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CLINICAL EVALUATION OF RESTORATIONS FOLLOWING AIR-ABRASIVE AND ROTARY PREPARATION OF CARIOUS CAVITIES AFTER 18 MONTHS OF FOLLOW-UP

Introduction. The longevity of composite restorations depends not only on the properties of restorative materials but also on the characteristics of hard dental tissue preparation. Air-abrasive preparation is considered a minimally invasive alternative to conventional rotary preparation; however, its impact on long-term clinical outcomes requires further investigation.

Objective. To evaluate the influence of air-abrasive and rotary preparation of carious cavities on the clinical effectiveness of restorations after 18 months of follow-up.

Materials and methods. A total of 120 patients aged 31–50 years who received 182 Class I restorations according to Black's classification were examined. Depending on the preparation protocol and adhesive pretreatment, three groups were formed: conventional rotary preparation with acid etching, air-abrasive preparation without etching, and air-abrasive preparation with etching. After 18 months, 140 restorations were evaluated according to the USPHS criteria. Statistical analysis included Fisher's exact test and multiple pairwise comparisons with Bonferroni correction.

Results. After 18 months, all investigated protocols demonstrated high clinical effectiveness. The proportion of restorations receiving an Alpha rating according to the USPHS criteria ranged from 93.8% to 100%, whereas no Charlie ratings were recorded in any group. The best outcomes were observed in the air-abrasive preparation with etching group. No statistically significant intergroup differences were found according to the USPHS criteria ($p > 0.05$). Rank analysis demonstrated a high level of agreement between laboratory indicators of the adhesive interface and long-term clinical outcomes of restorations.

Conclusions. Air-abrasive preparation combined with acid etching provides a high level of clinical effectiveness of restorations and demonstrates a tendency toward superior outcomes compared with the other investigated protocols. A strong agreement was established between the experimental characteristics of hard dental tissue surfaces and the clinical performance of restorations after 18 months of follow-up.

Key words: teeth, dental caries, air-abrasive preparation, rotary preparation, restorative treatment, USPHS criteria, clinical effectiveness.

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КЛІНІЧНА ОЦІНКА РЕСТАВРАЦІЙ ПІСЛЯ ПОВІТРЯНО-АБРАЗИВНОГО ТА РОТАЦІЙНОГО ПРЕПАРУВАННЯ КАРІОЗНИХ ПОРОЖНИН ЧЕРЕЗ 18 МІСЯЦІВ СПОСТЕРЕЖЕННЯ

Вступ. Тривалість функціонування композитних реставрацій залежить не лише від властивостей реставраційних матеріалів, але й від особливостей підготовки твердих тканин зуба. Повітряно-абразивне препарування розглядається як малоінвазивна альтернатива традиційному роторному препаруванню, однак його вплив на віддалені клінічні результати потребує подальшого вивчення.

Мета дослідження – оцінити вплив повітряно-абразивного та роторного препарування каріозних порожнин на клінічну ефективність реставрацій через 18 місяців спостереження.

Матеріали та методи. Обстежено 120 пацієнтів віком 31–50 років, яким виконано 182 реставрації каріозних порожнин I класу за Блеком. Залежно від протоколу препарування й адгезивної підготовки сформовано три групи: традиційне роторне препарування з протравлюванням, повітряно-абразивне препарування без протравлювання та повітряно-абразивне препарування з протравлюванням. Через 18 місяців оцінювали 140 реставрацій за критеріями USPHS. Для статистичного аналізу використовували точний критерій Фішера та множинні попарні порівняння з поправкою Бонферроні.

Результати. Через 18 місяців усі досліджувані протоколи продемонстрували високі показники клінічної ефективності. Частка реставрацій з оцінкою Alpha за критеріями USPHS становила 93,8–100%, тоді як оцінки Charlie не реєструвалися в жодній із груп. Найкращі результати спостерігалися при повітряно-абразивному препаруванні з протравлюванням. Статистично значущих міжгрупових відмінностей за критеріями USPHS не встановлено ($p > 0,05$). Проведений ранговий аналіз показав високу узгодженість між лабораторними показниками адгезивного інтерфейсу та віддаленими клінічними результатами реставрацій.

Висновки. Повітряно-абразивне препарування з протравлюванням забезпечує високий рівень клінічної ефективності реставрацій та демонструє тенденцію до кращих результатів порівняно з іншими досліджуваними протоколами. Встановлено узгодженість між експериментальними характеристиками поверхні твердих тканин зуба та клінічними показниками функціонування реставрацій через 18 місяців спостереження.

