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ORIGINAL ARTICLE

CLINICAL MANAGEMENT OF MARGINAL DEFECTS IN ADHESIVE RESTORATIONS

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Abstract: *Background*: Dental caries is a dynamic and continuous process resulting from cycles of demineralization and remineralization of dental hard tissues, with the balance between these cycles determining the disease stage. The aim of this study was to analyze the clinical success of direct light-cured composite restorations in posterior teeth; *Methods*: The study focused on marginal adaptation quality, preservation of occlusal morphology, and restoration survival according to their extent and location. A clinical-statistical study was conducted between March and December 2024 on a sample of 86 patients aged 18–62 years who attended a private dental office in Craiova, with all participants providing informed consent; *Results*: Statistically significant differences were found between types of restorations requiring repair, with certain types of repairs occurring more frequently than others. Specifically, restorations in teeth affected by abrasion and secondary caries were significantly more common than those involving tooth fracture or erosion. Secondary caries and restoration fracture were the only categories reaching individual statistical significance (p=0.048), however, overall distribution did not differ significantly from a random pattern (p=0.386); *Conclusions*: Repairs were more frequently necessary in cases involving dental abrasion and secondary caries, while tooth fracture and erosion cases were less common.

Keywords: marginal adaptation, direct composite restorations, secondary caries, dental abrasion

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1. Introduction

Dental caries is a dynamic and continuous process resulting from cycles of demineralization of the hard dental tissue, followed by cycles of remineralization. The balance between these two cycles determines the stage of the disease [1]. There is a close relationship between oral health and quality of life, just as it has been shown that socioeconomic status and the environment of origin have an impact on people's oral health [2].

Despite major achievements in oral health worldwide, caries remains a serious problem, especially among underprivileged groups in low, middle, and high-income countries, affecting 60% to 90% of schoolchildren and the vast majority of adults. It is also the most widespread oral health problem in several Asian and Latin American countries [3].

Amalgam has been the traditional material for filling cavities in posterior teeth for the past 100 years due to its long-term effectiveness and lower cost. Amalgam is still used as a restorative material in certain parts of the world. However, in recent years there have been concerns regarding the use of amalgam restorations, related to the release of toxic mercury into the body and its environmental impact as a result of its disposal into the atmosphere [4,5].

Composites have gradually become an aesthetic alternative to amalgam restorations, and there have been remarkable improvements in their mechanical properties to withstand the masticatory forces of posterior teeth [4,5].

Studies conducted in the last 10 years have provided numerous pieces of evidence regarding the low quality of composites, suggesting higher failure rates and the risk of secondary caries compared to amalgam restorations. Despite the benefits of amalgam, especially in the restoration of posterior teeth with proximal caries, it is unlikely that new research will change the opinion regarding its safety [4].

Other studies have suggested that the restorative material influences the survival rate of primary posterior restorations, with composite showing the best performance [6].

The longevity of direct posterior composite restorations is well established for permanent teeth. Cavity size, salivary infiltration, and occlusal imbalances are factors that significantly affect survival, especially in composite restorations. In addition to composites, another direct restorative material for posterior teeth aesthetics is resin-modified glass ionomer cement (RMGIC) and conventional glass ionomer cement (GIC) [7,8].

The results of many studies indicate that adhesive materials can be one of the therapeutic options for moderate to large two-surface Class II restorations in posterior teeth [9].

However, multi-surface composite restorations in posterior teeth require longer treatment time and precise technical skills. GIC cements are less technique-sensitive but are relatively fragile due to their lower flexural strength and wear resistance [10,11].

To increase the hardness and wear resistance of conventional GICs, improvements have been made to their consistency with the introduction of high-viscosity GICs. Furthermore, the application of a nanofilled varnish has been proposed to

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protect these materials, covering surface pores and thus improving the mechanical properties of the restorative material [12].

Minimally invasive therapy allows the use of more conservative restorative techniques, limiting cavity preparation mainly to the removal of necrotic tissue while preserving the intact healthy structure of the teeth [13].

Some patients may still undergo more invasive treatment despite the availability of effective evidence-based minimally invasive options. Dentists recognize the importance of continuous education and ongoing improvement of methods for treating dental caries [14].

