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ABSTRACT

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MICROLEAKAGE OF COMPOSITE RESTORATIONS UNDER DIFFERENT PROTOCOLS OF PREPARATION, ADHESIVE PREPARATION AND CARIOUS CAVITIES DEPTH

Aim: To assess the microflow of composite restorations in teeth prepared according to various protocols of preparation (traditional with rotary instruments and air abrasion), adhesive preparation (tissue etching and without etching) and the depth of carious lesions.

Material and methods: The study was carried ouconducted on 180 pre-prepared extracted teeth, divided into 4 groups of 45 samples each: GI, GII, GIIII, GIV. On the occlusal surface of the teeth, cavities of different depths were formed. In groups GI, GII according to the technique of traditional preparation with the use of rotary tools, in GIII, GIV – according to the technique of air abrasion. In GI and GIII groups, tissue etching was not performed, in the GII and GIV groups, 37 % phosphoric acid gel was used for etching. A one-component light-curing adhesive Charisma GLUMA® Bond 5 was put into the prepared cavities GI, GII, GIII, GIV, which then were filled with a light-hardening hybrid composite Charisma “SMART”. All samples were subjected to thermal cycling, varnished, immersed in a 1% aqueous solution of methylene blue for 24 hours, separated along the axis, and studied the penetration of the dye through a microscope.

Results: Data comparisons within groups with different cavity preparation protocols showed a difference in the mean values of the depth of dye penetration in each group, but it is not always statistically significant. Differences were recorded when comparing groups according to adhesive preparation protocols. The use of air abrasion in GIII reduced the restorations microleakage rates compared to GI (p < 0.05). In GIV there was a similar situation in comparison with GII, but not significant (p > 0.05).

Conclusions: The state of microleakage of restorations is influenced by both the cavities depth and the protocols of preparation and adhesive preparation, with the latter having a stronger effect. Mutually, these factors do not affect microleakage. Lower microleakage rates are recorded during preparation with the air abrasion technique.

Keywords: dental, caries. acid etching, adhesive, cavity preparation, air abrasion.

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МІКРОПРОТІКАННЯ КОМПОЗИТНИХ РЕСТАВРАЦІЙ ПРИ РІЗНИХ ПРОТОКОЛАХ ПРЕПАРУВАННЯ І АДГЕЗИВНОЇ ПІДГОТОВКИ ТА ГЛИБИНИ КАРІОЗНИХ ПОРОЖНИН

Мета: Оцінити мікропротікання композитних реставрацій в зубах, підготовлених за різними протоколами препарування (традиційне роторними інструментами і повітряною абразією), адгезивної підготовки (протравлювання тканин і без протравлювання) і глибини каріозного ураження.

Матеріали і методи: Дослідження проводили на 180 попередньо підготовлених видалених зубах, розподілених на 4 групи по 45 зразків в кожній: GI, GII, GIII, GIV. На оклюзійній поверхні зубів формували порожнини різної глибини. В групах GI, GII за технікою традиційного препарування із застосуванням ротаційних інструментів, в GIII, GIV – за технікою повітряної абразії. В GI і GIII групах протравлення тканин не проводили, в GII і GIV протравлювали 37% phosphoric acid gel. В підготовлені порожнини GI, GII, GIII, GIV вносили однокомпонентний світлозатверджуваний адгезив Charisma GLUMA® Bond 5 і пломбували світлотвердіючим гібридним композитом Charisma «SMART». Всі зразки піддавали термоциклюванню, покривали лаком, занурювали в 1% водний розчин метиленового синього на 24 години, сепарували по осі, вивчали проникнення фарбника через мікроскоп.

Результати: Порівняння даних всередині груп з різними протоколами препарування порожнин свідчили про різницю середніх значень глибини проникнення фарбника в кожній групі, але вона не завжди статистично значуща. Реєстрували відмінності при порівнянні груп за протоколами адгезивної підготовки. Використання повітряної абразії в GIII зменшувало показники мікропротікання реставрацій в порівнянні з GI ($p < 0.05$). В GIV була аналогічна ситуація в порівнянні з GII, але не суттєва ($p > 0.05$).

Висновки: На стан мікропідтікання реставрацій впливають як глибина порожнин, так і протоколи препарування та адгезивної підготовки, причому останні впливають сильніше. Взаємно ці фактори не впливають на мікропідтікання. Менші показники мікропротікання реєструються при препаруванні технікою повітряної абразії.