Ключові слова: зуби, карієс зубів, повітряно-абразивне препарування, роторне препарування, реставраційне лікування, критерії USPHS, клінічна ефективність.

Introduction. One of the priority tasks of clinical dentistry is to ensure the long-term functioning of restored teeth and maintain the clinical effectiveness of restorations. The longevity of restorations is influenced by numerous factors, including behavioral, clinical, material-related, and operator-dependent variables. The modern development of esthetic dentistry and adhesive technologies requires optimization not only of the chemical composition of restorative materials but also of the initial stage of their integration with hard dental tissues, namely the method of carious cavity preparation.

Despite its widespread use, conventional rotary preparation (RP) is associated with considerable vibration and thermal stresses, which may lead to the formation of enamel microcracks and the development of a thick smear layer that can potentially affect the quality of adhesive interaction between the restorative material and hard dental tissues. Contemporary dentistry continuously improves preparation approaches through the implementation of minimally invasive technologies [1]. These approaches involve conservative removal of pathologically altered tissues, minimal cavity designs, and the use of adhesive restorative materials [2]. Minimally invasive dentistry is based on the selection of a biologically justified rather than a purely mechanistic treatment strategy [3]. This innovative technique of selective caries removal preserves the structural integrity of dentin and the vitality of the dental pulp [4].

Various methods have been proposed for minimally invasive carious cavity preparation. One of them is air abrasion, which has evolved from a novel alternative cavity preparation concept into a principal means of achieving truly conservative preparation aimed at preserving the maximum amount of sound tooth structure.

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In addition, it creates favorable conditions for adhesion by increasing surface roughness and expanding the bonding area [3; 5–8].

Previous experimental studies have demonstrated that different preparation and adhesive pretreatment protocols result in distinct characteristics of surface microrelief, surface microgeometry, adhesive bond strength, and restoration microleakage [9–12]. However, the clinical significance of these laboratory differences requires confirmation under conditions of long-term restoration function.

At the same time, numerous laboratory studies evaluating surface roughness parameters (according to ISO standards) and adhesive bond strength *in vitro* reflect only the initial adhesion potential. They are unable to fully reproduce the complex biomechanical, thermal, and microbiological influences of the oral environment over time. Clinical evaluation using USPHS criteria during long-term follow-up remains one of the most widely accepted and validated approaches for assessing the long-term effectiveness of restorations. Comprehensive monitoring of such critical parameters as marginal adaptation, marginal discoloration, and resistance to secondary caries makes it possible to evaluate the potential relationship between experimentally determined surface characteristics and the clinical effectiveness of restorations.

Several clinical studies have reported no significant differences between air-abrasive preparation (AAP) and conventional rotary preparation (RP) regarding the clinical effectiveness of restorations when standard adhesive protocols are applied [13].

Evidence from systematic reviews investigating the use of air abrasion in other areas of adhesive dentistry has also failed to demonstrate an unequivocal clinical advantage over conventional techniques, highlighting the need for further controlled clinical studies [14].

The aim of the study was to evaluate the influence of air-abrasive and rotary preparation of carious cavities on the clinical effectiveness of restorations after 18 months of follow-up.

Materials and methods. The clinical study included 120 patients in whom 182 restorations were placed. After 18 months, 95 patients attended the follow-up examination, allowing the evaluation of 140 restorations. In some clinical cases, a single patient received several restorations on different teeth using different preparation protocols, which is permitted according to FDI recommendations. The restorations were divided into three groups depending on the preparation protocol and adhesive pretreatment of the carious cavities.

Group 1 included patients (n = 46) whose carious cavities were prepared using conventional rotary preparation (RP) with removal of caries-affected and demineralized tissues, followed by etching with 37% phosphoric acid gel. Enamel was etched for 30 s and dentin for 15 s according to the manufacturer's instructions. The cavities were then rinsed with water and dried with oil-free air.

Group 2 included patients (n = 48) whose carious cavities were prepared using air-abrasive preparation (AAP) with selective removal of caries-affected and demineralized tissues without acid etching. The cavities were rinsed with water and dried with oil-free air.

Group 3 included patients (n = 46) whose carious cavities were prepared using air-abrasive preparation (AAP) with selective removal of caries-affected and demineralized tissues, followed by etching with 37% phosphoric acid gel. Enamel was etched for 30 s and dentin for 15 s according to the manufacturer's instructions. The cavities were then rinsed with water and dried with oil-free air.

