 1	Sitting	t 2	Sitting	−0.4113 *
	T 1	Sitting	T 2	Sitting	−0.3813 *
	t 1	Supine	T 2	Sitting	−0.3875 *
	t 1	Sitting	t 2	Supine	−0.6238 ***
4	t 1	Supine	T 2	Sitting	−0.5138 ***
	t 1	Supine	t 2	Supine	−0.7050 ***
	T 1	Supine	t 2	Supine	−0.5650 ***
	t 1	Sitting	T 2	Sitting	−0.4325 **
	t 1	Supine	t 2	Sitting	−0.4250 **
	T 1	Sitting	t 2F	Supine	−0.4313 **
	t 1	Sitting	T 2	Sitting	−0.4250 **
5	t 1	Sitting	T 2	Supine	−0.3788 *
	t 1	Supine	T 2	Sitting	−0.4650 **
	t 1	Supine	T 2	Supine	−0.4188 *
	t 1	Supine	t 2	Supine	−0.4013 *
	T 1	Sitting	T 2	Sitting	−0.4088 *
	T 1	Supine	T 2	Sitting	−0.4875 ***
	T 1	Supine	T 2	Supine	−0.4413 **
	T1	Supine	t 2	Supine	−0.4238 **

*** extremely significant, ** very significant, * significant.

Tukey–Kramer multiple comparison test revealed that the results obtained by the t1 on the first day are statistically different from most of those obtained by the T2 and t2 on the third, fourth, and fifth day. The same result was obtained for the t1 for the second, third, fourth, and fifth day. Regardless of the day and working position, the results obtained by the T1 are statistically different from those obtained by the t2. The supine working position results obtained by the T1 are statistically different from those obtained by the T2 in the sitting working position. Regarding the working positions, the results obtained by each study participant showed no statistical difference between sitting and supine positions.

Concerning the difference between the width of the chamfer finish line and the size of half of the diameter of the diamond used (0.5 mm), the one-sample t-test was applied. The results are presented in Table 4.

Table 4. One-sample *t*-test results.

Day	Position	Operator	<i>p</i> Value
1	Sitting	t1	0.063994
		t2	0.010706
		T1	0.067921
		T2	0.008313
	Supine	t1	0.250468
		t2	0.009490
		T1	0.228685
		T2	0.000665
2	Sitting	t1	0.339675
		t2	0.058413
		T1	0.164699
		T2	0.002523
	Supine	t1	0.175214
		t2	0.054753
		T1	0.023827
		T2	0.003541
3	Sitting	t1	0.215394
		t2	0.011014
		T1	0.979703
		T2	0.000546
	Supine	t1	0.912950
		t2	0.005235
		T1	0.682645
		T2	0.000232
4	Sitting	t1	0.414484
		t2	0.010518
		T1	0.025135
		T2	0.000115

Table 4. Cont.

Day	Position	Operator	p Value
5	Supine	t1	0.053662
		t2	0.000508
		T1	0.353181
		T2	0.003294
	Sitting	t1	0.784815
		t2	0.007352
		T1	0.420487
		T2	0.000668
	Supine	t1	0.797351
		t2	0.022264
		T1	0.374402
		T2	0.001337

4. Discussion

Practitioners' preferred method for tooth preparation margin design is the chamfer or heavy chamfer finish line [17,18]. It offers optimal marginal bulk for the restorations. Sadid-Zadeh et al. evaluated 392 STL files of posterior preparations for monolithic zirconia crowns and 82% presented a chamfer finish line [19]. In a research conducted by Shankar et al., 84% of 100 laboratory casts prepared for anterior all-ceramic crowns presented a radial shoulder finish line [20].

The fracture resistance of all-ceramic restorations, especially in the case of posterior crowns is a controversial topic in the research literature. According to Camille Haddad and Kathy Azzi, the marginal design of the abutment significantly affects the resistance of these aesthetic restorations [21]. Beuer et al. reported that the shoulder margin provided a higher fracture resistance than the deep chamfer and chamfer margins [22]. Sadan et al., in their study, found that both shoulder and chamfer finish lines are adequate for densely sintered alumina and zirconia restorations [23]. According to Alzahrani et al., the heavy chamfer margin could increase the breaking load of monolithic zirconia crowns [24].

Comparing the chamfer and the heavy chamfer finish line, Jalalian et al. demonstrated a higher fracture resistance for the heavy chamfer margins than the chamfer margins. The heavy chamfer finish line is recommended for posterior aesthetic restorations since it improves the biomechanical performance of posterior single zirconia crowns [25]. In an article-type review performed by Camille Haddad and Kathy Azzi, the conclusions showed that the monolithic zirconia crowns with knife-edge margins displayed superior fracture resistance at maximum occlusal forces compared to other types of finish lines [21].

For tooth preparation with a chamfer/heavy chamfer finish line the torpedo diamond, the round-end tapered diamond and the round-end taper with guide pin diamond can be used. The selection of a specific diamond bur is not scientifically supported [26]. According to Hooper, the most frequently used diamond bur in dental education is the torpedo-shaped diamond [27]. Boening et al. [28] and Mansueto et al. [29] demonstrated that it was much easier for dental students to prepare the finish line with round-end diamond burs than the torpedo diamond burs. In a study conducted by Măroiu et al., they used cylindrical shape diamond burs and rounded-tip Arkansas stones to prepare the tooth for ceramics [30]. Siegel and von Fraunhofer demonstrated that the efficiency of the rotary instruments is conditioned by the amount of dentinal debris on the diamond surface resulting from the tooth preparation [31]. Repeated use of rotary cutting instruments decreases their cutting efficiency [32]. For this reason, in our study a new round-end tapered diamond bur was

used for each molar preparation contradicting Seymour's results which highlighted that using new diamond bur will result in a wider finish line [1].

In a study conducted by SG Mihali et al., using minimal invasive preparation is essential in adhesive dentistry. The authors observed no failures for veneers with a maximum thickness of 0.5 mm [33]. Rammersberg et al. showed that a minimally invasive 0.5 mm width of the chamfer would result in good stability for posterior metal-free Artglass crowns cemented by adhesive technique [34]. According to Pan et al., for deciduous tooth preparation, a 0.4–0.6 mm shoulder and chamfer finish lines are recommended to ensure material strength and preserve the restoration's marginal integrity [35]. Our results show wide variations regarding the obtained width of the heavy chamfer (Table 1, Figures 3–7). The T1 participant approached the ideal width on the third working day in the sitting position of the patient (0.50125 mm) (Table 1). Considering the mean values obtained by all the participants in the study, the determined 0.5 mm value was best approximated by the t1 participant (0.45 mm), followed by the values of T1, T2, and t2 (Table 2). The values achieved by the t1 participant are less than 0.5 mm for most preparations (Table 1 and Figures 3–7) contradicting the minimum necessary width for preventing the fracture of posterior zirconia crowns [17,18]. The two experienced participants, T1 and T2, obtained the most stable values (Figures 3–7) due to their higher experience levels. Extremely significant differences can be found in the results obtained by T1 and T2 in different patient positions (Table 3). The finish lines prepared by the T2 participant are considerably wider than those prepared by the T1 person for each preparation regardless of the day and working position. The students obtained similar results to their instructors; t1 prepared less invasive than t2 (Table 1, Figures 3–7). A study was performed by examining STL (Standard Tessellation Language) files of dental students from the records of the tooth preparations for metal-ceramic crowns. It was observed that the majority of the finish line's width was between 0.5 and 1 mm, the maximum was approximately 2 mm and the minimum was 0 mm [36]. The present study's results are similar, as observed in Table 1.

Siegel and von Fraunhofer demonstrated in the case study [31] that most dental practitioners prefer to remove the tooth structure in excess during the preparation of the tooth. Our specialists (T1, T2) removed more dental tissues than 0.5 mm (Table 2, Figures 3–7). A minimum thickness of 0.5 mm is essential to prevent warpage of zirconia restorations [37]. Hey et al., in their study, found that most of the inexperienced participants removed too much rather than too little tooth structure [38], as in the case of t2.

Diamond burs with rounded ends and inactive guide pins allow a more suitable preparation at the margins without increasing the risk of hard tissue damage or other mechanical or thermal side effects [28]. According to Xiaoxiang Xu et al. [39], standardized practical training can improve dental students tooth preparation skills. Individual training must be conducted based on different tooth, patient, and bur positions. Improvement in the dental students' performance was observed in another study, in which the preparations were performed with used diamond burs [29].

In the present study, it was demonstrated that the working position does not influence the quality of the tooth preparation. These results agree with In-Jae Won et al., which concluded in a study conducted in 2011 that the working position does not influence the marginal width of the preparation [12]. Lee and Choi obtained different results. They demonstrated that the removed tooth structure at the margins is higher in the random operator position than in ergonomic position [13].

According to LeBlanc, virtual training and in vitro preparations are viable methods of developing dental practitioners' skills [40]. In disagreement, in a study by Stoilov et al., it was observed that students using digital assessment tools had significant problems recognizing and correcting their preparation deficiencies [41]. Haptic and traditional simulators could be used equally to train dental students in acquiring skills and understanding relevant concepts about tooth preparation [42].

Digital technology [43,44] and the use of magnification [45] can be helpful not only in minimal tooth preparation, but also in achieving the proper postures according to the

principles of ergonomics [46]. Carpentier et al. and Aldosari concluded that magnification significantly improves the posture but not the quality of tooth preparation [47,48]. In contrast, Eichenberger et al. showed that magnification devices improved the precision of tooth preparation in a simulated clinical condition. Very significant differences were noted when a microscope was used for the tooth preparation followed by preparation using loupes; precision was lowest without magnification aids, with prescription glasses if needed ($p < 0.0001$) for both indirect and direct vision ($p < 0.05$) [45].

Combining digital and traditional education and evaluation methods are essential for effective dental education and highly quoted preparation activity. Traditional methods do not allow an objective evaluation of the quality of tooth preparation. Therefore, implementing digital techniques is mandatory in preclinical and clinical education [49]. Using simulators and magnification in preclinical training improves the achievement of ergonomic positions. Intraoral scanners allow for objective evaluation, self-evaluation, and their use to improve the quality of future restorations.

The most common investigative methods available to practitioners [30] for evaluation require further investigations using magnification, digital scanners, and optical microscopy. The expansion of the number of participants and the variety of the prepared teeth is also the subject of future research concerning the limits of the minimally invasive preparation for CAD/CAM technologies.

Limitations of our study:

- In vivo conditions could not be reproduced perfectly. Even the best simulators cannot reproduce the intraoral conditions perfectly (visibility, muscle and tongue tonicity, saliva, and the patient's movements).
- The low number of participants—a higher number could give different results depending on skill and experience.
- The use of one type of tooth for the preparation—different types of teeth from different regions could lead to different results and improve the complexity of the study.
- Subjective human assessment of the measurements. Using total digital working methods (scanning and digital analysis) can improve the accuracy of the measurements.

5. Conclusions

Within the limitations of this in vitro study we can conclude that daytime or week-long tiredness and patient position do not affect the width of the chamfer prepared by experienced and inexperienced persons.

The experience and the operator's working position influence the width of the finish line. The preparation depth can be conditioned by the methodology of the instruction (work position), and the instructor's work style.

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Case Report

Full-Mouth Rehabilitation of a Patient with Gummy Smile—Multidisciplinary Approach: Case Report

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Abstract: The impairment of aesthetic function leads to a decreased quality of life. An unaesthetic smile due to excessive gingival exposure demands, most of the time, a complex treatment in which the objective is the vertical reduction of the amount of exposed fixed gingiva by obtaining a complete exposure of the anatomical crown of the teeth and restoring the ideal dimensions of the biological width. This paper presents a case of a 48-year-old female patient who was unsatisfied with her aesthetics and had disturbed masticatory function due to the absence of some posterior teeth. The cone beam computed tomography was performed to evaluate the facial and dental morphology. The treatment plan included diode laser and piezo-surgery utilization for the frontal area of the upper arch and implants to restore the distal area of the lower and upper arch. Zirconia ceramic was used for the final restorations. This complex and multidisciplinary full-mouth rehabilitation lasted for two years, and the patient was pleased with the result. This case showed that a well-established treatment plan is necessary to obtain long-lasting results. The use of adequate procedures and equipment ensures a predictable result.

Keywords: oral rehabilitation; laser-assisted crown-lengthening; piezo-surgery; implants; zirconia ceramics



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1. Introduction

Inadequate facial aesthetics due to an unaesthetic smile, especially in the case of a gummy smile, with a high smile line, can harm patients' quality of life, even leading to psychological problems in some cases [1]. The American Academy of Periodontology (AAP) defines the gummy smile as a deformity and mucogingival condition that affects the area around the teeth [2]. The excessive gingival display is characterized by overexposure of the maxillary gingiva during smiling or speaking [3]. According to Allen, gum exposure of less than 2–3 mm can be considered attractive. An overexposure of more than three mm is known as the gummy smile [4] and is generally considered an aesthetic problem [5]. In some European countries, a gingival display up to 4 mm or more is acceptable [4]. Etiological factors related to a gummy smile can be gingival (passive eruption), skeletal (vertical maxillary excess), and muscular (upper lip hyperfunction) [6]. The high smile line and excessive gingival exposure must be considered during the treatment plan [6] because sometimes corrections are needed during full-mouth rehabilitation.

The treatment procedure depends on the diagnosis and the etiological factors.

Aesthetic crown lengthening is one of the most common surgical treatments for a gummy smile. The objective of this procedure is the vertical reduction of the amount of exposed fixed gingiva by obtaining a complete exposure of the anatomical crown of the teeth and restoring the ideal dimensions of the biological width [7]. Following crown-lengthening surgery, the biological width is restored to a minimum of 2 mm, with the epithelial attachment of 0.97 mm and connective tissue of 1.07 mm width [8].

During the development of the treatment plan, tridimensional imagistic investigations are necessary. Cone beam computed tomography (CBCT) can provide accurate information about the alveolar bone and the periodontal status of the teeth. Measurements can be performed to define the length of the anatomical crown and root, which is necessary to realize the surgery correctly [9].

The greatest desire during the surgery is good visibility, without bleeding in the working area. The diode laser's most significant advantages are the non-bleeding operative field, tissue evaporation ability, adequate sterilization of the interventional area and minimal postoperative pain and edema [10].

Piezo-surgery offers a promising alternative to bone resection with significant benefits compared to traditional methods. It reduces the bleeding rate by 25–30% because it does not damage the soft tissues or blood vessels, ensuring a clean operating field during the intervention [11]. Its combination with the minimal flap technique significantly reduces postoperative pain and edema [12].

The gingival phenotype and the suture technique influence the evolution of the healing process after the surgery [13].

Dental implants have been considered one of the most important discoveries in dentistry in the past decades. In modern dentistry, the implant-prosthetic approach allows the treatment of partially edentulous spaces with fixed restorations, considerably improving the patient's quality of life [14]. The implant therapy, combined with zirconia ceramic restorations, allows the rehabilitation of function and aesthetics [15].