Ключові слова: зуби, карієс, кислота, адгезив, препарування порожнини, повітряна абразія.

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INTRODUCTION

The durability of restorations in teeth depends on many factors, one of which is the quality of the fit of the composite restoration to the walls of the carious cavity. The state of adaptation of restorations to the hard tissues of the tooth is studied by various methods, including assessing the density of the fit of the material with marginal microleakage. Microleakage often occurs during the bonding process between the composite resin and the hard tissue of the tooth, which can lead to secondary caries [1].

During the setting process, polymer composite materials can undergo shrinkage, which causes difficulties with effective sealing on the tooth surface, potentially leading to the penetration of bacteria [2]. Possible reasons for the violation of the marginal fit of restorations can be the incremental technique of introducing the composite material into the carious cavity [3], polymerization shrinkage of the composite material [4], protocols of adhesive preparation methods [5], method of the carious cavity preparation [6]. Therefore, appropriate pretreatment of bonding surfaces (restoration – tooth tissue) is crucial [7].

Recently, the treatment of dental caries has changed radically from traditional restorative treatment to or minimally invasive dentistry (MID) [8]. Traditional restorative techniques involve removing a large part of the tooth structure to eliminate cariogenic bacteria, preparing the teeth for mechanical retention of the restoration and resistance to occlusal forces, and removing demineralized dentin. With the advent of adhesive dental materials that micromechanically bond to the tooth and thereby ensure its strength and reliability, the need for extensive removal of tooth structure for restoration retention has disappeared [9].

Among the MID methods, deserves attention an air-jet abrasion (AA) for its gentle treatment of hard tissues during the preparation of carious cavities, which has evolved over time from a new concept of an alternative method of carious cavity preparation to the main means of ensuring truly conservative preparation to preserve the strongest possible tooth structure [10]. The indications for the use of air abrasion in modern dentistry are very wide [11]. It can be defined as a method of delivering abrasive material under different pressures to remove deposits and stains on teeth, modify the surface of dental materials or remove tooth structure [10]. However, the use of this method is recommended for the preparation of only shallow carious cavities [11].

Given the conflicting data on the impact of Al_2O_3 particles on tooth enamel, a more complete understanding of the use of enamel sandblasting is needed. This may justify its clinical use as a substitute or in combination with traditional phosphoric acid etching for adhesion [12].

Literature reviews show that the results of studies on the impact of different protocols of preparation and adhesive preparation of carious cavities on the state of marginal adaptation of restorative materials are quite contradictory, and its state has not been investigated in carious lesions of different depths.

OBJECTIVES

The aim of the study was to evaluate the microleakage of composite restorations in teeth prepared according to different protocols of preparation (traditional rotary instruments and air abrasion), adhesive preparation (tissue etching and without etching) and depth of carious lesion.

The null hypothesis is that (1) different preparation protocols and (2) different adhesive preparation protocols of carious cavities do not affect the microleakage status of restorations.

MATERIAL AND METHODS

The study of marginal permeability of restorations was performed on 180 previously prepared extracted teeth, divided into 4 groups: GI, GI, GI, and GIV. The protocols of preparation and adhesive preparation of cavities and the number of included samples are given below.

Cavity preparation protocol. In groups GI (n = 45), GII (n = 45), cavities of different depths were formed on the occlusal surface of the teeth by the traditional preparation (TP) technique using rotary instruments – a diamond fissure bur in a high-speed tip with a water spray. New burs were used after every five samples. The prepared cavities were washed with a syringe, dried with oil-free air.

In groups GIII (n = 45), GIV (n = 45), cavities of different depths were formed on the occlusal surface of the teeth using the air abrasion (AA) technique with Al_2O_3 particles of 50 µm size at an angle of 45° under an air pressure of 60 psi at a distance of 2 mm using a Sandman Futura sandblasting unit (Denmark).

Protocol for adhesive cavity preparation. In GI and GIII, no preliminary etching of tooth tissues was performed. In groups GI and GIV, all cavities were etched with 37 % phosphoric acid gel. Enamel was etched according to the manufacturer's instructions for 30 seconds, and dentin – for 15 seconds. The teeth were thoroughly rinsed for 30 seconds and air-dried without lubrication.