A group treated with conventional rotary preparation without prior acid etching was not included in the study because such a protocol is not accepted in routine clinical practice.

Prepared cavities in Groups 1, 2, and 3 were treated with a one-component light-cured adhesive system, Charisma GLUMA® Bond 5 (Heraeus Kulzer, Germany), followed by incremental placement of the light-cured hybrid composite Charisma SMART (Heraeus Kulzer, Germany).

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Each composite increment was applied in a 2-mm layer and light-cured for 40 s with the curing light positioned 2 mm from the composite surface.

The inclusion criteria were: International Caries Detection and Assessment System (ICDAS) visual criteria (moderate occlusal caries of molars, ICDAS™ codes 3–4) [15], Class I carious cavities according to Black's classification, patient age between 31 and 50 years, DMFT index not exceeding 12, satisfactory oral hygiene, absence of parafunctional habits, absence of non-carious cervical lesions in the evaluated teeth, presence of occlusal and proximal contacts, absence of contraindications to dental treatment, and the possibility of attending follow-up examinations.

The exclusion criteria were severe periodontal disease, teeth with pulpal pathology or previous endodontic treatment, carious lesions located on surfaces other than the cavity included in the study, and absence of adjacent or antagonistic teeth.

Clinical evaluation was performed according to the criteria developed and modified by Ryge (1980) and adopted by the United States Public Health Service (USPHS) [16]. According to ADA recommendations, the minimum follow-up period required for evaluating the effectiveness of composite restorations is 18 months [17].

Fisher's exact test was used to compare categorical variables between groups. In cases of statistically significant differences, multiple pairwise comparisons with Bonferroni correction were performed. Statistical significance was established at $p < 0.05$.

The authors fully complied with the requirements of Articles 43 and 45 of the Fundamentals of Ukrainian Health Legislation, the principles of the Declaration of Helsinki, "Recommendations for Physicians Involved in Biomedical Research Involving Human Subjects" (1964, revised in 1983), and Directive 2001/20/EC of the European Parliament and of the Council of 4 April 2001, as amended. The study protocol was approved by the University Ethics Committee for Experimental and Clinical Research (Protocol No. 1/05, May 1, 2025). Written informed consent was obtained from all participants after a complete explanation of the study objectives and methods.

Results. Ninety-five patients attended the follow-up examination, allowing the evaluation of 140 restorations (76.9% of the initial number). Cases lost to follow-up were associated with patients' failure to attend the recall visit and were not related to unsatisfactory restoration performance.

After 18 months of clinical follow-up, all restorations demonstrated high levels of clinical effectiveness. The proportion of restorations receiving an Alpha rating according to the USPHS criteria ranged from 93.8% to 100%, whereas no Charlie ratings were recorded in any of the groups (Table 1).

The best outcomes were observed in the group treated with air-abrasive preparation followed by acid etching, in which the proportion of restorations receiving an Alpha rating reached 100% for five of the seven USPHS criteria.

The least favorable outcomes were observed in the air-abrasive preparation without acid etching group, as reflected by a higher frequency of Bravo ratings for marginal adaptation, marginal discoloration, and secondary caries.

Statistically significant intergroup differences were not identified ($p > 0.05$). However, the observed trends indicate an important role of adhesive pretreatment of hard dental tissues in ensuring the long-term clinical effectiveness of composite restorations.

Discussion. Despite the absence of statistically significant differences between the groups, a consistent tendency toward better clinical outcomes was observed when air-abrasive preparation was combined with subsequent acid etching (Group 3).

Both rotary preparation (RP) and air-abrasive preparation (AAP) modify the tooth surface; however, both techniques result in the formation of a smear layer [18; 19], which partially occludes dentinal tubules, impedes adhesive penetration, and interferes with the formation of an optimal hybrid layer.