2. Case Report

This case report is a full-mouth rehabilitation of a 48-year-old female patient. She wanted to improve her aesthetics, disturbed by the shape and orientation of the upper frontal teeth and the excessive visibility of the gingiva. The patient also reports difficulties in mastication due to the absence of numerous posterior teeth in the lower arch. To establish the preliminary diagnosis, intraoral examinations (Figure 1a) and a panoramic X-ray (Figure 1b) were performed.

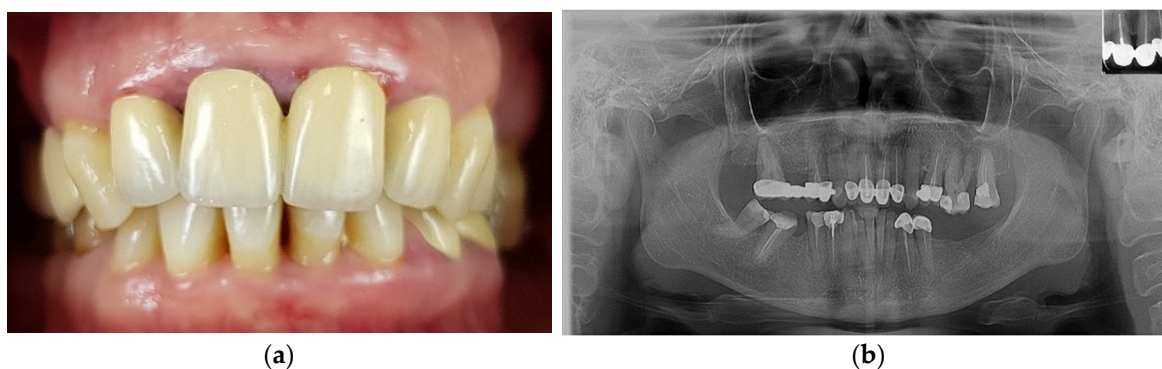


Figure 1. Initial situation of the patient: (a) Unaesthetic metal-ceramic crowns with chronic inflammation of the gingival margins and oblique interincisal line; (b) Initial panoramic X-ray.

The clinical examination revealed the presence of inadequate metal-ceramic restorations, teeth with unsatisfactory periodontal status (grade I mobility), aesthetical and functional problems. A full-mouth CBCT scan was performed for the final diagnosis and to establish the treatment plan. The treatment objective was to perform full-mouth rehabilitation and improve the smile's aesthetics by reducing the excessive gingival displacement.

A crown-lengthening surgery was planned before the prosthodontic rehabilitation. The long-term success of future restorations is conditioned by accurately reestablishing the vertical dimension and the occlusal plane. The functional rehabilitation of the jaws needed an implant-prosthodontic approach. The treatment plan was established following the patient's agreement, considering the principles of the Declaration of Helsinki involving

To obtain long-lasting results, the placement of the margins of the future restorations must be at a minimum distance of 5 mm from the alveolar bone. Therefore, this desirability was considered during the surgery (Figure 5).

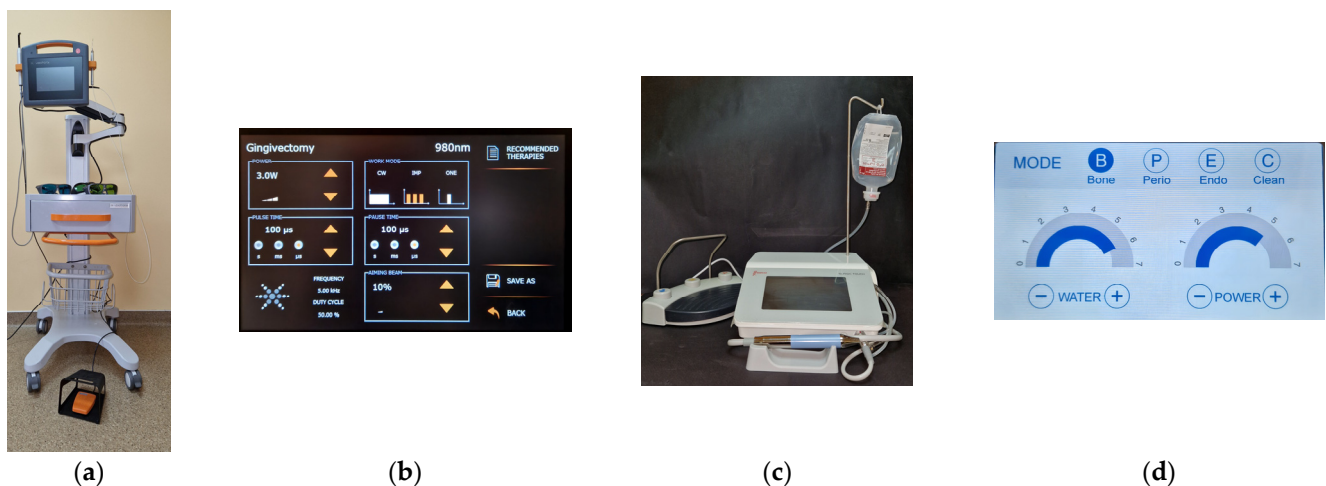


Figure 4. The used devices and the settings: (a) Lasotronic Smart M Pro laser; (b) The setting of the laser device for the gingivectomy; (c) Ultrasurgery III LED piezo-surgery device; (d) The setting of the piezo-surgery device.



Figure 5. The steps of the crown-lengthening surgery: (a) The abutments after the removal of the old restorations and a preliminary preparation before the surgery; (b) Predefinition of the gingival margins using the surgical guide and the Lasotronic Smart M Pro laser; (c) The limits of the new gingival margins after the removal of the surgical guide; (d) The aspect of the prosthodontic field after the piezo and laser surgery.

After performing the surgery and extracting the right central incisor, socket preservation and bone augmentation were done to maintain the alveolar bone dimensions. Provisional restoration was made to restore the aesthetics and function temporarily. Complete healing was achieved after six months. As expected, the results obtained were stable. The gingival contour was exposed but symmetrical and satisfactory during the smile. The final preparation of the abutments was performed with a heavy chamfer finish line, and zirconia ceramic restorations were used for the prosthodontic rehabilitation (Figure 6). The bite template was used to reestablish the vertical dimension. The color of the restorations was B1 (Vita Classical shade guide).

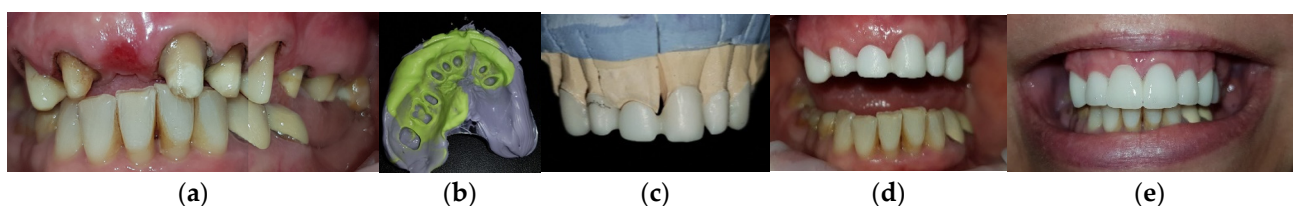


Figure 6. The steps of the prosthodontic rehabilitation: (a) Final aspect of the abutment after the healing period; (b) One-step impression with A silicone—Variotime Heavy Tray and Medium Flow (Zhermack); (c) The zirconia frame on the master cast; (d) The try-in of the zirconia frame; (e) The final restoration after cementation.

After the extraction of teeth 15 and 17, two implants were inserted. The osseointegration of the implants can be seen in the panoramic X-ray after six months (Figure 7).

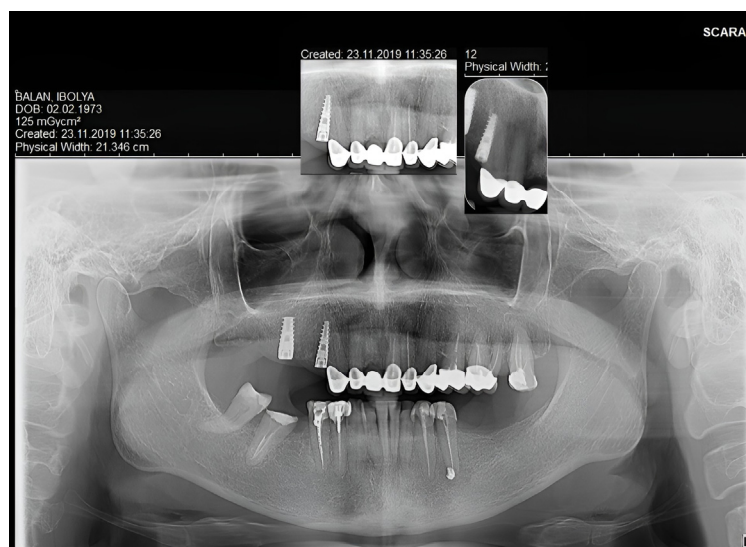


Figure 7. Panoramic X-ray with the osseointegrated implants and the maxillary prosthodontic rehabilitation on the natural teeth.

Pre-prosthetic treatments were performed on the lower arch during the upper arch healing period. The endodontic retreatments of the lower premolars were successful. The preparation of the teeth was carried out with a subgingivally placed heavy chamfer finish line. Single crown zirconia ceramic restorations and a bridge were realized, preserving tooth vitality in all abutments (Figure 8).

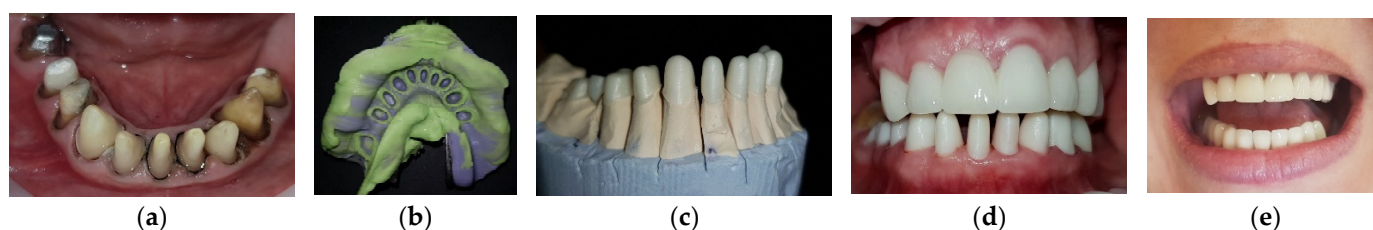


Figure 8. The steps of the prosthodontic rehabilitation: (a) The prepared abutments with the first impression cord; (b) One step impression with A silicone; (c) The zirconia frame on the master cast; (d) The try-in of the zirconia frame; (e) The final restoration after cementation.

For the restoration of the edentulous space on the lower arch, implant therapy was applied. Two implants were inserted.

In the case of the upper arch, a screw-retained titanium-based zirconia ceramic bridge was realized after the osseointegration period. The closed impression tray technique was used (Figure 9).

A panoramic X-ray was taken to verify the osseointegration of the lower implants (after six months) (Figure 10).

Due to the lack of parallelism of the implant bodies, a cemented zirconia ceramic bridge was realized to re-establish the function on the lower arch. In this case, the open-tray technique was used for the impression (Figure 11).

The final aspect of the complex, multidisciplinary full-mouth rehabilitation is presented in Figure 12.

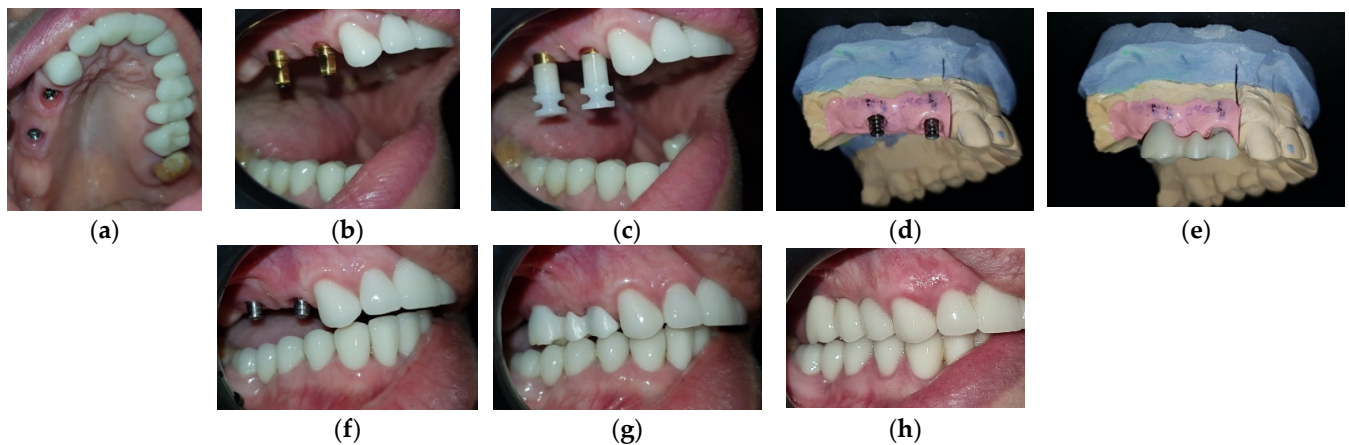


Figure 9. The sequences of the implant-prosthetic therapy in the maxilla: (a) The emergence profile after the removal of the healing caps; (b) The impression copings in the mouth; (c) The transfer caps applied on the impression copings; (d) The master cast with the artificial gingiva and titanium abutments; (e) The zirconia frame on the master cast; (f) The intraoral try-in of the titanium abutments; (g) The intraoral try-in of the zirconia frame; (h) The final restoration after the intraoral fixation.



Figure 10. Panoramic X-ray with the osseointegrated implants on the lower arch and the good marginal adaptation of all the restorations.