In the prepared cavities of GI, GI, GIII, GIV, a single-component light-curing adhesive Charisma GLUMA® Bond 5 (Heraeus Kulzer, Germany) was applied, after which the light-curing hybrid composite Charisma "SMART" (Heraeus Kulzer, Germany) was applied using the incremental layer technology. Each layer of the composite was applied with a thickness of 2 mm and polymerized with a lamp at a distance of 2 mm from the surface of the layer for 40 seconds.

When forming the cavity depth, the visual criteria of the International Caries Detection and Assessment System (ICDAS) [13] were taken into account: moderate stage caries (ICDAS™ codes 3 and 4); extensive stage caries (ICDAS™ codes 5).

For artificial aging of the restorations, the samples were subjected to a thermal cycling process consisting of 200 cycles alternating between 5±2°C and 55±2°C with a holding time of 60 seconds at each temperature with intervals between baths of 10 seconds. The thermal cycling regime was observed according to the method of Umer F. et al. (2011) [14].

The prepared teeth were covered with 3 layers of nail polish, not reaching 1 mm to the edge of the restoration and around it. The samples were placed in a 1% aqueous solution of methylene blue for 24 hours, washed in running water for 1 hour. The teeth were separated in the medio-distal direction through the center of the restorations with cooled diamond discs. To eliminate defects and coarse roughness, the surface of the cuts was polished to a mirror shine using Sof-Lex polishing discs (3M ESPE).

The degree of dye penetration between the restoration and tooth tissues was assessed using an Olympus BH-2 microscope (Japan) at × 40 magnification and expressed in points [15]: 0 = no dye penetration; 1 = dye penetration into the enamel part of the cavity wall; 2 = dye penetration into the dentine part of the cavity wall but not including the pulpal floor of the cavity; 3 = dye penetration including the pulpal floor of the cavity. Each sample was examined by two experts, and the results were recorded separately.

Statistical analysis was performed using the MS Excel for Windows 10 statistical package. Quantitative indicators were determined by parametric criteria in the form of the mean (M) and its error (m). To compare quantitative data in the studied groups in the case of their normal distribution, Student's T-test was used, and in case of deviation from normal distribution – Mann–Whitney U-test. To study the influence of different protocols of preparation and adhesive preparation and the depth of carious cavity lesion on the state of microleakage of restorations, one-way and two-way analysis of variance (ANOVA) were performed. All data were considered statistically significant at $p < 0.05$ level.

The authors take full responsibility for ensuring compliance with Articles 43 and 45 of the Law of Ukraine "Fundamentals of Health Legislation of Ukraine", the Declaration of Helsinki's "Recommendations for Physicians Involved in Biomedical Research Involving Human Subjects" (1964, revised in 1983), Directive 2001/20/ EC of the European Parliament and the Council of the EU of April 4, 2001 (as amended). Informed consent was obtained from all participants, who were made fully aware of the study's objectives and procedures. All participant data were anonymized and securely stored in password-protected files, accessible solely to the research team.

RESULTS

The obtained data on the absolute distribution of samples by the depth of dye penetration into the tooth tissue show that the highest number of restoration microleakage scores is observed in the groups in which the teeth were prepared according to the TP protocol (GI and GII) (Table 1).

Table 1– Distribution of marginal microleakage scores of restorations

ICDAS criteria	Group	N	Microleakage Scores			
			0	1	2	3
Moderate stage caries (ICDAS™ codes 3)	GI	15	5	5	3	2
	GII	15		15		
	GIII	15	5	8	2	
	GIV	15	3	11	1	
Moderate stage caries (ICDAS™ codes 4)	GI	15		8	5	2
	GII	15	2	11	1	1
	GIII	15	4	9	1	1
	GIV	15	3	10	2	
Extensive stage caries (ICDAS™ codes 5)	GI	15	2		5	8
	GII	15	2	7		6
	GIII	15	5	7	2	1
	GIV	15	8		2	5

Moreover, this distribution pattern is characteristic of almost all cavities of different depths (ICDAS™ codes 3, 4, 5), which is confirmed by the average values of microleakage scores (Table 2).

Comparison of data within groups with different cavity preparation protocols (Table 2, 3) indicates a difference in the average values of the dye penetration depth in each group, but it is not always statistically significant. Thus, between groups of samples with the TP technique, the greatest microleakage is significant (*p – 0.026*) only in group GI, without tissue etching, in cavities within the mantle dentin (codes 4). In samples prepared using the AA technique (GIII, GIV), there was no significant difference in microleakage of restorations at any cavity depth ($p > 0.05$). This makes the use of the AA technique promising for caries lesions of different depths without taking into account the approaches to adhesive preparation.