The aim of this study was to analyze the clinical success of direct light-cured composite resin restorations in posterior teeth. The study focuses on the quality of marginal adaptation of the restorations, as well as the preservation of the occlusal surface morphology, and their survival, depending on their extent and location.

2. Materials and method

The studies were carried out according to the approval no. 412/04.11.2025 issued by the Ethics and Scientific Deontology Committee of the University of Medicine and Pharmacy of Craiova.

The clinical-statistical study was conducted between March and December 2024 on a sample of 86 patients, aged between 18 and 62 years, who attended a private dental clinic in Craiova. All patients provided informed consent regarding their participation in the study.

Furthermore, patients were required to be cooperative, willing to participate in the study, and able to attend periodic follow-up appointments. Patient data were collected from direct clinical examinations and patient records.

The variables evaluated included patient age and gender, tooth type, extent and location of restorations, quality and longevity of direct restorations, restorative materials used, harmful habits, parafunctional activities, secondary caries, and maintenance therapy.

Restorations performed with composite materials by a single operator were examined and evaluated. To be included in the study, restorations had to have been functional in the oral cavity for at least three years and performed by the attending dentist so that the restorative material used was known. Only restorations on teeth with an occluding antagonist and adjacent teeth were included in the study. Occlusal relationships had to be favorable and stable for the teeth included in the study.

All patients had complete dental arches. Patients with removable prostheses or extensive edentulism were excluded. Additional exclusion criteria included a history of drug abuse, medication dependency, or alcohol abuse; unavailability for periodic follow-up; severe bruxism; periodontally compromised teeth; endodontically treated teeth; and patients with unstable medical or physiological conditions.

After applying the exclusion criteria, a total of 380 direct restorations made of light-cured composite resin in posterior teeth were included in the study.

Data were collected in Microsoft Excel and statistically processed.

The restorative materials used in the clinic were:

- Nanohybrid composites (Tetric EvoCeram, Ivoclar Vivadent, Schaan,

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Liechtenstein and Filtek Z250; 3M ESPE);

- Nanocomposites (Universal Filtek Supreme XT; 3M ESPE).

The clinical protocol followed over the years included the following steps:

- All dental surfaces were cleaned to remove dental plaque and the salivary pellicle using a prophylactic paste without fluoride (Cleanic, Kerr, Orange, CA, USA) and a dental brush, using conventional rotational speeds.
- Depending on the prepared cavity, anesthesia was administered.
- Teeth were isolated using cotton rolls and a rubber dam system.
- Cavities were prepared using diamond/extradure burs in spherical, pear-shaped, and cylindrical forms (Komet, Lemgo, Germany) with water cooling (Figure1).
- Cavity preparation was performed until the cavity margins were confirmed to be located in sound enamel and the cavity walls in sound dentin.
- Class II cavities were restored using a pre-contoured sectional matrix system (Palodent Plus, Dentsply, York, PA, USA).
- Enamel was selectively etched with 37% phosphoric acid (Figure 2), and a two-step adhesive (Adper Single Bond, 3M ESPE) (Figure 3) was applied to both enamel and dentin according to the manufacturer's instructions and light-cured for 20 seconds.

Figure 1. Diamond and super-hard burs used for cavity preparation.

Figure 2. 37% phosphoric acid used for demineralizing the cavity walls.

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Figure 3. Dentin adhesive Adper Single Bond (3M ESPE).

- The restorative materials were placed in layers no thicker than 2 mm.
- The restorative materials were light-cured for 20 seconds using an LED curing light (D-Light; GC) with an intensity of 1200 mW/cm² (Figure 4).
- Occlusal contact was checked using colored articulating paper.
- Restorations were finished with fine and extra-fine flame-shaped diamond burs (H135F.314.014 and 368LEF.314.016, Komet) for gross finishing, while fine finishing was performed using carbide burs (H48LF.314.012, Komet).
- Cervical adaptation and proximal contact were checked with dental floss and finished as needed using flexible discs (System Compo, Komet).
- Restorations were then polished with polishing points (9523uf.204.030, Komet) and diamond-particle polishing paste (Gradia Diapolisher, GC).

Figure 4. LED light-curing unit.