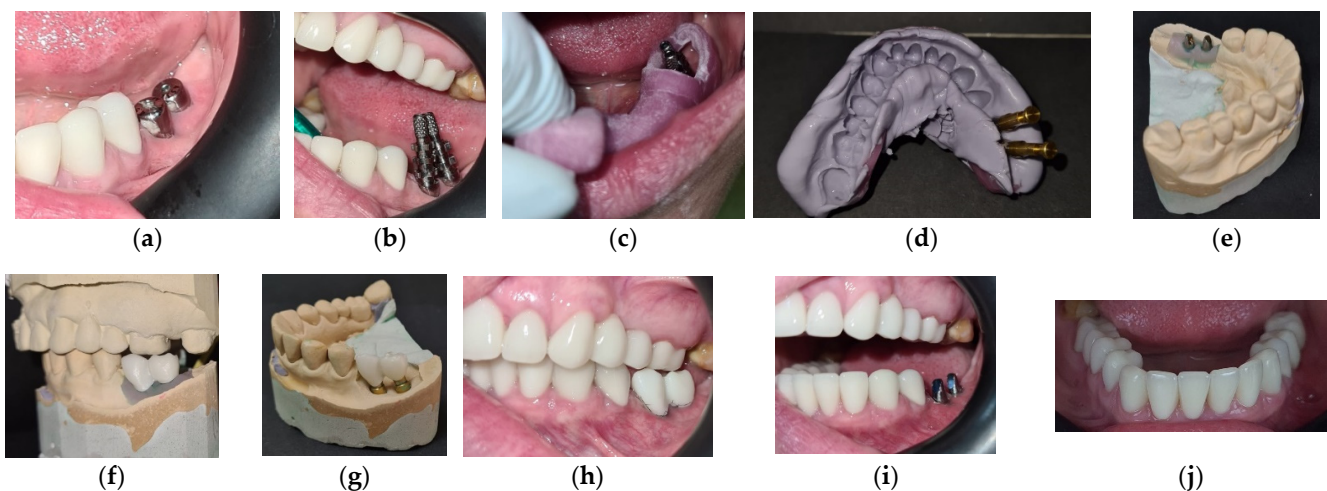


Figure 11. The sequences of the implant-prosthetic therapy in the mandible: (a) The healing caps; (b) The impression copings in the mouth; (c) The try-in of the open tray; (d) The impression with the technical analogs (e) The prepared abutments and the artificial gingiva on the master cast; (f) The zirconia framework on the cast; (g) The final restoration on the cast; (h) The try-in of the zirconia frame; (i) Closing the hole on the abutments; (j) The final restoration after the cementation.

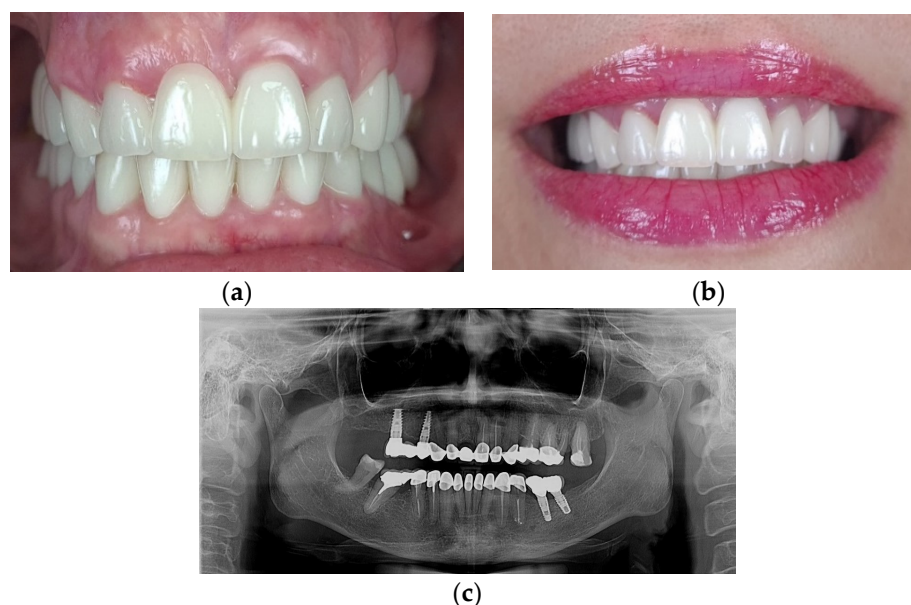


Figure 12. The final result of the full-mouth rehabilitation: (a) Intraoral aspect of the restorations; (b) The improved smile with minimal gingival display; (c) Panoramic X-ray after one year.

3. Discussion

Several studies have demonstrated the need for these surgical interventions to obtain an aesthetic smile, predominantly in the case of female patients [16], as in the presented case. The patient's initial problem was the gingival smile with the visibility of unaesthetic metal-ceramic prosthetic works. In this situation, resolving the patient's primary problems was possible only by performing full-mouth rehabilitation.

The surgical correction of the upper clinical crown:root ratio and gingival displacement was necessary before the prosthodontic approach.

According to Narayan et al., the pretreatment planning included a complex clinical evaluation regarding:

- The patient's systemic health and her expectations;
- The evaluation of the face and smile line;
- The lip thickness and size;
- The size and shape of the teeth;
- The gingival biotype and the width of keratinized gingiva;
- The thickness and contour of the alveolar bone [17].

CBCT evaluation was performed by measuring the existent and the future crown: root ratio and the crestal bone relation to the cemento-enamel junction to decide the surgery type.

In the presented case a, mock-up guided crown lengthening procedure was performed based on the diagnostic wax-up, similar to the technique described by Jurado et al. [18] in their case report. Using a precise 3D-printed surgical guide for crown lengthening can help to prevent or reduce the chance of under or over-contouring hard and soft tissues during the procedure [19].

The crown-lengthening surgery combined two modern, minimally invasive techniques (laser therapy for soft tissue remodeling and piezo-surgery for bone resection) and the conventional technique to obtain long-lasting results with minor post-interventional symptoms and reduced healing time. The methods reduced surgical chair time and operative trauma, accelerating the healing process and making the patient more comfortable. The flapless surgery was undesirable because it did not allow direct visualization of the operative field and can be challenging regarding soft tissue damage [20]. Performing a reduced flap without vertical incisions was beneficial.

The thick gingival phenotype of the patient facilitated the healing process. Three months post-operatively, stable results were obtained, probably due to minimally invasive techniques and the favorable gingival phenotype. The recovery period, a controversial topic in the literature, can differ individually. After soft tissue remodeling, the final rehabilitation can be done after a healing period of three months [21,22]. According to Herrero et al., in the case of bone remodeling with biological width modification, the healing period must be about six months before the prosthodontic rehabilitation [23], and it is essential to define a proper distance between the finish line and the bone margin during post-surgical prosthodontic treatment [24]. In our case, the healing period was six months.

After this period, the re-preparation of the teeth was carried out with a subgingivally-placed heavy chamfer finish line at a greater distance from the bone margin than 5 mm. Zirconia ceramic single crown restorations and bridges were used for aesthetic and functional rehabilitation. Several studies have been carried out regarding the marginal adaptation of these restorations, which are superior to conventional metal-ceramics [25,26]. Proper teeth preparation and a good impression technique are essential to achieve the best results [27,28]. In the case of digital workflow during the zirconia frame's design, the cementation space can influence the quality of the marginal adaptation. Defining the dimensions of this space must be done with caution [29]. Dittmer et al. [30] and Kohorst et al. [31] demonstrated in their studies that the successive application and firing of ceramic layers on the zirconia frame could cause marginal discrepancies, contradictory to Vigolo et al. findings [32]. The zirconia framework presents a lower occurrence of discrepancies than metal-ceramics [33]; this can contribute to obtaining long-lasting aesthetical results. The perfect marginal fit of the restorations is essential in maintaining periodontal health and ensuring the restorations' natural appearance, especially in the frontal area.

In the literature, different recommendations can be found for the cementation of zirconia ceramic restorations on teeth and implants. Some studies recommend the adhesive cementation technique in case of poor retention of the abutments [34,35]. Other studies have shown the importance of treating the inner surfaces of zirconia restorations to achieve good adhesion after cementation [36,37]. In the presented case, the zirconia restoration internal surface was sandblasted and treated with Ivoclean (Ivoclar). The vitality of the teeth influenced our choice of adhesive material. The adhesive cementation was abandoned to avoid pulpal irritation related to etching. Resin-modified glass ionomer cement was used for the final cementation of the restorations in the case of natural teeth.

In the case of implants, the fixation method (screw or cement retained) of the restorations might not directly influence their survival rate. However, it can lead to certain complications (mainly periimplantitis) [38]. Each retention method has its indication with advantages and disadvantages [39]. According to de Brandao et al., there is no evidence of differences in the marginal bone loss around the cement and screw-retained restorations [40]. Several studies demonstrated a higher success rate of screw-retained restorations versus classically cemented ones [38,41]. Park et al. recommend choosing the appropriate fixation method depending on the implants' parallelism and considering the occlusal relations. It is crucial in the case of the upper premolar region the possibility to place the access hole of the screw on the central fossa [42], as it was in our case.

The patient was satisfied with the obtained results, even though she still had a moderate gummy smile. The lip-repositioning surgery represents future possibilities for better aesthetical results [43], as does the injection of botulinum toxin A [44].

The patient chose a less invasive way to improve the final aesthetics in the future by using hyaluronic acid filler to make the lips look fuller and more youthful.

The limitations during the follow-up:

- Lack of periodical CBCT evaluation (at three months, six months, and one year)
- Lack of periodical periodontal evaluation using periodontal probing.

Digital planning and using a 3D-printed surgical guide can improve the expected results. A good collaboration between a multidisciplinary dental team and a facial plastic surgeon can result in even better aesthetics.

4. Conclusions

The crown-lengthening surgery is an efficient method to improve aesthetics in the case of a gingival smile. Laser therapy and piezo-surgery are modern methods that allow minimally invasive and efficient interventions with fast postoperative recovery. The zirconia ceramic restorations can be used to restore aesthetics and function with good results. Screw-retained restorations have a better long-term prognosis compared to cemented ones, demonstrated by the one-year follow-up Panoramic X-ray.

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Institutional Review Board Statement: The case report was conducted according to the guidelines of the Declaration of Helsinki on experimentation involving human subjects, as revised in 2013. Ethical review and approval were waived due to the design of the present case report. Our Institutional policy does not require the Ethical Committee approval in this case as the patient signed the informed consent requested for the publication of the present case report. Ethical approval was not sought for the present case report also because no experimental procedures were performed during the patient's treatment, and none of the materials or equipment used were prototypes. All of them are available on the market in their current form, and they were used according to the manufacturer's instructions without requiring off-label protocols.

Informed Consent Statement: Informed consent was obtained from the patient. Written informed consent has been obtained from the patient to publish this paper.

Data Availability Statement: The dataset analyzed during this case report are available from the first author on request.

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Article

Evaluation of Intraoral Full-Arch Scan versus Conventional Preliminary Impression

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Abstract: An accurate impression is vital during prosthodontic rehabilitation. Digital scanning has become an alternative to conventional impressions. This study compares conventional preliminary impression techniques with digital scanning, evaluating the efficiency, treatment comfort, and true-ness. Impressions of 28 patients were taken using conventional and digital techniques. The efficiency of both impression techniques was evaluated by measuring the mean working time. A visual analog scale questionnaire (1–10) was used to appreciate the participants' perceptions of discomfort. Morphometric measurements, which were carried out to determine the differences between the casts, were made on the buccolingual cross sections of teeth 11 and 31 and the distolingual and mesiobuccal cusp tips of each first molar. The total treatment time was 75.5 min for conventional and 12 min for digital impressions. The patients scored a mean discomfort assessment of 6.66 for conventional and 9.03 for digital scanning. No significant differences existed between the examined areas ($p < 0.05$, Wilcoxon and Mann–Whitney tests) of the digital casts obtained by both techniques. The intraoral scan can be considered as an alternative to conventional preliminary impressions for performing study model analysis during orthodontic treatment planning. The digital impression is more comfortable and accepted by the patients than the conventional impression and has a shorter working time.

Keywords: intraoral scanning; digital impression; conventional impression; digital dentistry



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1. Introduction

The dental arch impression is essential to prosthodontists' and orthodontists' daily activity. It is used to reproduce the dental arch's negative to obtain a model for treatment planning, patient communication, or the realization of restorations [1]. The goal of every practitioner is to realize precise impressions, which are a prerequisite for fabricating dental restorations with a proper marginal fit [2]. The accuracy of the casts depends on numerous factors: materials and techniques used; type, size, and rigidity of the impression trays used; application of tray adhesive; shrinkage of the impression materials; type of dental stone; and its compatibility with the different types of impression materials [3–5]. Nowadays, the most used impression materials are polyvinyl siloxanes, polyethers, and irreversible hydrocolloids [1].

Intraoral scanning was developed in the 1980s and represented an acceptable alternative to conventional impression techniques, providing information for various situations such as diagnosis, orthodontic measurements, restorative dentistry, and implant-supported prosthodontics [4–8]. Improved patient acceptance, comfort, reduced vomiting reflex, reduced distortions, three-dimensional immediate pre-visualization and evaluation of the preparations, cost and time efficiency, more accessible communication with the dental laboratory, and data storage are the benefits of digital scanning [9–11]. The intraoral scanners provide direct digitalization by scanning the oral cavity with a camera. The extraoral

scanners provide indirect digitalization by scanning a cast resulting from the conventional impression techniques [12,13]. All systems provide only sectional images covering a small area. The scanners' software converts the data from the scans into STL (standard tessellation language) files, resulting in a three-dimensional image of the jaws. The obtained image's accuracy depends on the matching algorithm [14]. Although digital scanning shows a rapid and continuous development, it has disadvantages such as difficulty detecting subgingival finish lines of the preparations, inaccuracy in case of bleeding, and moisture near the gingival margins. Artificial reflective surfaces in the oral cavity can also cause errors during scanning [15,16]. A strong advantage of intraoral scanners compared to conventional impressions is the possibility to rescan missing areas or correct mistakes and evaluate the scanned areas by direct visualization on the laptop or computer screen [17].

In the case of conventional impressions, mistakes during the recording can sometimes be detected only after pouring the casts; however, corrections must be made by repeating the impression procedure, otherwise the casts will not be accurate. The Trios 3 intraoral scanner's scanning technology is based on confocal microscopy. Its light source is based on a structured light scanner with infrared light inside [18]. This study compared conventional preliminary impression techniques and digital scanning, evaluating the efficiency, treatment comfort, and trueness of the obtained models.

2. Materials and Methods

This comparative study included the upper and lower jaw of 28 patients (14 females and 14 males). The sample size was calculated by using G*Power version 3.1.9.6. software (Franz Faul, Universität Kiel, Kiel, Germany); this size would provide greater than 95% power to detect significant differences, with an effect size of 0.80 at a level of significance of $\alpha = 0.05$. All the participants were investigated at the Faculty of Dental Medicine of the George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Targu Mures between 10 March 2023 and 20 March 2023. The inclusion criteria were good oral hygiene, fully dentate maxillary and mandibular jaws, an age range of 18–25, and Angle Class I molar relationships with minor malocclusion such as crowding, rotation, or diastema. Patients with systemic health problems and allergies to the materials used, prosthodontic rehabilitation (crowns or bridges), or orthodontic appliances were excluded.

The clinical trial consisted of digital and conventional preliminary impressions of the dental arches, obtaining the STL files, and performing the dimensional comparison of the digital models. The same medium-experience operator performed the clinical examinations and realized the impressions to obtain comparable testing conditions and reduce or avoid mistakes [19].

The study was conducted according to the Declaration of Helsinki and approved by the Ethics Committee of our University (2127/24 February 2023). All the participants provided informed consent in written form.