Table 2 – Mean marginal microleakage scores of restorations (M±m)

ICDAS criteria	**Group**			
	GI	**GII**	**GIII**	**GIV**
Moderate stage caries (ICDAS™ codes 3)	1.13 ± 0.3	1.0 ± 0	0.80 ± 0.17	0.87 ± 0.13
Moderate stage caries (ICDAS™ codes 4)	1.60 ± 0,20	1.07 ± 0,30	0.93 ± 0.21	0.93 ± 0.15
Extensive stage caries (ICDAS™ codes 5)	2.27 ± 0.30	1.67 ± 0.30	0.93 ± 0.23	1.27 ± 0.40

Table 3 – Results of Student's T-test (p)

ICDAS criteria	**Group**				
		GI	**GII**	**GIII**	**GIV**
Moderate stage caries (ICDAS™ codes 3)	GI		*p > 0.05*	*p > 0.05*	*p > 0.05*
	GII	*p > 0.05*		*p > 0.05*	*p > 0.05*
	GIII	*p > 0.05*	*p > 0.05*		*p > 0.05*
	GIV	*p > 0.05*	*p > 0.05*	*p > 0.05*	
Moderate stage caries (ICDAS™ codes 4)	GI		*p - 0.026*	*p - 0.01*	*p - 0.005*
	GII	*p - 0.026*		*p > 0.05*	*p > 0.05*
	GIII	*p - 0.01*	*p > 0.05*		*p > 0.05*
	GIV	*p - 0.005*	*p > 0.05*	*p > 0.05*	
Extensive stage caries (ICDAS™ codes 5)	GI		*p > 0.05*	*p - 0.0003*	*p - 0.02*
	GII	*p > 0.05*		*p - 0.03*	*p > 0.05*
	GIII	*p - 0.0003*	*p - 0.03*		*p > 0.05*
	GIV	*p - 0.02*	*p > 0.05*	*p > 0.05*	

The most significant are the differences when comparing groups according to the protocols of adhesive preparation of carious cavities. The use of AA preparation technique without prior etching (GIII) of hard tooth tissues reduces the microleakage of restorations by 1.4 ($p > 0.05$), 1.7 (*p – 0.01*) and 2.4 times (*p – 0.0003*) than with TP without prior etching (GI) in carious cavities with a depth of ICDAS™ codes 3, 4, 5, respectively. Preparation using the AA technique with etching of tooth tissues (GIV) also reduces the microleakage of restorations than in the TP preparation group (GII), but this difference is minor and not significant ($p > 0.05$).

Based on the one-way analysis of variance, it was found that with increasing depth of carious lesion, microleakage indicators worsen in groups GI (*p – 0.009*) and GII (*p – 0.05*), but in groups GIII and GIV such a pattern was not observed ($p > 0.05$).

Two-way analysis of variance (ANOVA) allowed us to establish the dependence of the influence of technological protocols for the preparation of carious cavities and their depth on the marginal microleakage of restorations (Table 4). The state of microleakage is affected by both the depth of the cavities (*p – 0.001*) and the protocols of preparation and adhesive preparation (*p – 0.0002*), with the latter having a stronger effect. Mutually, these factors do not affect microleakage ($p > 0.05$).

Table 4 – The influence of the depth of carious cavities and technological protocols for their preparation on marginal microleakage of restorations (ANOVA summary table)

Source of Varia	**SS**	**df**	**MS**	**P-value**
Depth of carious cavities	10,67778	2	5,338889	0,001218
Technological protocols	15,66111	3	5,22037	0,000227
Interaction	4,655556	6	0,775926	0,417136
Within	128,4	168	0,764286	

DISCUSSION

When restoring teeth with composite materials, for several reasons, there is sometimes a violation of the density of the restorations' fit to the hard tissues of the teeth, which leads to their microleakage with the subsequent development of secondary caries [1]. With the introduction into practice of an innovative technique for selective removal of tissues affected by the carious process by air abrasion, there arises a need to scientifically substantiate the possibility of its use in various protocols of adhesive preparation of cavities to minimize microleakage of restorations at different depths of tissue lesions.