- Occlusal contact was checked using colored articulating paper.
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Restoration Evaluation

The evaluators consisted of two experienced clinicians and an observing student, who were trained to assess restorations using the FDI criteria. After individual calibration on the web-calib platform, the evaluators assessed a set of 16

restoration images, assigning scores to each. The evaluation results showed excellent inter-rater agreement, with average values ranging between 0.939 and 0.989 for the following variables: surface staining, marginal discoloration, overall functional properties, restoration fracture, and marginal adaptation and retention of restorations.

The criteria used for evaluations included aesthetic aspects (marginal appearance and surface staining), functional characteristics (all criteria except occlusion and wear), and biological considerations (all available criteria).

The primary outcomes were expressed as the survival rate and success rate of restorations. Survival was defined as a restoration that does not require replacement (FDI-2 scores of 1-4), while success was defined as a restoration not requiring replacement or repair (FDI-2 scores of 1-3).

Failure criteria included: fracture of the tooth and/or restoration, presence of secondary caries, presence of postoperative sensitivity, presence of wear lesions (erosion, abfraction, and abrasion), endodontic treatment, or tooth extraction.

The obtained data were statistically analyzed using the chi-square test of independence, calculating the p-value, with significance defined as $p > 0.05$.

3. Results

The study included 86 patients, of whom 48 were women and 38 were men, the patients' ages ranged from 18 to 62 years. For this study sample, a total of 324 adhesive restorations were selected on maxillary and mandibular molars (Table 1).

A chi-square test was performed to assess the association between patients' gender and the type of dental restorations. Since $p= 0.727$ is much greater than the significance threshold of 0.05, it was concluded that there is no statistically significant association between patients' gender and the type of restorations. These restorations were periodically evaluated, and it was found that some were still properly adapted, others required replacement, and some restorations were only repaired (Table 2).

Table 1. Distribution of patients by gender and type of fillings.

Gender	Type of fillings			p (Chi-Square test)
	Class I	Class II	Class III	
F	98	76	20	0.727
M	68	52	10	

Table 2. Distribution of fillings that need to be restored or repaired according to the gender of the patients.

Gender	Correctly fitted fillings	Fillings that required repair	Fillings that need to be redone	p (Chi-Square test)
F	120	54	20	0.026
M	85	22	23	
p	0.597	**0.032**	0.080	

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The p-value (0.026) is less than 0.05, which means there is a statistically significant difference in the distribution of restoration types between females and males. Thus, it can be stated that the patient's gender significantly influences the outcome of the dental restoration, whether it is a proper adaptation, requires repair, or complete replacement.

Regarding properly adapted restorations, there is no statistically significant difference between females and males in terms of the number of correctly adapted restorations. The distribution is similar for both genders. For restorations that require repair, a statistically significant difference between genders was observed. Females had a significantly higher number of restorations that required repair compared to males. Considering restorations that need to be replaced, the result is close to statistical significance but does not reach the standard threshold of 0.05. There is a suggested tendency for males to require replacement more often, but the difference is not statistically significant.

The repair of restorations was performed in the following situations (Table 3):

- secondary caries;
- restoration fracture;
- tooth fracture;
- teeth with erosion;
- teeth with abrasion;
- adjustment of the anatomical contour.

Table 3. Distribution of fillings that need to be repaired according to the causal factor.

Compromised fillings		**77**
Type of repair	secondary caries	20
	restoration fracture	18
	tooth fracture	3
	teeth with erosion	4
	teeth with abrasion	21
	adjustment of the anatomical contour	11

Table 4. Distribution of fillings that need to be repaired according to the causal factor.

Compromised fillings		**77**
The type of filling that needs to be restored	secondary caries	12
	restoration fracture	12
	tooth fracture	4
	teeth with erosion	6
	teeth with abfraction	3
	postoperative sensitivity	6

The differences between the types of restorations requiring repair are statistically significant. In other words, certain types of repairs occur significantly more often than others. For example, "teeth with abrasion" and "secondary caries" are much more frequent

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than “tooth fracture” or “teeth with erosion.” The replacement of restorations was performed in the following situations (Table 4):

- postoperative sensitivity;
- secondary caries;
- restoration fracture;
- tooth fracture;
- teeth with erosion;
- teeth with abfraction

Secondary caries and restoration fractures are the only categories that reach individual statistical significance ($p = 0.048$). However, overall, the distribution is not significantly different from a random one ($p = 0.386$). It cannot be stated that a certain type of compromised restoration predominates significantly over the others, the differences appear to be random.