2.1. Impressions

For digital scanning, the 3Shape Trios 3 intraoral scanner (3Shape A/S, Copenhagen, Denmark) was used, with an LED light source, a scanning accuracy of $6.9 \pm 0.9 \mu\text{m}$, and a precision of $4.5 \pm 0.9 \mu\text{m}$. The scanner was calibrated and handled according to the manufacturer's recommendations [20]. During the scanning procedure, OptraGate Small Refill (Ivoclar Vivadent, Schaan, Lichtenstein) cheek retractors were used to control the accessibility and visibility in the scanning area. The dental arches were gently dried, and a saliva ejector was used to control the saliva. After the warm-up period of the scanner tube (ten minutes), the scanning procedure started at the maxillary arch from the patient's left side with a scanning path from the occlusal surface of the third molar to the incisors, followed by the lingual and the buccal scan of the dental arches [21,22]. The scanner head was maintained at 0–5 mm from the teeth. It is recommended to wait for about five scanner clicks before continuing the scan to obtain a good starting point. The head of the scanner was moved slowly and gently, and a faster click was heard during the continuous scan.

While checking the scanning procedure on the screen, the missing areas were corrected. All the intraoral scans were performed under the same uniform light conditions [23], avoiding the dental chair's light reflection into the patient's mouth. For each patient, a single scan was performed.

For the conventional full-arch impressions, the Kromopan (Lascod S.p.a., Sesto Fiorentino, Florence, Italy), a chromatic irreversible hydrocolloid impression material with 168 h of dimensional stability, was used. The color changes will help the practitioner optimize the material's working and setting time (purple: mixing period; pink: loading the tray; white: setting period). The material was prepared according to the manufacturer's recommendations. The powder was extracted from the package by using a measuring spoon. For each spoon full of powder, a 1/3 measure of water was added to the mixing bowl and was mixed until the consistency and color were homogenous. A sterile, standard, perforated plastic impression tray with accurate dimensions was used for each impression. Alginate adhesive was used to prevent the displacement of the material during the removal of the tray from the mouth. The patients were asked to rinse their mouth with water to eliminate mucin and decrease the surface tension of the teeth for eliminating air bubbles during impression. The impression tray with the alginate was inserted in the mouth by retracting, with a dental mirror, the lips of the patient on one side and rotating, from the other side, the impression tray into the mouth. After the tray was centered and seated on the dental arch, the pressure was released and the tray was maintained lightly in place to avoid distortions. The setting of the alginate materials starts from the tooth surface to the tray. After thirteen seconds of setting time, the impressions were removed from the mouth, examined for defects under good lighting conditions, rinsed, disinfected, stored in sealed plastic bags, and sent to the laboratory and pored immediately.

The type IV SheraPremium universal super hard die stone (Shera Material Technology GmbH & Co. KG, Lemförde, Germany) was used to pour the casts. After two hours, the hardness of the stone was 270 MPa, with a setting expansion of 0.10%. The hardness after 24 h was 290 MPa. The working time was 4.5–5.5 min, and the setting time was approximately 30 min. The obtained casts were scanned using a Medit Identica Hybrid 3D laboratory scanner (MEDIT corp., Seoul, Republic of Korea). This scanner has three axes and three color cameras (static part) with high resolution ($<7\text{ }\mu\text{m}$) and a flexible multi-die plate (active part) for the automatic scan of up to eight models at the same time. The scanning time was reduced by 74% by the scanner's blue light LED scan technology. With the intelligent multi-view scan technology, areas that are difficult to capture (interproximal areas, undercuts) could be scanned safely and quickly.

The digital data obtained from the scans were converted into STL files compatible with the Exocad software (Rijeka 3.1).

2.2. Comparison of the STL Files

Twenty-eight upper and lower arch impressions were obtained with both techniques. The digital data obtained by indirect and direct scanning were imported into Exocad software (Figure 1a) and superimposed by the tripoding procedure and the best-fit algorithm of the software. The best-fit algorithm is capable of aligning STL files by a set of measured points to match, as closely as possible, that of their counterpart. It can calculate discrepancies between images automatically and make it easier to visualize the discrepancies between the images by color. The disadvantage of the best-fit algorithm is that the deviation may be different from what occurs during the intraoral scanning. For smaller scans (one quadrant) it seems to be suitable, with an acceptable error range [24].

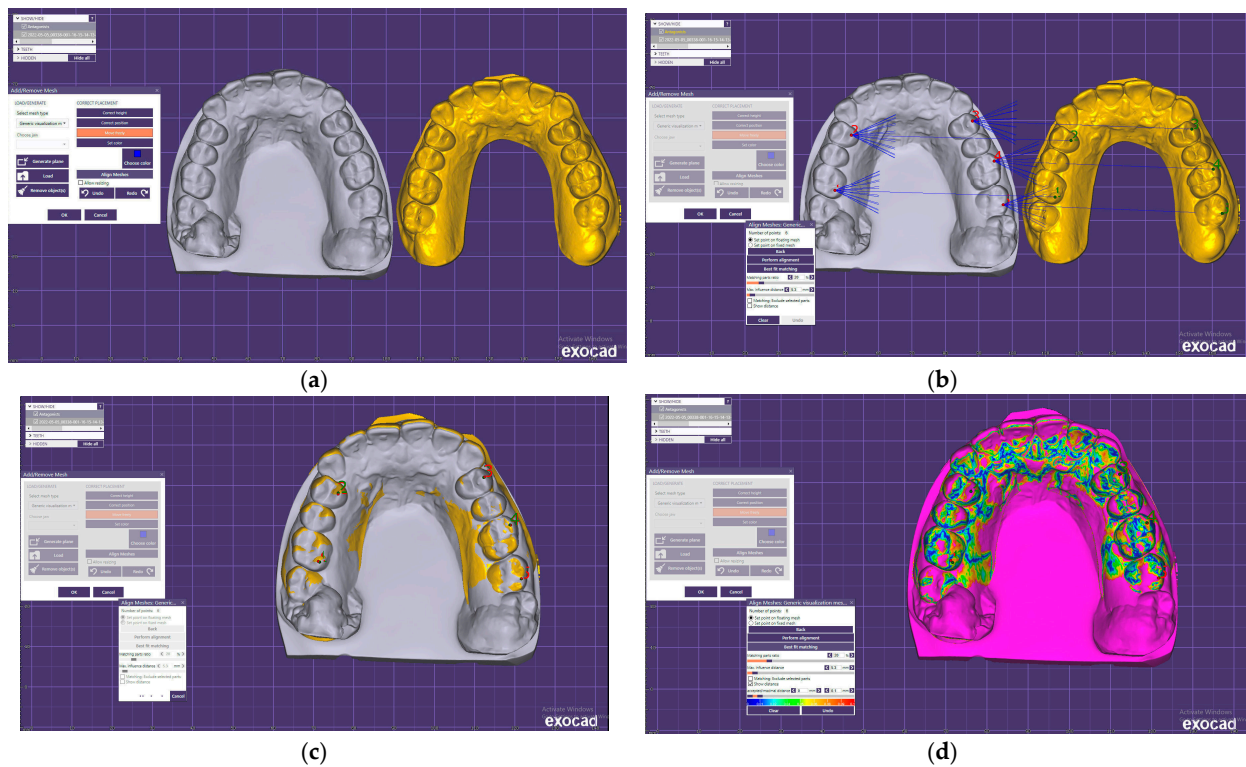


Figure 1. The digital scans in Exocad software: (a) study model obtained by indirect scan (gray) and study model obtained by direct scan; (b) the reference points for the tripoding procedure; (c) superimposed digital models; (d) color scale for the differences in the digital scans.

During this study, five reference points were used for a higher superimposition accuracy of the digital models obtained by direct and indirect scans. Two reference points were localized at the palatal cusps of the right first premolars and first molars. Three reference points were located at the buccal cusps of the left first premolars and first and second molars (Figure 1b,c). The differences between the superimposed digital casts were examined using a color scale (Figure 1d). The cold shades of the spectrum indicated minor differences between the two models, while the warm colors showed increasingly significant differences between the digital scans.

The morphometric differences were evaluated by measurements of the buccolingual cross sections of teeth 11 and 31 and of the distolingual and mesiobuccal cusp tips of teeth 16, 26, 36, and 46; the FDI dental notation system was used (Figure 2).

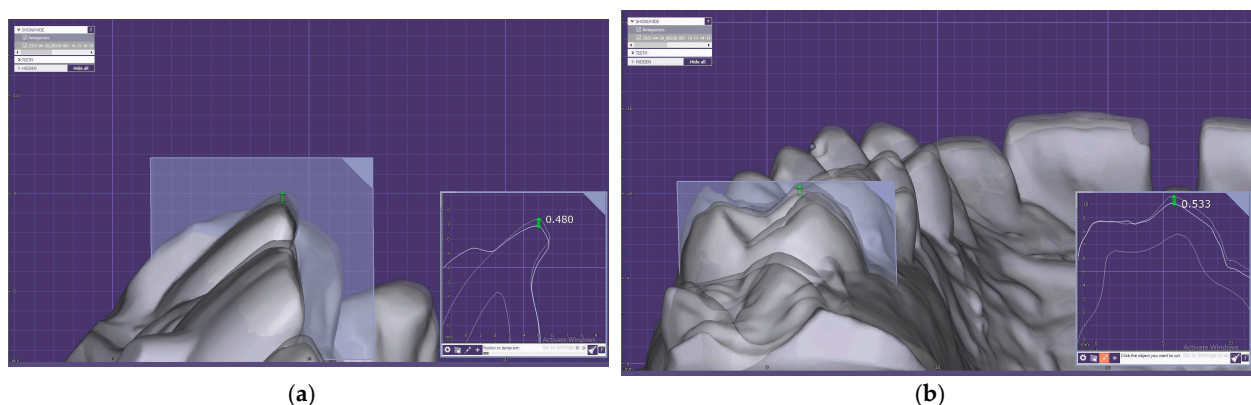


Figure 2. The morphometric measurements in Exocad software: (a) differences in the cross section of tooth 11; (b) differences in the cross section of tooth 16.

2.3. Time Efficiency, Patient Point of View

A second operator recorded the duration of each conventional impression or intraoral scan in seconds, and for statistical interpretation, the results were converted in minutes. The mean of total treatment time was calculated for both techniques. For conventional preliminary impressions, the working time was recorded from the moment of preparing the impression material until the scanning of the study model with the laboratory scanner for the upper and lower arches was performed. For the digital impressions, the time was recorded after the complete warm-up of the scanner tip, from the beginning of the intraoral scan until the data were imported into the software.

The patients were asked to answer a visual analog scale questionnaire (1—lowest score, 10—highest score), similar to that of Yuzbasioglu et al. [3], to score their overall discomfort and perception of the effectiveness of the methods used.

2.4. Statistical Analysis

The statistical analysis was performed by using GraphPad Prism 9 for macOS version 9.5.1 software. The outlier analysis and exclusion were performed using the ROUT method. The statistical significance was set at $p < 0.05$. The mean (M), median (Me), and standard deviation (SD) were calculated. The Shapiro–Wilk test was used to check the distribution. Wilcoxon and Mann–Whitney tests were also used.

Null hypothesis:

- There are no significant differences between the conventional preliminary impression technique and intraoral scan trueness.
- The digital impression is more comfortable and less time-consuming than the conventional preliminary impression.

3. Results

The descriptive statistics of the morphometric measurements obtained for both impression techniques are presented in Table 1.

Table 1. The morphometric differences between the models obtained by conventional and digital techniques at the reference teeth for the upper and lower arches—descriptive statistics.

	Upper Arch (mm)			Lower Arch (mm)		
	11	16	26	31	36	46
Minimum	0.1700	0.1040	0.002000	0.1050	0.1320	0.000
25% Percentile	0.1785	0.1670	0.2040	0.1673	0.1990	0.1320
Median	0.2290	0.2310	0.2675	0.2090	0.2390	0.2530
75% Percentile	0.2980	0.3850	0.3480	0.2873	0.4530	0.3880
Maximum	0.3310	0.4970	0.6200	0.3460	0.6300	0.4410
Range	0.1610	0.3930	0.6180	0.2410	0.4980	0.4410
Mean	0.2355	0.2770	0.2581	0.2155	0.3171	0.2426
Std. Deviation	0.05577	0.1265	0.1552	0.07027	0.1560	0.1390
Std. Error of Mean	0.01054	0.02390	0.02932	0.01328	0.02948	0.02627
Lower 95% CI of Mean	0.2139	0.2279	0.1980	0.1883	0.2566	0.1887
Upper 95% CI of Mean	0.2571	0.3260	0.3183	0.2428	0.3776	0.2965

To observe that there is no statistical difference between the two impression methods, the standard acceptable value was set at zero. The results of the Wilcoxon test revealed that the difference between the two impression methods is statistically significant ($p < 0.0001$). The Mann–Whitney test was applied to determine if there were differences between the values obtained at the lower and upper arch. The results are presented in Table 2.

Table 2. The differences between lower and upper arch.

	Mann–Whitney	Difference	<i>p</i> -Value
11 vs. 31	301.5	0.02000	0.1394
16 vs. 46	338	−0.02200	0.3808
26 vs. 36	364.5	0.02850	0.6571

No statistically significant differences were found regarding the scanned area, except for the frontal and lateral left inferior arch. The results obtained by comparing the values on the same dental arch are presented in Table 3.

Table 3. The differences regarding the values on the same dental arch.

	Mann–Whitney U	Difference	<i>p</i> -Value
11 vs. 16	353	−0.00200	0.5279
11 vs. 26	302	−0.03850	0.1418
16 vs. 26	378	−0.03650	0.8229
31 vs. 46	350	−0.04400	0.4963
31 vs. 36	236	−0.03000	0.0098 **
36 vs. 46	295	−0.01400	0.1129

** very significant.

The mean value of the working time for the conventional impression of both arches was 75.50, and for the digital impression it was 12.00 ($p < 0.0001$, Mann–Whitney test).

On a 1–10 visual analogue scale, the patients scored the discomfort and effectiveness of the impression techniques used. The obtained data and results of the Mann–Whitney test are presented in Table 4.

Table 4. Patient perception of the impression techniques.

	Conventional Impression	Digital Impression	<i>p</i> -Value
Minimum	4.000	8.000	<0.0001 ****
Median	6.750	9.000	
Maximum	8.500	10.00	
Mean	6.500	9.018	
Std. Deviation	1.333	0.7756	
Std. Error of Mean	0.2520	0.1466	
Lower 95% CI	5.983	8.717	
Upper 95% CI	7.017	9.319	

**** extremely significant.

4. Discussion

The present study investigated the trueness of casts resulting from digital and conventional full-arch impressions in fully dentate young patients. The trueness of the impression represents the difference in the obtained geometry compared to the original, while the precision of the impression represents the differences between repeated impressions [25]. According to Sanda et al., trueness indicates the degree to which the digital scan reproduces the analog cast or dental arch and precision shows the degree to which the digital models obtained by repeated scans of a model or dental arch correspond with each other [26]. According to the International Standard Organization (ISO) definition from 1994 [27], both factors must be considered when the accuracy of the impressions is examined. Digital

impressions are becoming increasingly common due to their comparable accuracy to conventional impressions [28]. In this study, precision between the conventional and intraoral scans was not evaluated, only trueness. To evaluate the trueness of the impressions, gold-standard data must be used as the true value. This true value can be obtained by coordinate measuring machines, industrial 3D scanners, or dental laboratory scanners [26]. The extraoral scan was considered a reference in this study because the stone casts resulting from conventional impressions are still commonly used in orthodontics. The accuracy of industrial scanners ranges from 1 to 10 μm ; the accuracy of laboratory scanners ranges from 2 to 10 μm . Therefore, the accuracy of a digital model obtained by laboratory scanners is comparable to that of an industrial 3D scanner [29], with interpretable results.