In the current study, a comparative assessment of microleakage of restorations in teeth prepared according to the protocols of traditional preparation and air abrasion with preliminary tissue etching and without etching was carried out.

With the traditional technique of preparation with rotary instruments, the microleakage of restorations is lower in the group of samples with preliminary tissue etching at different depths of cavities than without etching, but this difference is insignificant ($p > 0.05$). This is consistent with the results of studies on the basis of which the authors indicate the importance of using tissue etching technology [6], since it lays the foundation for micromechanical retention and chemical interaction between adhesive systems and dental substrates [7].

The samples of teeth prepared using the air abrasion technique did not have a statistically significant difference in any case according to the adhesive preparation protocols ($p > 0.05$), although the data of Rifane T.O. et al. (2024) indicate a different pattern of air-abrasive and etched enamel in favor of the latter. Sandblasting of enamel gave an uneven surface with wedge-shaped roughness and the absence of a clear pattern. And when the enamel was additionally etched with 35 % phosphoric acid, this led to a heterogeneous pattern with irregularities, crystallite exposure and slight dissolution in the peripheral region of the prisms [12], which should increase the possibility of tight contact between the adhesive and the tooth tissues.

Comparison between groups according to preparation protocols shows heterogeneous results. Significantly lower rates of microleakage of restorations were registered when preparing with air abrasion without additional tissue etching than in the similar group with traditional ($p – 0.01$, $p – 0.0003$ depending on the depth of the cavity). A similar trend was observed between the groups with tissue etching, air abrasion gave better results than traditional preparation, but this difference was not significant ($p > 0.05$). Our data are consistent with other studies that indicate better microleakage performance for one of the composites in the group of teeth prepared by air abrasion [16]. This is likely due to the greater penetration of the adhesive into the dentin using air abrasion [17], which increased the prepared surface area, improved surface energy, and facilitated better micromechanical adhesion of the adhesives [18]. However, there are studies that show no difference between the preparation techniques [19].

The state of microleakage of restorations depending on the depth of cavities was investigated. With traditional cavity preparation protocols, with increasing cavity depth, the microleakage of restorations significantly increases regardless of tissue etching ($p < 0.05$). With air abrasion, the depth of cavities does not affect microleakage ($p > 0.05$), which makes it possible to use this preparation method with any adhesive preparation protocol. It is not possible to compare the results of our study with others due to the lack of data in the available literature on the effect of cavity depth on microleakage. However, the theoretical basis can explain this dependence. With the incremental technique of introducing composite into the cavity, internal creep of each layer of hardened composite, disruption of adaptation and connection between increments, and the formation of voids between each increment are possible [3]. That is, the deeper the carious cavity, the more layers of composite are introduced and the greater is the risk of side effects. The deterioration of microleakage of restorations can also be influenced by the features of the histological structure of dentin in the superficial and peripulpal layers: different orientation of collagen fibers, density and diameter of dentinal tubules, area of intertubular dentin [20]. The current study was conducted in a static environment in vitro. However, in the oral cavity, restorations are exposed to a dynamic environment, where they are constantly influenced by oral fluid, microbiota, nutritional characteristics, occlusal forces, bad habits and other factors. The study used certain composite materials and adhesives, an air abrasion device with certain preparation parameters, and intact teeth. All these factors can affect the reproducibility of results in the clinic, therefore the issue of the influence of preparation protocols and adhesive preparation of carious cavities on the microleakage of restorations requires further research.

CONCLUSIONS

According to the results of the study, the null hypothesis is rejected. The state of microleakage of restorations is affected by both the depth of cavities and the protocols of preparation and adhesive preparation, with the latter having a stronger effect. These factors do not mutually affect microleakage. Lower rates of microleakage are recorded when preparing with the air abrasion technique.

PROSPECTS FOR FUTURE RESEARCH

It is planned to investigate how the protocols for preparing carious cavities and adhesive preparation affect other indicators of restoration quality.

AUTHOR CONTRIBUTIONS

Yurii Lakhtin – work concept and design, responsibility for statistical analysis, writing the article, critical review, final approval of the article.

Denys Hryhoriev – work concept and design, data collection and analysis, writing the article, final approval of the article.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

CONNECTION WITH SCIENTIFIC WORKS

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ARTIFICIAL INTELLIGENCE DISCLOSURE

The authors did not use AI in this paper.

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