At the time of examination, 43 restorations (13.27%) were functional, and 205 restorations (63.27%) were considered clinically successful. Seventy-seven restorations (23.76%) failed.

The therapeutic approach for managing localized dentin sensitivity emphasizes identifying contributing factors and evaluating the condition of existing restorations to determine an appropriate, minimally invasive intervention. In situations where tooth 3.7 exhibits short-duration sensitivity to cold and sweet stimuli, clinical examination may reveal an occluso-mesial physiognomic restoration showing occlusal abrasion, along with secondary carious involvement at the gingival margin of the vertical component (Figure 5).

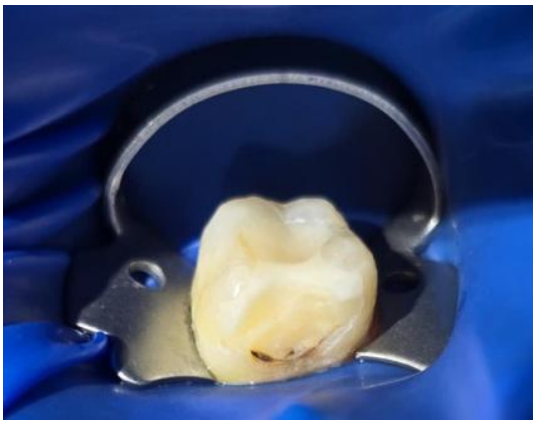

Figure 5. Initial appearance of the occlusal-mesial filling.

A decision was made to partially remove the restoration, reshaping the marginal contour for better adaptation and to prevent marginal microleakage (Figure 6).

Figure 6. Preparing the new cavity design.

After cavity cleaning, a demineralizing gel was placed in the cavity (Figure 7).

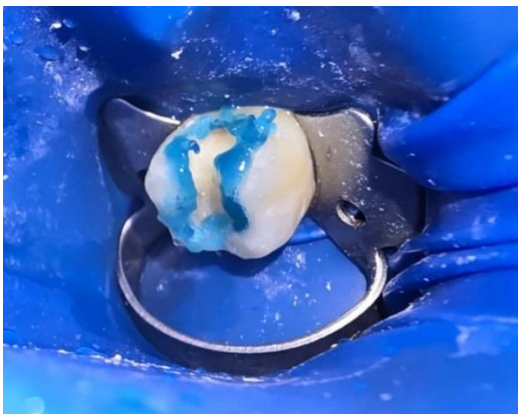

Figure 7. Applying demineralizing gel.

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The demineralizing gel was rinsed off and the cavity was dried. A dentin adhesive was applied (Figure 8) and light-cured (Figure 9).

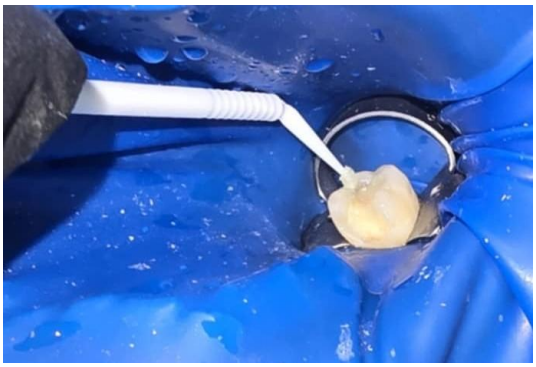

Figure 8. Applying the adhesive system.

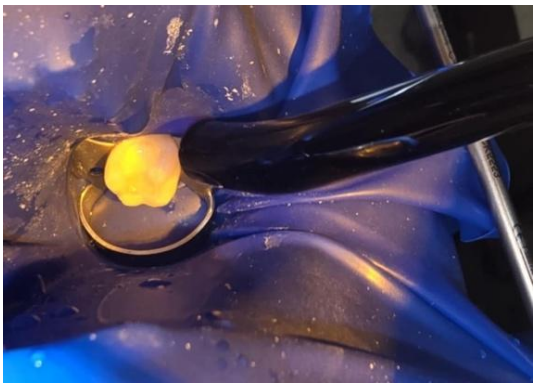

Figure 9. Light curing of the adhesive system.