Before each digital impression, the intraoral scanner was calibrated according to the manufacturer's recommendations [19] to avoid possible mistakes. The recommended scanning path was used during the intraoral scans: from occlusal to palatal towards buccal. According to Müller et al., this scanning strategy provides the highest precision and trueness in full-arch scans and minimizes the mistakes and inaccuracies of the final working models [30]. According to Schirmer and Wiltshire [31], measurement differences of less than 0.20 mm for orthodontic study models were clinically acceptable. This reference value was determined to be higher (about 0.30 mm) by Hirogaki et al. [32]. Our results follow those obtained by Hirogaki et al. Bell et al. [33] stated that a 0.27 mm difference is not clinically significant. However, in the case of orthodontic appliances, the 3D printing procedure can increase the differences, leading to a higher number of errors. Our results are acceptable in the case of study casts. No significant differences were found between the values of the morphometric measurements for the upper and lower arches. The average difference between the values obtained with the two impression techniques was 317.8555 microns. The newest intraoral scanners and their more precise registration techniques can lead to better results and/or working models. However, in the case of orthodontic working models, these values can generate differences and misfits of the orthodontic appliances. Several factors can influence the results. The scanners' different technologies (light, laser, or contact) do not affect the scanner's overall reliability but the scanning technique. The presence of blood, saliva, or humidity in the scanned area, limited mouth opening, tongue movements, and the patient's movements can determine inaccurate scans [34,35]. In our study, the main differences were obtained in the case of molars for both arches, probably because of their bigger surface and reduced visibility or access, which can lead to a higher probability of errors. Several studies have reported comparable or even higher accuracy for intraoral scans compared with conventional impressions for short-span fixed prosthodontic works up to a quadrant [36–40]. Other studies demonstrated that the transfer accuracy for full-arch scans was higher in the case of conventional impression techniques when precise impression materials were used (polyvinyl siloxane, polyether, vinylsiloxanether, directly scannable vinylsiloxanethers [12,40,41]), and the casts were scanned with an extraoral scanner [13]. Our findings are like those obtained by Ender et al. in their study [42]. The digital impressions resulted in more accurate digital models than conventional ones [37]. The lower accuracy of conventional alginate impressions was related to the impression material, impression technique, cast pouring, and stone expansion [43–45]. The alginate is the least accurate impression material, as demonstrated by Bud et al. in their study [46]. Intraoral scanning has limitations in detecting subgingival finish lines on prepared teeth or in case of bleeding [47].

The participants in this study were young patients without exposed root surfaces, undercuts, edentulous spaces, or prosthodontic works, which allowed an easier scan and conventional impression. The examined arches were integral, without deep margins or bleeding areas, and the models obtained were study models for orthodontic treatment planning. The digital impression technique was more effective regarding working time and more comfortable; it was preferred by the patients, with a meaningful assessment of 6.66 for the conventional impressions and 9.03 for the digital impressions. These results are supported by many current studies [11,48–50] but contrast with that of Gründheid et al. [51].

According to that study, conventional alginate impression techniques were preferred by patients because of the dimensions of the scanner's tip. Siquera et al. considered that intraoral scanning procedures can improve the patient experience regarding preference and comfort during impressions [17]. Our results demonstrated that the intraoral scan was less time-consuming than the conventional preliminary impression. The total working time was 75.5 min for conventional and 12 min for digital impressions. These findings are supported by other studies [1,10,49,52,53]. Only a few studies reported a reduced working time for conventional impressions [54,55]. Wismeijer et al. [56] reported a significantly higher overall preference of the patients for using the digital impression technique. However, the perception of the patients regarding the working time of the digital impressions was more negative than in the case of the conventional impressions.

The operator's experience positively influences the intraoral scanning time and accuracy. The beginners obtain a scan with a higher number of images and a longer scanning time than medium- and high-experience operators [19]. The operator's experience can influence the accuracy of both digital and conventional impressions. In our study, the conventional and digital impressions were performed by the same medium-experience person.

The scan size influences the accuracy of the obtained images. Several studies demonstrated the higher accuracy of the smaller scan areas compared to full-arch scans [19]. A noticeable clinical benefit of using intraoral scanners for impressions is reducing the risk of cross infections [57]. Conventional impression materials can suffer dimensional or surface modifications following immersion in different disinfectant solutions [58]. By using conventional techniques, the laboratory team is exposed to different infectious microbial agents, increasing the risk of cross contamination. With a fully digital workflow, the infection risk can be limited to the direct contact of the patient with the scanner's tip and the dentist. The infection risk can be reduced considerably by using adequate surface disinfectants and sterilization protocols for the scanner tips [57].

The limitations of the present study were: the use of a single impression material and a single intraoral scanner; only tridimensional superimposition of the cast being analyzed; certain areas with or without deviations that could remain unobserved and quantified; and the precision of the impressions not being examined. Other materials and new advanced intraoral scanners, with their more complex workflows, could lead to different, better results. The lack of standardization of the landmarks used to perform the measurements does not allow an accurate assessment of the precise accuracy evaluation. For an accurate assessment of the accuracy, more clinical trials are needed using more impression materials and more intraoral scanners.

5. Conclusions

Based on the findings of this study, the following conclusions were drawn:

- The intraoral scan can be considered as an alternative to the conventional preliminary impression for performing study model analysis during orthodontic treatment planning.
- The digital impression is more comfortable and accepted by the patients than the conventional impression and has a shorter working time.
- The performance of the impression techniques used can be corrected with experience and good clinical skills.

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Article

Is Laser Therapy an Adjuvant in the Treatment of Peri-Implant Mucositis? A Randomized Clinical Trial

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Abstract: (1) Background: Early diagnosis and treatment of peri-implant mucositis may reduce inflammatory markers and halt the progression of the condition to peri-implantitis. Adjunctive laser treatment may have therapeutic benefits that are not yet well known. The aim of this study was to determine the advantages and limitations of laser therapy as an adjuvant in the treatment of peri-implant mucositis. (2) Methods: A total of 42 patients with at least 2 implants situated in different hemiarches were included in this study and divided into two groups: G1 (received laser therapy) and G2 (no laser therapy). Periodontal health status indices were recorded at the initial moment (T0), and all patients underwent non-surgical debridement therapy accompanied by oral hygiene training. In patients from group G1, one implant site received adjuvant laser therapy (subgroup IL), and the other one did not receive active laser light (IC). The plaque index (PI), probing pocket depth (PPD), and bleeding on probing (BOP) values recorded after 3 months (T1) and 6 months (T2) were analyzed and compared with those at T0. (3) Results: PI values considerably reduced at moment T1 and T2 for both G1 and G2 ($p = 0.0031$). PPD was also reduced, but the difference between the groups and the three recording moments was not statistically significant. Statistically significant differences were found when comparing the BOP values between G1 IL and G1 IC for T0/T1 ($p = 0.0182$) and T1/T2 ($p < 0.0001$), but there was no significant difference between G2 and G1 IL or G1 IC. (4) Conclusions: Laser therapy as an adjunct to conventional treatment of peri-implant mucositis leads to a statistically significant reduction in bleeding on probing at 3-month and 6-month re-evaluations. Moreover, it leads to an evident reduction in probing depth but with no statistical significance. These results should be interpreted with caution, and more in-depth research should be performed to create a complete laser therapy protocol for peri-implant mucositis.

Keywords: laser; peri-implant mucositis; peri-implantitis; adjuvant therapy



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1. Introduction

Implant-assisted edentulous therapy has become a routine treatment in dentistry nowadays as it is increasingly widespread among clinicians worldwide [1]. Although dental implants are a reliable treatment method with a high survival rate (94.6%), the prevalence of peri-implant disease has been reported by several longitudinal and cross-sectional studies [2–9]. Peri-implant mucositis has a prevalence of 29.48% at implant level

and 46.83% at patient level, and for peri-implantitis, the prevalences are 9.25% and 19.83%, respectively [10].

Over the years, several studies have defined implant success criteria [11–13]. The success of dental implants is determined through a comprehensive assessment, reported at different levels: implant, peri-implant soft tissues, prosthetic work, and patient. Judging by the state of the implant, success criteria are absence of mobility, pain, radiolucency, and peri-implant bone loss (more than 2 mm in the first year). For peri-implant soft tissues, the success criteria should be the absence of suppuration and bleeding. Implant success is reached when the prosthetic work has no technical/prosthetic complications and has provided adequate functional and esthetic rehabilitation. For the patient, the success criteria are the satisfaction provided by the esthetics and the ability to perform the masticatory function without any discomfort and/or paresthesia [13].

Most of the complications associated with dental implants are inflammatory conditions of the soft and hard tissues around them, which are induced by the accumulation of bacterial biofilm [14]. Such conditions, which have been called peri-implant mucositis and peri-implantitis, must be clearly defined and differentiated from the peri-implant health status, to establish a proper diagnosis and institute an appropriate treatment.

The new classification of periodontal and peri-implant diseases elaborated and published by American and European researchers is intended to simplify and clarify their diagnosis [15,16]. An element of novelty was the inclusion of peri-implant conditions within this classification, starting from the idea that the periodontologist is the clinician to diagnose and treat them. This classification provides specific criteria to accurately define peri-implant status in daily practice: signs of gingival inflammation, bleeding on probing (BOP), probing pocket depth compared to previous visits (PPD), and radiographically detectable bone loss (RBL) [17].

Peri-implant health is defined by the absence of signs of peri-implant soft tissue inflammation, the absence of bleeding and/or suppuration on gentle probing, the absence of increased probing depth (PPD) compared to previous visits, and the absence of radiographic bone loss (RBL) beyond the changes of the crestal bone level that appeared due to initial bone remodeling after implant placement [18].

Peri-implant mucositis is characterized by the presence of bleeding and/or suppuration on gentle probing with or without increased probing depth compared with previous examinations and the absence of additional changes in radiographic bone loss that occurred after initial bone remodeling [19].

The means by which peri-implantitis diagnosis is made depends on the presence or absence of previous records. Using previous records, peri-implantitis is defined by the presence of signs of bleeding and/or suppuration on mild probing, increased PPD compared with previous examinations, and the presence of RBL versus crestal bone level changes after initial bone remodeling that should not be higher than 2 mm. In the absence of previous radiographic records, the signs used to define a case of peri-implantitis are the presence of bleeding and/or suppuration on gentle probing, and $PPD \geq 6$ mm and $RBL \geq 3$ mm apical to the most coronal part of the intraosseous portion of the implant [20].

The pathological process always begins with peri-implant mucositis, which affects only the soft tissue around the implant. This pathological condition is reversible when detected early and treated properly [21–23]. The standard protocol in the treatment of peri-implant mucositis consists of training and monitoring the patient regarding oral hygiene measures and instituting non-surgical therapy [24–26]. For the non-surgical treatment of peri-implant mucositis, different methods have been studied such as techniques that improve dental plaque removal, locally applied antiseptics, generally administered antibiotics, probiotics, or the use of mouthwashes containing chlorhexidine [27–33].

Regarding the use of laser therapy as an adjuvant in the treatment of peri-implant mucositis, the results of the studies conducted are controversial [34–37]. That is the main reason why we aimed to evaluate the advantages and limitations of using laser therapy in the treatment of peri-implant mucositis in this study.

2. Materials and Methods

2.1. Study Design

This clinical study was conducted as a double-blind, randomized clinical trial.

2.2. Selection of Patients

Out of 76 adult patients with dental implant restorations who presented at the dental office in Targu Mures (Romania) for periodic check-ups, between 3 January 2021 and 22 December 2022, we selected 42 patients who met the following inclusion criteria:

- Presence of at least one implant on two different hemiarches;
- Implants must be pillars of fixed prosthetic works;
- Presence of bacterial plaque and signs of inflammation of the peri-implant gingival tissue.
- The exclusion criteria were the following:
- Presence of radiographically detectable bone loss after the initial remodeling of the bone;
- Presence of systemic diseases with an impact on the periodontal tissues (diabetes, immunological diseases, acute articular rheumatism, tuberculosis, etc.);
- Pregnancy or breastfeeding;
- Non-surgical peri-implant treatment performed in the last 6 months;
- Antibiotic treatment in the last 6 months;

The use of non-steroidal anti-inflammatory drugs (Figure 1).

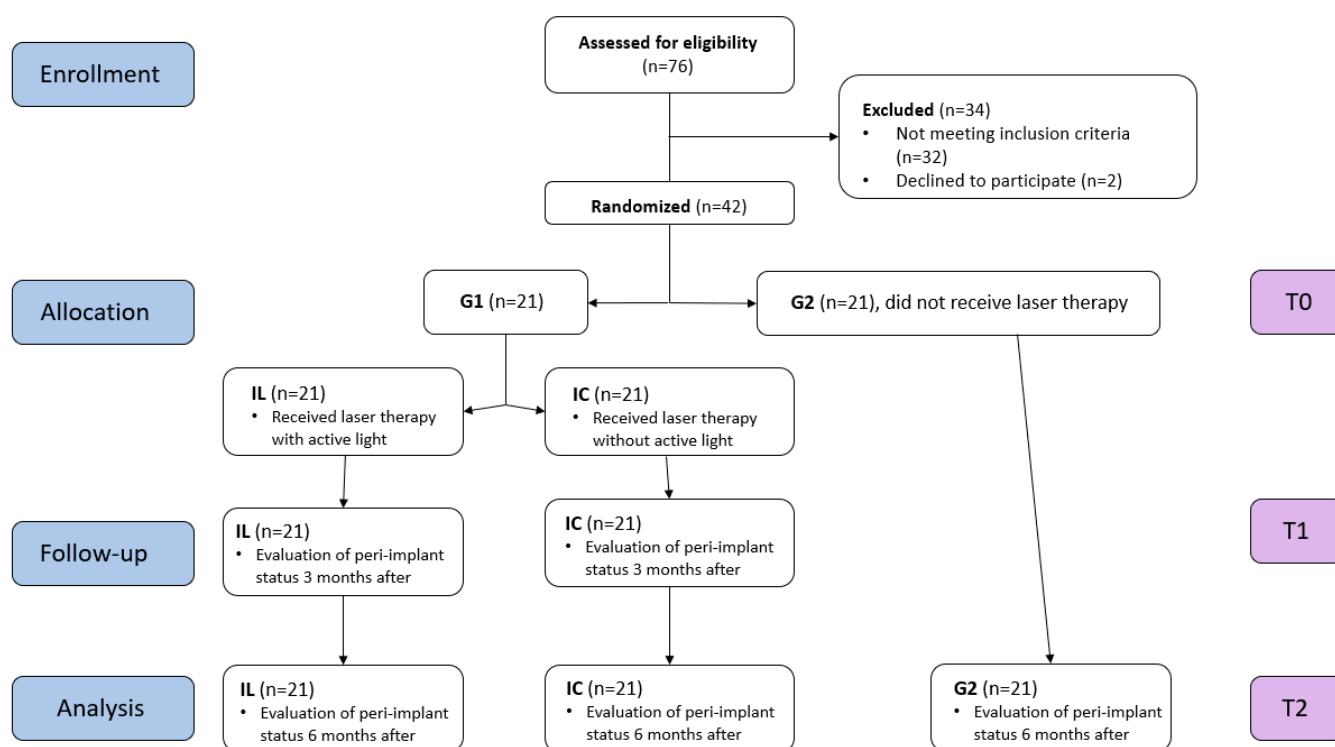


Figure 1. Flow diagram of the study.