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Table 1

Clinical status of restorations after 18 months according to the USPHS criteria, %

Group	Rating code	USPHS Criteria						
		Anatomic form	Color match	Surface roughness	Marginal adaptation	Marginal discoloration	Secondary caries	Discomfort
1	Alpha (A)	97.8	97.8	97.8	95.7	97.8	97.8	95.7
	Bravo (B)	2.2	2.2	2.2	4.3	2.2	2.2	4.3
2	Alpha (A)	100	97.9	95.8	93.8	93.8	95.8	97.9
	Bravo (B)	–	2.1	4.2	6.3	6.3	4.2	2.1
3	Alpha (A)	100	100	100	97.8	97.8	100	97.8
	Bravo (B)	–	–	–	2.2	2.2	–	2.2

The obtained findings confirm the decisive role of adhesive surface pretreatment regardless of the preparation method used. Acid etching effectively removes the smear layer, opens dentinal tubules, modifies the internal microstructure of dentin, and increases its surface roughness parameters [20; 21]. According to numerous studies, the etch-and-rinse protocol represents a critical stage of adhesive pretreatment. This approach promotes reliable micromechanical retention and facilitates chemical interaction between the adhesive system and dental substrates. Consequently, it serves as a key factor in achieving stable bonding and adequate adaptation of the restoration to the cavity margins [6; 18; 22]. Thus, preliminary acid etching of hard dental tissues contributes to smear layer removal, dentinal tubule opening, formation of a more favorable hybrid layer, and improved marginal adaptation of the restoration.

In a series of previous experimental studies, air-abrasive preparation combined with acid etching was shown to produce the most favorable surface profile of hard dental tissues, provide the highest adhesive bond strength, and ensure the lowest level of marginal dye penetration [9–12]. These effects are associated with an increased active surface area, enhanced surface micro-roughness, and improved surface energy, all of which contribute to more effective adhesion [8; 23–25]. Although rotary and air-abrasive preparation produce similar surface microrelief characteristics and differ only slightly in their effects on dentin structure, air abrasion has demonstrated a greater ability to enhance resin penetration depth [19; 26].

To evaluate the agreement between laboratory and clinical findings, a rank-based analysis of the parameters obtained in previous experimental studies was performed. Ranks were assigned according to the relative position of each group for a given parameter: rank 1 corresponded to the most favorable result, rank 2 to an intermediate result, and rank 3 to the least favorable result (Table 2).

Minimal microleakage alone does not guarantee the best clinical outcome. Rather, the combination of favorable surface microgeometry, high adhesive bond strength, and low microleakage provides the most predictable clinical performance.

Regardless of the laboratory approach used (assessment of surface microrelief, microgeometry, microleakage, or adhesive bond strength), the same ranking sequence of the experimental groups was observed (4, 2, 3, 1), indicating a high degree of consistency in the morphological characteristics of hard dental tissue surfaces following different preparation protocols. A similar ranking pattern was identified for the clinical groups, with the sequence being 3, 1, and 2.

The obtained findings demonstrate a high level of agreement between the experimental characteristics of the adhesive interface and the long-term clinical outcomes of restorations. At the same time, the morphological and mechanical advantages of air-abrasive preparation combined with acid etching did not

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Table 2

Comparative rank analysis of laboratory and clinical indicators of restoration effectiveness

Parameter	Rank of indicators by clinical group		
	Group 1	Group 2	Group 3
Adhesive potential of hard dental tissue microrelief [12]	2	3	1
Hard dental tissue microgeometry [10]	2	3	1
Dye microleakage [11]	3	1	2
Bond strength of the restorative material to dentin [9]	2	3	1
Clinical effectiveness of restorations according to USPHS criteria after 18 months	2	3	1

translate into a statistically significant clinical advantage during the 18-month follow-up period.

Conclusions. After 18 months of follow-up, all investigated preparation protocols demonstrated a high level of clinical effectiveness of restorations. The proportion of restorations receiving an Alpha rating according to the USPHS criteria ranged from 93.8% to 100%, whereas no Charlie ratings were recorded in any of the groups.

The use of an acid-etching protocol following cavity preparation was associated with a tendency toward improved marginal adaptation, reduced marginal discoloration, lower incidence of secondary caries, and greater patient comfort, regardless of the preparation method employed.

Air-abrasive preparation followed by acid etching demonstrated the most favorable clinical outcomes after 18 months of follow-up; however, no statistically significant differences were found compared with conventional rotary preparation combined with acid etching.

Rank analysis demonstrated a high level of agreement between laboratory characteristics of the adhesive interface (surface microrelief, surface microgeometry, microleakage, and adhesive bond strength) and the long-term clinical outcomes of restorations.

The obtained findings indicate that air-abrasive preparation combined with acid etching may be considered an effective minimally invasive alternative to conventional rotary preparation for the treatment of Class I carious lesions according to Black's classification.

Use of Artificial Intelligence. No artificial intelligence tools were used in the preparation of this article.

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