The patients were informed about the procedure and about the fact that they could leave this study at any time, and signed an informed consent. Sample size was determined using the power analysis calculation. A total of 17 patients per group were estimated to provide 90% power for the detection of 1.0 mm of difference in the probing pocket depth (PPD) between the two groups with a standard deviation of 0.8 mm, 0.05 type I error, and 0.1 type II error. Considering the potential withdrawal of patients, we sought to enroll at least 21 patients per group.

2.3. The Periodontal Protocol

The periodontal status was evaluated by a periodontologist other than the one who performed the laser therapy.

Patients who, at the check-ups, after the completion of the fixed prosthetic treatment with implant support, showed accumulation of bacterial plaque and signs of peri-implant gingival inflammation underwent a new periodontal examination. After the radiographic examination proved the absence of bone loss and after the initial physiological remodeling of the bone, the following indices were recorded in a periodontal record:

- Plaque index (PI): the presence (+) or absence (−) of bacterial plaque on the buccal, lingual, mesial, and distal surfaces following the application of a plaque disclosing solution. The PI value was calculated by dividing the sum of all surfaces presenting dental plaque by the total number of surfaces examined, multiplied by one hundred;
- Probing pocket depth (PPD): the distance from the gingival margin to the apical limit of the peri-implant gingival groove measured in 6 places (mesio-buccal/centro-buccal/disto-buccal/mesio-oral/centro-oral/disto-oral) with a constant force;
- Bleeding on probing (BOP): by giving the following scores: 1, minimal punctate bleeding; 2, linear bleeding or in drops; 3, spontaneous or profuse bleeding, with or without suppuration [38].

Patients were divided into two groups:

- Group 1: 21 patients who received instructions regarding dental plaque removal and underwent scaling around the implant surface using titanium curettes. Only one out of the two implants each patient had benefited from laser treatment. The peri-implant status was evaluated at the time of the initial examination (T0), three months after (T1), and 6 months after (T2).
- Group 2: 21 patients who received instructions regarding dental plaque removal and underwent scaling around the implant surface using titanium curettes. The peri-implant status was evaluated at the time of the initial examination (T0) and at 6 months (T2).

2.4. The Laser Protocol

Laser therapy was randomly performed for one of the implants (IL) for each patient in group 1. For the second implant, located on another hemiarch, the same protocol was followed but without active light (IC). The patients and the periodontologist who evaluated the periodontal status were informed that only one of the implants benefited from laser therapy without specifying which one. During the irradiation, both the patient and the doctor wore protective glasses. The peri-implant sites were irradiated at moments T0 and T1 by the same clinician for the same implant site.

Laser therapy was performed with a dental diode laser (Prime, Litemedics, Lambda SpA, Milano, Italy), with a power of 12 Watt, in pulsed system and operating wave of 980 nm, using the working mode “periodontology”. A 320-micrometer optical fiber was inserted in the gingival sulcus and moved in a mesio-distal direction, both on the buccal surface and on the lingual surface, for 30 s.

2.5. Statistical Analysis

All data were collected in Microsoft Excel worksheets (Microsoft Corporation, Washington, DC, USA, 2018). Statistical analysis was performed with GraphPad Prism version 8.0.0 for Windows (GraphPad Software, San Diego, CA, USA). For each group of data, descriptive statistics such as mean, standard deviation, median, minimum, and maximum value were determined. Data normality was determined by the Kolmogorov–Smirnov test. The difference between the values of the clinical indices recorded at T0, T1, and T2 was determined using Fischer’s and ANOVA tests. The significance level chosen was set at 0.05.

3. Results

Patients selected to participate in this study, based on the inclusion and exclusion criteria, were aged between 27 and 58 years. Group 1 consisted of 12 women with mean age of 43 years and 9 men with a mean age of 45 years. Group 2 included 11 women with an average age of 46 years and 10 men with an average age of 42 years. For each patient, the values of the main indicators of peri-implant health status were recorded: plaque index (PI), bleeding on probing (BOP), and probing pocket depth (PPD). The mean values recorded for PI, BOP, and PPD for each group are presented in Table 1.

Table 1. Mean values of PI, PPD, and BOP.

Index	Group	Moment T0	Moment T1	Moment T2
PI (%)	G1	41.07	19.46	5.31
	G2	42.85	-	17.85
PPD (mm)	G1 IL	3.28	2.80	2.33
	G1 IC	3.33	2.85	2.61
	G2	3.38	-	3.23
BOP (score)	G1 IL	2.14	0.52	0.33
	G1 IC	2.19	0.66	0.47
	G2	2.23	-	0.80

T0 = initial examination, T1 = three months after, and T2 = six months after.

At the initial examination (moment T0), high PI values were recorded for most patients, with an average of 41.07% in the G1 group and 42.85% in the G2 group. In the G1 group at moment T0, 5 patients had PI values >50%, 12 recorded PI values of 30–50%, and 4 patients had PI between 10 and 30%. After a rigorous prophylactic cleaning session and patient instruction regarding dental plaque control, the PI values recorded at moments T1 and T2 were lower for all patients in the G1 group. Thus, at moment T1, no patient had a PI > 50%, and 3 had a PI value of 30–50%; for 17 patients, we recorded PI values of 10–30%, and 1 patient had a PI < 10% (Figure 2).

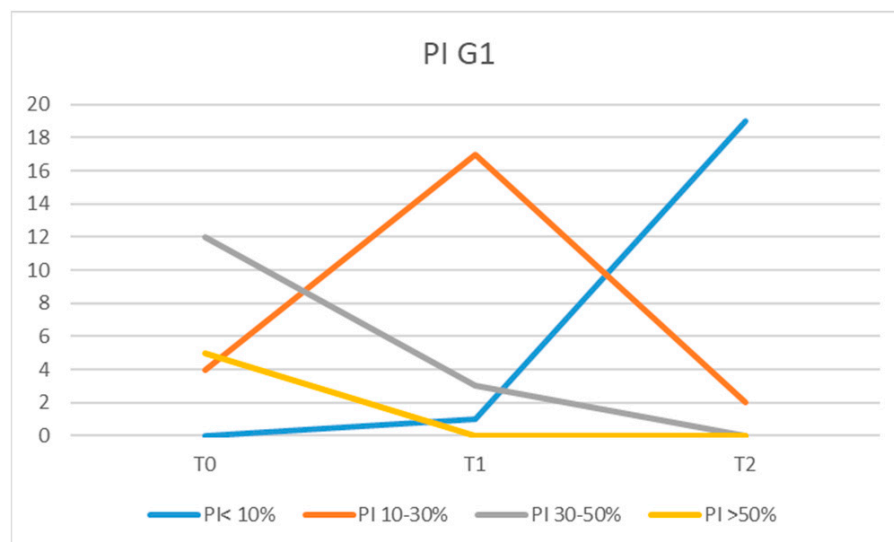


Figure 2. Values of PI in G1 at T0, T1, and T2.

The values recorded for PI in patients from group G2 at T2 moment, were low in most patients compared with the T0 moment. The values recorded at T2 were PI > 50% for three patients, PI = 30–50% for four, PI = 10–30% in eight of the patients, and PI < 10% in six of them (Figure 3). However, three patients had PI values similar to those recorded at moment T0, and two patients showed higher PI values.

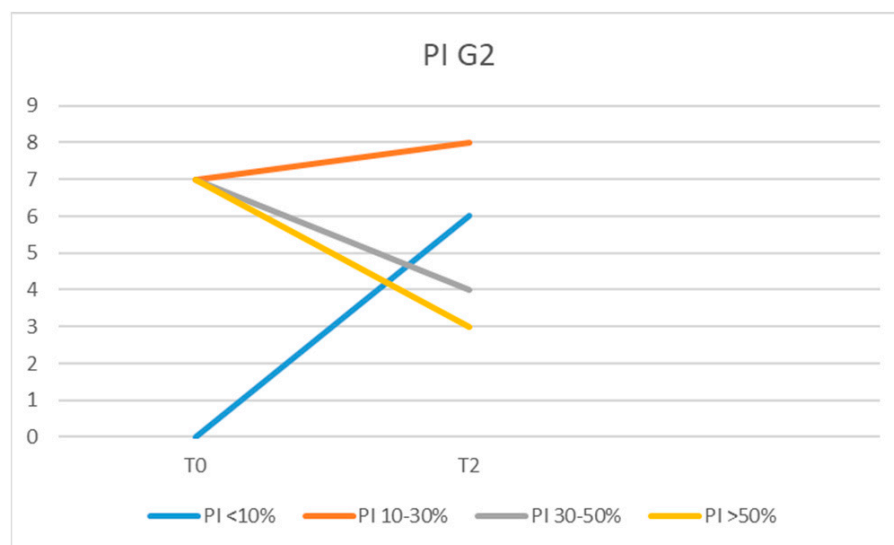


Figure 3. PI values in G2 at moments T0 and T2.

When comparing the average values of the plaque index between G1 and G2 at moment T2, a statistically significant reduction ($p = 0.0311$) was observed in patients from group G1.

The values recorded for PPD in the peri-implant sites in group G1 IL at moment T0 were 4 mm for 10 patients, 3 mm for 7 patients, and 2 mm for 4 of them. At moment T1, we recorded PPD = 4 mm in four patients, PPD = 3 mm in nine, and PPD = 2 mm in eight of the examined patients. At the 6-month examination (T2), the patients presented the following values: 1 had PPD = 4 mm, 8 had PPD = 3 mm, and 12 of them had PPD = 2 mm (Figure 4).

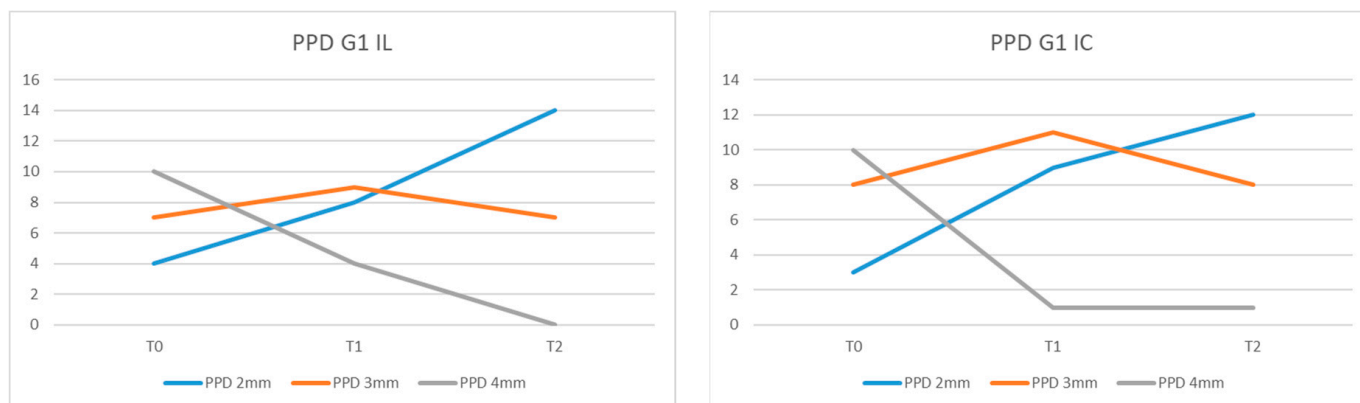


Figure 4. PPD values in G1 IL and G1 IC at moments T0, T1, and T2.

In G2, we recorded at the initial examination (T0) PPD = 4 mm in 10 of the examined patients, PPD = 3 mm in 9, and PPD = 2 mm in 2 of them (Figure 5).

The mean probing pocket depth (PPD) in the G1 IL group was 3.28 mm at T0, 2.80 mm at T1, and 2.33 mm at T2. For G1 IC, the values recorded for PPD were 3.33 mm (T0), 2.85 mm (T1), and 2.61 mm (T2). For G2, the average PPD values were 3.38 mm at T0 time and 3.23 mm at T2 time.

The difference between the mean values of PPD at T0, T1, and T2 between the G1 IL and IC groups was statistically insignificant ($p = 0.48$) as well as between G1 IL and G2 at the time of T2 ($p = 0.4003$). Comparing the mean values of PPD between G1 IL and G1 IC at T1 versus T0, no statistically significant difference was found ($p = 0.48$). Even when comparing the mean values of PPD for G1 IL and G1 IC, there was no statistically significant difference recorded at T2 compared with T1 ($p = 0.194$).

When recording the bleeding on probing (BOP), we found that all patients included in our study presented a higher score than one at moment T0.

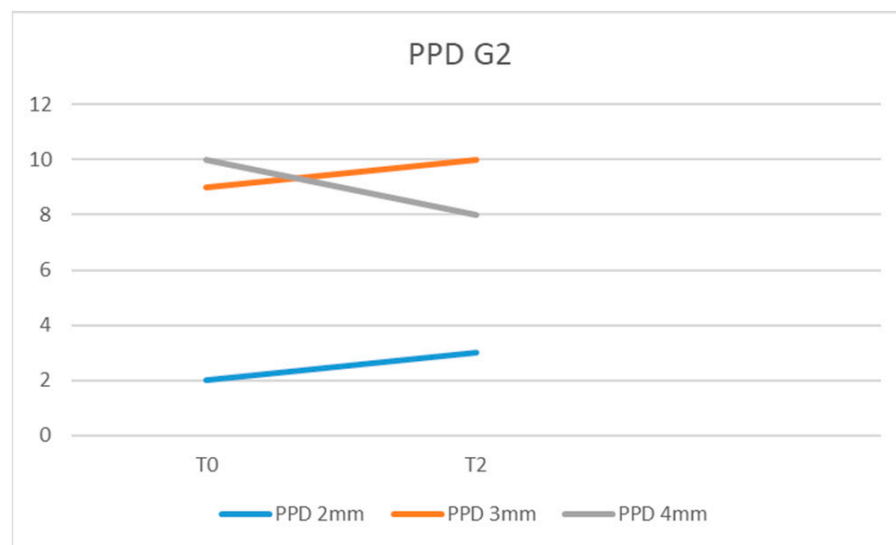


Figure 5. PPD values in G2 at moments T0 and T2.

In G1 IL, at moment T0, no patient had BOP = 0, 4 had BOP equal to 1, 10 had BOP = 2, and 7 had BOP = 3. At moment T1, 10 patients had BOP = 0 and 11 patients BOP = 1, and at time T2, 14 of them had BOP = 0, and 7 patients BOP = 1 (Figure 6).



Figure 6. BOP values in group G1 IL and G1 IC at moments T0, T1, and T2.

In the G2 group at the initial examination (T0), 7 patients presented BOP = 3; 12 had BOP = 2; and, in 2 patients, we recorded BOP = 1. At the 6-month examination (T2), the recorded scores for BOP were 2 for 3 patients, 1 for 11 patients, and 0 for 7 of them (Figure 7).

The average values of BOP at time T0 were 2.14 for the patients of the G1 IL group, 2.19 for those in the G1 IC group, and 2.23 for patients from group G2. In the G1 IL group, the mean BOP values were 0.52 (T1) and 0.33 (T2), while in the G1 IC they were 0.66 (T1) and 0.47 (T2). In the G2 group at time T2, the mean BOP value was 0.80.

The difference between the mean BOP values at moments T0, T1, and T2 between the G1 IL and IC groups was statistically significant ($p = 0.0162$). When comparing mean BOP values in G1 IL versus G1 IC, a statistically significant reduction was observed ($p = 0.0182$) in T1 versus T0 and a highly significant difference between T2 and T1 ($p < 0.0001$). Comparing the mean BOP values between G2 and G1 IL, the difference was not statistically significant ($p = 0.0743$) nor between G2 and G1 IC (0.0584).

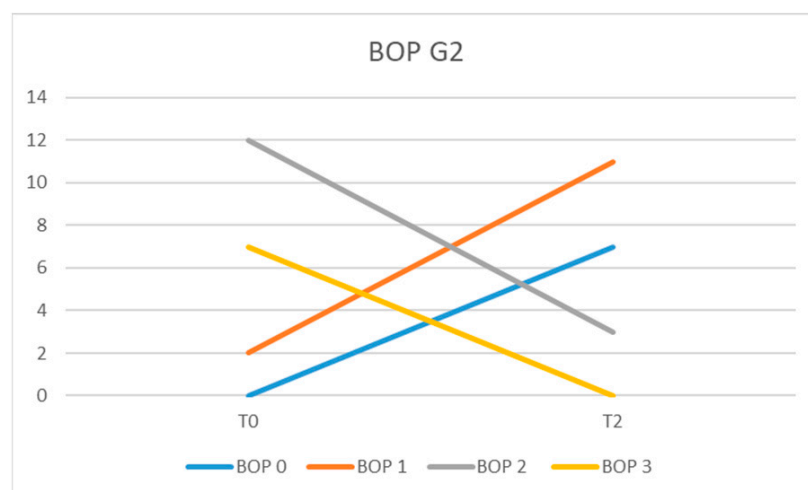


Figure 7. BOP values in group G at moments T0 and T2.

4. Discussion

Implant treatments are becoming more and more frequent and so are the potential negative effects that can come with implant-associated pathologies such as peri-implant mucositis and peri-implantitis. A recent review examined the potential risk factors for implant failure and treatments available and stated that pocket depth reduction can be achieved in the short-term with laser, and air powder abrasive could aid in cleaning a contaminated implant surface. The authors also stated that plaque control, surgical pocket elimination, and bone recontouring are other efficient treatments for peri-implantitis [21].

In our study, we tried to create patient groups that were as homogeneous as possible in terms of age and sex, so that these demographics did not influence the study results.

To establish the diagnosis of peri-implant mucositis, we examined the patients clinically (PI, PPD, and BOP) and radiographically. In G1, these assessments were made for two implants located at a certain distance from each other to ensure an objective assessment of the peri-implant status. If the patient presented several implants, the two implants that had the highest values of the recorded periodontal indices were included. In G2, the implants that recorded the most advanced signs of peri-implant mucositis were included. In group 1, laser therapy was randomly applied to one implant (IL), so that we could compare the values of the periodontal indices for IL with those obtained from the implant that did not receive active light (IC) in the same patient. Thus, the evaluation of the laser therapy was an objective one without oral hygiene habits, which differ from one patient to another, influencing the results.

We used PI, which assesses the plaque accumulation in the entire oral cavity as a percentage, to have an overview of the oral hygiene of each patient. The results of our study showed that there were patients who were not monitored at three months (T1) and had PI values comparable or even higher than those at the time of T0 during the 6-month examination (T2). The findings that the mean values of PI for G2 at the time of T2 were not significantly lower than at T0 and that, at G1, the differences between the PI values at these times were significant prove the importance of repeated controls at intervals of 3 months in patients with implant therapy. The frequency of intervals between training sessions and professional cleaning usually varies between 3 and 6 months, and their frequency should be based on the risk profile of each patient [39]. Monk et al. observed that patients with a history of periodontal disease are more compliant regarding oral hygiene measures and with periodic check-ups [40]. Supportive therapy provides the clinician with the opportunity to monitor peri-implant status, and professional dental care improves peri-implant health and, hence, the success rate of dental implants. The patient's informed consent form should include the accordance of the patient to comply with personal and professional peri-implant supportive therapy. Rokn et al. observed that after 5 years of

implant loading without following a regular maintenance schedule, one in five patients presents with peri-implantitis [41].

In this study we recorded no statistically significant change in PPD recording between G1IL, G1IC, and G2 at moment T2. However, we recorded reductions in PPD values for most patients, which explain the remission of inflammatory phenomena. Al Rifaiy et al. observed a statistically significant decrease ($p < 0.001$) in PPD in patients who benefited from laser therapy, both when comparing the values obtained at 12 weeks with the initial one and when comparing those recorded in patients who did not benefit from it [42]. The same results of statistically significant reduction of PPD after using laser therapy were obtained by Lerario et al. [43]. The finding that 89% of the implant sites presented at initial levels of PPD higher than 4 mm may explain the difference to the results of our study, in which 71% of patients presented at an initial PPD = 4 mm and no value was higher than 4 mm.

For the BOP evaluation, we chose to use the variant of giving a score, proposed by American researchers [38], because it allows the quantification of bleeding on probing at each individual implant site. The percentage evaluation in the entire oral cavity would not have allowed us to evaluate the results of the laser therapy at each implant's level. In our study, the finding that mean BOP values in G1 IL were significantly reduced at T2 compared with T0 and compared with G1 IC demonstrates that laser therapy can be an adjuvant in the treatment of peri-implant mucositis. Similar results were obtained by Al Rifaiy et al., who concluded that antimicrobial laser therapy, as an adjuvant in the treatment of peri-implant mucositis, is more effective than simple mechanical instrumentation [42]. In a study conducted on 125 implants, the authors observed significantly reduced values of PPD and BOP, with values $\leq 5\%$, in patients treated with laser [43]. Repeated adjunctive application of laser therapy at 0, 7, and 14 days at peri-implant sites produced significant clinical improvements after an observation period of at least 2 years [44]. The results of the study by Sánchez-Martos et al. showed that patients who received laser therapy as an adjunct to conventional treatment of mucositis had less bleeding at the 3-month reassessment than patients who received only conventional therapy ($p < 0.001$) [45].

Starting from the observation that in patients who received adjuvant laser therapy, BOP was positive at 44 sites at T0 and 6 sites at 3 months (T1), while for patients who received only mechanical treatment, BOP was positive at 52 sites at T0 and 28 of places at 3 months (T1), Tenore et al. considered that laser therapy can be used as an adjunct to mechanical therapy method [37]. Mariani et al. concluded that the additional use of laser showed small additional benefits in the treatment of peri-implant mucositis after a one-year observation period, which was not statistically significant [35].

On the other hand, the results of other clinical studies led the authors to the conclusion that the additional use of laser had no further positive influence on peri-implant healing compared with mechanical instrumentation as monotherapy [34,46]. Atieh et al. concluded that in the management of peri-implant mucositis, the combined use of diode laser and mechanical debridement provided no additional clinical advantage over mechanical debridement alone [47].

Adjunctive therapy such as laser or photodisinfection treatment could provide an auxiliary advantage in peri-implantitis, as was illustrated for periodontitis, especially in patients with other systemic pathologies, such as diabetes, myocardial infarction, or rheumatoid arthritis [48–51].

Early diagnosis of peri-implant mucositis and the application of effective therapeutic methods are preventive measures in the occurrence of peri-implantitis [52].

The limitations of our study consist of the small group of patients evaluated and the evaluation of only clinical indexes; microbiological or biochemical data could have offered a more complete image of laser treatment efficacy. Another limitation is lack of comparison with other adjuvant methods in order to assess treatment superiority.

Given that the data regarding adjuvant laser treatment of peri-implant mucositis are sparse and controversial, future clinical trials are needed to evaluate the potential benefit of this approach.

5. Conclusions

The peri-implant health status is directly correlated with the maintenance of oral hygiene; therefore, the clinician must give importance to supportive therapy in order to increase the success rate of dental implants.

Laser therapy as an adjunct to conventional treatment of peri-implant mucositis led to a statistically significant reduction in probing bleeding at 3-month and 6-month re-evaluations. When PPD \leq 4 mm, laser therapy leads to an evident reduction in probing depth but not enough to be statistically significant.

The conclusions of the present study should be considered preliminary and interpreted with caution. Further randomized clinical trials should be conducted to obtain solid conclusions.

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Conflicts of Interest: The authors declare no conflict of interest.

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STUDY REGARDING TOOTH SHADE MATCHING USING DIGITAL DENTAL PHOTOGRAPHY

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Abstract

Choosing the right color is crucial in oral rehabilitation. Shade matching has often been a dilemma in the past but remained a crucial procedure even in our daily practice, especially in the case of frontal restorations. Digital photography is a common way of communication between medical team members and could be used in dental practice with a high success rate for accurate shade selection. The study aims to qualitatively compare the L*, a*, and b* values of shade matching obtained by digital photographs with two different devices: a smartphone (with flash and without flash) and a digital camera using the Vita Classical shade guide. The results showed that a correctly set DSLR camera could be used successfully to perform shade matching; older smartphones with automatic settings are not suitable for shade matching.

Keywords: digital dental photography, shade matching, DSLR camera.

1. Introduction

The concept of oral rehabilitation has been greatly reevaluated in digital dentistry. Patients attribute a much more significant role to aesthetics than to function [1]. Choosing the right color is crucial for successful treatment [2]. Shade matching had often been a dilemma in the past [3] but remained a crucial procedure even in our daily practice, especially in the case of frontal restorations. The visual color determination is subjective.

Digital methods were introduced to eliminate subjectivity: colorimeters, spectrophotometers, digital cameras, and intraoral scanners [4]. Digital photography is a common way of communication between medical team members and could be used in dental practice with a high success rate for accurate shade selection [5]. The number of dentists who use smartphones instead of professional DSLR cameras to document clinical cases, determine

the color of future restorations, and communicate them to the dental technician is increasing due to smartphones' easy accessibility and handling [6]. Having additional information with the help of photographs, dental technicians can create dental restorations with greater accuracy and naturalness and achieve the results expected by patients [7]. The oldest color system, created by Professor Albert H. Munsell in 1905, defines the three dimensions of color: hue, value, and chroma. This system has been widely used in many fields of color science as a standard system of color determination [8]. The CIELAB system, standardized by the Commission Internationale de l'Eclairage (CIE), is used to research the optical parameters of dental structures and materials. It allows the expression of each color as a point with three coordinates, defined numerically: L* (Lightness), a* (Red/Green Value), b*

(Blue/Yellow Value). The system allows the calculation of chroma (C^*) and hue (H^*) [9]

The study aims to qualitatively compare the L^* , a^* , and b^* values of shade matching obtained by digital photographs with two different devices: a smartphone (with flash and without flash) and a digital camera with the Vita Classical shade guide.

2. Materials and Methods

Seven vital and intact coronary central incisors were photographed in randomly selected people of different ages, both women and men. The digital shade matching was performed, and the Vita Classical shade guide was used for the visual shade selection.

All the participants in this study signed permission to use their history files for educational purposes and studies.

- The equipment used for the workflow: iPhone 11 (12 Mpx camera), Nikon D750 FULL-FRAME 24 MPX digital camera, Photo lens: SIGMA 105 mm F 2.8 MACRO with 1: 1 multiplication factor, Viltrox Macro ring lite JY670 ring flash, 18% gray card, Cheek retractors, and Weifeng WF-6663A tripod.

- Device settings: M (manual) operating mode, MF (manual focus) mode, diaphragm: $f / 14$, exposure time: $1/125$ s, ISO (sensitivity) 160, and WB (white balance) – flash set to Manual function at $1/8$ power.

With the devices fixed on a tripod in the same position, continuous sets of photos were taken at the same 20 cm distance: digital photos with a DSLR camera and ring flash, photos with the smartphone with flash, and photos with the smartphone without a flash.

All the photographs were transferred to the computer and processed using Adobe Photoshop Lightroom CC software and the CIELAB system to define color accuracy. The $L^*a^*b^*$ values were identified in the photographs. For the L value, 0 was for black color, and 100 represents a perfect reflecting diffuser. The a^* and b^* axes have no defined limits. Positive a^* is red, negative is green, positive b^* is yellow, and negative is blue. The system allows the calculation of chroma (C^*) and hue (H^*).

Protocol used to process the obtained photos:

The photos were imported into the Adobe Photoshop Lightroom CC library. A single photo was selected and switched to development mode. A grid from the view-loupe overlay-grid option was selected to calibrate. The photos were standardized with the help of a gray card by touching it with the tool dedicated to establishing the white balance. The $L^* a^* b^*$ exposure values were adjusted as close as possible to 54, 0, and 0, using the indicator positioned on the gray card. This value was adjusted on the keyboard arrows or entered manually. The photo was extended so that the upper central incisor occupied the entire screen. Adobe Photoshop Lightroom CC software initially opens in RGB color mode. By right-clicking on the histogram and clicking on Show Lab Color Values, we switched to the CIELAB model. The indicator was positioned at the central grid on the tooth, and the values $L^* a^* b^*$ were recorded. Another grid next to the center area was chosen if there were light reflections. These actions were repeated for all photos in the set.

Before taking each photo, the following aspects were taken care of: the patient's clothing should be a neutral color, the patient should not show traces of makeup, the teeth should be clean and moist, the ambient light should be appropriate,

and the patient should be positioned in front of a white wall, lips and cheeks should be retracted, the position of the gray card should be under the upper central incisors, and a distance of 20 cm should be between the camera and the tooth.

The first series of photos used a Nikon d750 professional DSLR camera with a large image sensor (full-frame). The focal length is 105 mm, macro photography's most frequently used distance. The image stabilization lens, OS, allows shooting at longer exposure times, even from the hand, without needing a tripod. Minimum focusing distance is another crucial aspect.

The Viltrox Macro ring lite JY670 ring flash is a LED flash with relatively high power for dental photography with a white ring for diffusion in front of the LEDs to not create harsh shadows in the photo.

The manual camera and manual focus mode were used for taking pictures. The camera was mounted on a tripod. The aperture was set to F 14 to provide a good depth of field. The shutter speed was 1/125 seconds at 160 ISO (image sensitivity) with the flash set to 1/8 power and the white balance on the flash. The shooting process was repeated until the photo was clear, with a correct illumination of the teeth.

A tripod-mounted smartphone iPhone 11, was used to take the next series of photos in automatic mode. The photos were obtained for each patient in JPEG format, with flash and without flash. Once the shooting process was complete with all the devices and methods mentioned in the study, the photos were imported into the Adobe Photoshop Lightroom CC library to make the necessary adjustments and to extract the L, a, and b values.

The imported photos should be well-focused and well-lit. The most commonly used image

file formats are JPEG, TIFF, and RAW, the latter being considered the true digital negative because the original, uncompressed data is in RAW format. RAW images take up considerably more storage space than JPEG but offer advanced image editing. The histogram of each photograph can be visualized in the software.

When the pictures are taken with a white background, histograms may indicate an overexposure of the image due to light shades. The correct white balance setting is when the red/green/blue channels show the peaks of the graphics identical to those of the individual color channels. An 18% gray or Medium Gray card was used to adjust the exposure because it is the most used in determining the exposure and the correct white balance (Figure 1).

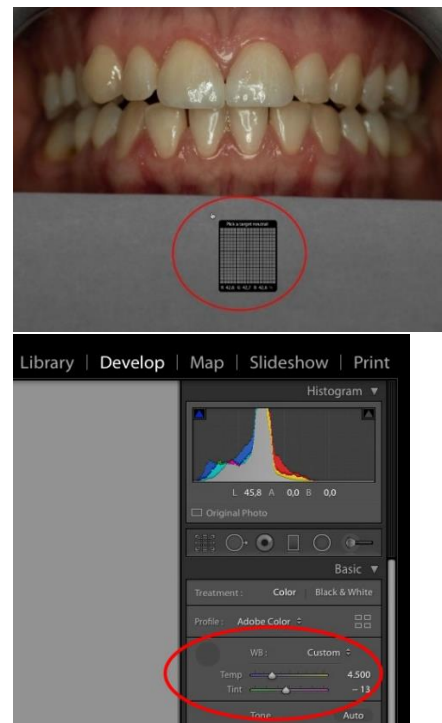


Figure 1. Achieving the correct white balance using the 18% gray card and the white balance selector.

In Develop mode, the indicator was positioned on the gray card in the area below the upper frontal

group, then in the upper right corner, below the histogram. The exposure was adjusted from the keyboard arrows until the correct $L = 54$, $a = 0$, and $b = 0$ values were obtained. This process was repeated on each photo of each patient.

A crucial goal in dental photography is to obtain photos that reproduce the natural color of the teeth. The correct white balance (WB) of the pictures is essential. The white balance has several settings available, depending on the lighting conditions the photo is taken. For dental photography, the primary light source is the flash (5500 Kelvin), representing a standardized natural illuminant; the white balance must be set in flash mode. The 18% gray card was used to set the correct white balance.

After all the necessary settings were done, the L a b values were extracted from each photograph (DSLR camera, Mobile phone with flash and without flash) (Figure 2, 3).

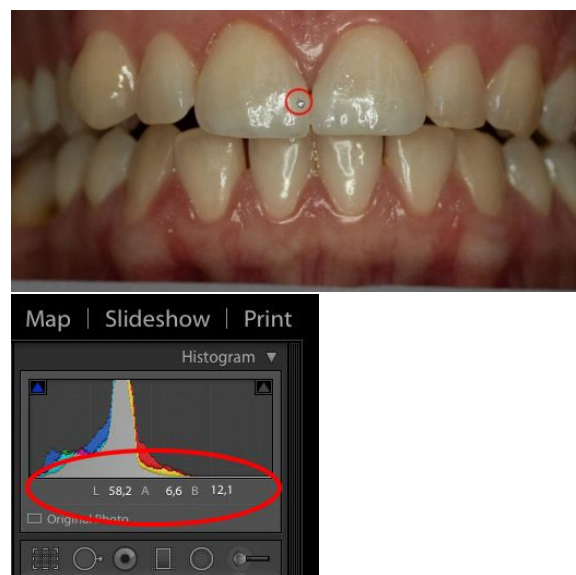


Figure 2. Using the indicator to view L^* , a^* , b^* value.

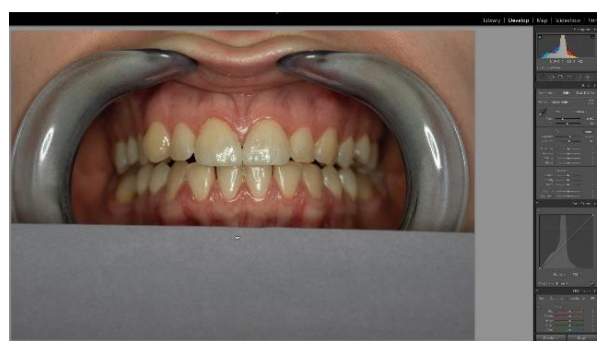


Figure 3. Extracting the L^* , a^* , b^* values for each photo.

The same operator performed each determination three times, and the final value was obtained from their average. After all the necessary settings were done, the L*, a*, b* values were extracted from each photograph (DSLR camera, Mobile phone with flash and without flash). The same operator performed each determination three times, and the final value was obtained from their average. The obtained values were recorded and compared with each other for each patient, respectively, with the Vita Classical shade guide (Table 1) and the color obtained by visual shade matching for each patient.

Table 1. This is a table. Tables should be placed in the main text near to the first time they are cited.

Shade	L*	a*	b*
C4	34,92	7,23	12,87
A4	43,05	8,34	14,97
C3	46,29	6,79	12,88
B4	50,02	8,17	18,33
A3,5	48,94	8,49	15,70
B3	49,28	7,97	16,83
A3	56,16	7,96	14,58
D3	55,65	7,19	11,69
D4	55,57	6,18	14,40
C2	54,83	6,87	13,40
C1	55,87	5,15	8,81
A2	60,55	6,99	12,46
D2	59,41	5,59	8,59
B2	61,90	6,09	12,55
A1	63,46	5,05	9,11
B1	59,85	4,24	7,34

Statistical analysis was performed using the GraphPad Prism 9 for macOS version 9.3.1 (350). The statistical significance was set at $p < 0,05$. The mean (M) and standard deviation (SD) were calculated. The used tests: t-test, Pearson test.

3. Results

The results of the visual shade matching performed for each subject are presented in Table 2.

Table 2. Result of the visual shade matching

Patient	Color
1	A2
2	C2
3	A3,5
4	A1
5	C3
6	B2
7	B2

Descriptive statistic of the L*, a*, b* values extracted from each photograph is represented in Table 3.

Table 3. This is a table. Tables should be placed in the main text near to the first time they are cited.

Value	How to obtain the value	Mean (M)	Standard Deviation (SD)	95% CI
L *	DSLR Camera	57,87	6,409	52,04-63,90
	Phone Camera with flash	62,16	6,942	55,74-68,58
	Phone Camera without flash	65,13	7,109	58,55-71,70
a *	DSLR Camera	6,714	0,9477	5,838-7,591
	Phone Camera with flash	3,443	1,475	2,079-4,807
	Phone Camera without flash	4,414	2,962	1,675-7,153
b *	DSLR Camera	12,57	2,764	10,02-15,13
	Phone Camera with flash	26,73	5,121	21,99-31,46
	Phone Camera without flash	21,60	6,032	16,02-27,18

The Pearson test results shown that the values (L^* , a^* , b^*) recorded after analysing the photos taken with the phone with or without flash are correlated ($r = 0.6759$, $p = 0.0487$; r

$= 0.9913$, $p < 0.0001$; $r = 0.8191$, $p = 0.0121$), and aren't correlated with those recorded after analysing the photos taken with the DSLR camera.

The t-test results showed no statistical differences between the mean of the L^* values obtained after using the three types of cameras ($p = 0.2115$, $p = 0.0703$, $p = 0.2141$). Regarding the mean of the a^* value, a very significant statistical difference ($p = 0.0052$) was observed between those obtained after analysing the photographs performed with a digital camera and smartphone with flash; between the other values were found no statistical differences. In the case of the mean of the b^* values, it was demonstrated that are extremely significant differences between ($p = 0.0006$) the mean values obtained in case of the photographs obtained with the digital camera and smartphone with flash and very significant differences in the other cases ($p = 0.0087$; $p = 0.0078$)

After assessment of the obtained data, they were compared with the values of the Vita Classical shade guide. Following the evaluation based on the closest standard values, the most appropriate colour was chosen for each value L^* , a^* , b^* (Table 4).

Table 4. The values obtained transformed into Vita Classical shade guide colours.

Patient	DSLR Camera			Smartphone with flash			Smartphone without flash		
	L^*	a^*	b^*	L	a^*	b^*	L	a^*	b^*
1	D2	C3	A2	A1	B1	B4	A1	B1	B4
2	B3	A3/B3	B3	A1	B1	B4	A1	B1	B4
3	A3,5	C4	A3,5	A3,5	B1	B4	C1	A1	C2
4	B2	A1	C1	A2	B1	B4	C2	A1	A3,5
5	B2	D4	A2	A1	D4	B4	A1	A3,5	B4
6	B2	D3	A2	A1	B1	B4	A1	B1	B4
7	B2	C3	A1	B1	B1	B4	A1	B1	B4

4. Discussion

The values obtained by different photographic methods differ somewhat in the case of each camera used, but no statistically significant differences were obtained regarding the L values.

All the devices are accurate for the first step of shade matching, the choice of brightness.

The values closest to those obtained by visual assessment of the L values were obtained with the DSLR camera, demonstrating that this device is the most suitable for use in this clinical phase. Taking photos with a DSLR camera requires knowledge of settings, techniques, and photo terms. However, there are some disadvantages of DSLR cameras;

they are expensive, heavy, bulky, and not easy to carry [10].

Great attention should be paid to ISO sensitivity, a number defined by the International Standard Organization and indicates the film's or sensor's sensitivity to the light source. The higher it is, the higher the sensitivity of the sensor is. Increasing the ISO also attracts some negative aspects, materialized by the image noise captured by the sensor, compared to an image taken with a small ISO. This noise translates into images of specific grain size; the higher the ISO increases, with colour distortion and an annoying effect [11]. The new smartphones have a good ISO value, allowing greater light sensitivity with low noise [12].

The most accurate record was in the case of patient "3" for the L value and b value. The determined colour was the same as in the visual shade matching case. The phone with flash indicated the same L value, but the other values were different as in the visual shade matching case and the colour recorded with the DSLR camera.

In the case of the smartphone, we tend to have the characteristics of L and a value for the light shades of the shade guide, respectively b values in the range of the yellow group (B) of the shade guide. These shades are not differentiated. They are almost similar in each patient, which indicates an incorrect exposure while taking pictures with the smartphone. The use of the flash resulted in the most inconclusive values. The precise display of teeth in digital photographs requires high exposure settings [13].

In the DSLR camera case, these values seem more differentiated, and the shade obtained from the L values even coincides with the one visually appreciated in the patient "6", "7".

The camera settings must be done manually, as in the DSLR case. In the case of the phone, the automatic settings were used, which resulted in the recording of very close shades, different from those obtained by visual appreciation or with the DSLR camera.

The light source during the photo session can significantly influence the image's quality. In our case, the photos were taken in natural light using a flashlight. Due to this, we had to adjust the white balance on the photos using a gray card to help the standardization process in Photoshop software [14]. Sampaio et al. demonstrated that the gray card has a significant effect used with a DSLR camera and ring flash system or with an iPhone 7 [15]. According to Maddula et al., the use of the gray card during the digital photo sessions results in better registration and evaluation of the tooth shade than those realized without the gray card [16]

The phones with automatic settings can not adapt perfectly to the light source. The values obtained are quite different from those obtained with the DSLR camera.

Due to the posture of each photographed patient may be differences in the obtained results. The patient's soft tissues can create a different contrast and influence the results.

The extraction of values must be performed on several areas of the labial surface because the teeth have a different coloration on certain parts of the surfaces. In our case, only one area was chosen to extract values, which may be another reason for obtaining these more dispersed values. The gender and age of the photographed patients were not taken into account. Studies in the literature confirm that these differences exist. A study by MG Demirel and MT Tuncdemir shows significant differences between all three parameters: $L^* a^* b^*$, in people of different

sexes. Thus, most discrepancies were found in men compared to women. They also noted significant differences between young and older people and fewer differences between middle-aged and older people. [17] Goodkind and Schwabacher reported that, on average, women have lighter, less reddish, and yellow teeth. Teeth also tend to become darker in color and more reddish with age [18].

A study by Bostjan Pohlen highlighted the capability of visual shade matching of a group of students of different sex and inexperienced in such determinations. He concluded that gender plays an essential role in choosing a color. In its results, women manage to appreciate color more accurately than men. One possible cause may be genetics [19].

Visual appreciation is subjective. Many factors, such as sex, age, visual acuity, clinical experience, condition, and emotions, influence it. The human eye cannot perceive brightness, chroma, and hue separately, which can be influenced by this aspect. Choi, following his study, concluded that digital analysis of tooth colour is more accurate and reproducible than the visual method [17,20]. The correct digital shade matching will be successfully reproduced by the restorations only if the dental technician can process this data as required.

Digital photography is a reliable method for shade selection in dental offices. Using the 18% gray reference card leads to highly standardized colours, especially in the case of the DSLR camera and the ring flash.

A study conducted by Prabhat Shrestha from Kist Medical College, in which the photos obtained with a DSLR camera and an iPhone 11 were compared, reports that the most

significant differences in the obtained colour values resulted from the smartphone [21].

One of the reasons why the smartphone values are different is the JPEG image format. To make precise adjustments and extract the correct results, we need access to raw files (RAW) obtained by a DSLR camera [11, 20]. The newest smartphones can generate the same image format as DSLR cameras [22].

Constance Boissin believes that the DSLR camera can be replaced with that of the iPhone. [23]

In a study comparing the photos taken with the DSLR and iPhone X camera, no noticeable difference was observed between the photos taken by these devices. However, they respected a distance of at least 24 cm [6] A two-lens camera iPhone 11 was used in this study, one with a wide angle of view and the other with a standard angle, similar to the focal length of the human eye. The images obtained through the digital camera are superior to those obtained with the iPhone 11. The DSLR camera has a much better performance configuration: the DSLR camera's large image sensor, which provides high colour accuracy of images, and DSLR lenses that are specially treated during the manufacturing process to provide a clear and well-defined image, those in the Medium Pro range [23, 24]. Related to Mohammadi et al., the shade matching with calibrated smartphone and the use of Adobe Photoshop software assure high precision and reliability during the procedure [25].

Sirintawat et al. demonstrated that combining different techniques during shade selection would result in the most accurate determination [26].

5. Conclusions

- A correctly set DSLR camera can successfully perform shade matching.
- The use of older smartphones with automatic settings is not an accurate shade matching procedure.
- Additional knowledge and a well-trained practitioner is needed to process the images in Photoshop software.

- The light source can considerably influence the digital shade selection. It is desirable to use natural light.

The digital shade matching facilitates the rapid transmission of the information to a well-trained dental technician and allows the individualization of the restorations.

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