The restorative material was shaped and light-cured. Excess material was removed, and the restoration was finished and polished (Figure 10).

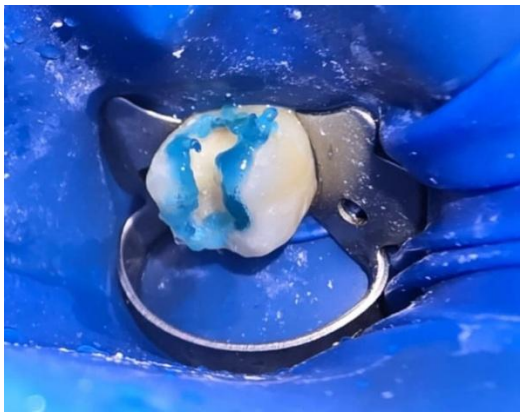

Figure 10. Final appearance of the occlusal-mesial restoration.

During routine clinical evaluations, the assessment of molar 4.6 may reveal a vestibular pit restoration with signs of marginal microleakage. Additional findings can include the presence of an occlusal carious lesion accompanied by pronounced abrasion on the occlusal surface of the tooth (Figure 11).

The restoration and altered hard dentin were removed, and a Class IB cavity was prepared (Figure 12).

Figure 11. Applying the adhesive system.

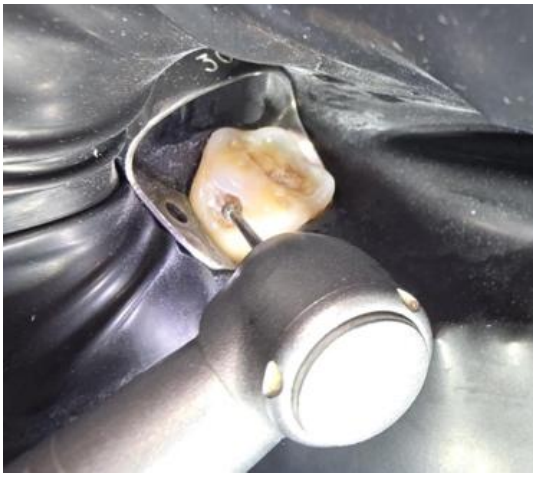

Figure 12. Light curing of the adhesive system.

Altered tissue was also removed from the occlusal surface, creating a Class IA cavity (Figure 13).

A demineralizing gel was applied to the enamel, and after 20 seconds the dental surfaces were rinsed and dried (Figure 14). The dentin adhesive was applied with a brush,

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light-cured, and layers of composite material were placed (Figure 15).

Figure 13. Applying the adhesive system.

Figure 14. Light curing of the adhesive system.

Figure 15. Light curing of the adhesive system.

The restorations were finished, occlusion was checked (Figure 16), and then polished (Figure 17).

Figure 16. Applying the adhesive system.

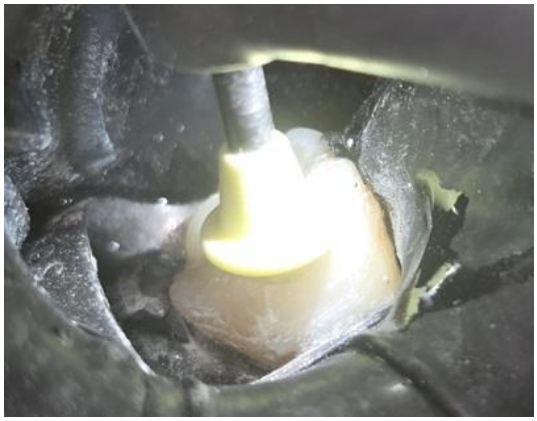

Figure 17. Light curing of the adhesive system.

Figure 18. Light curing of the adhesive system.

The clinical management strategy for posterior restorative defects is centered on preserving dental structure and function through careful assessment and minimally invasive intervention tailored to the specific characteristics of each situation.

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Figure 19. Applying the adhesive system.

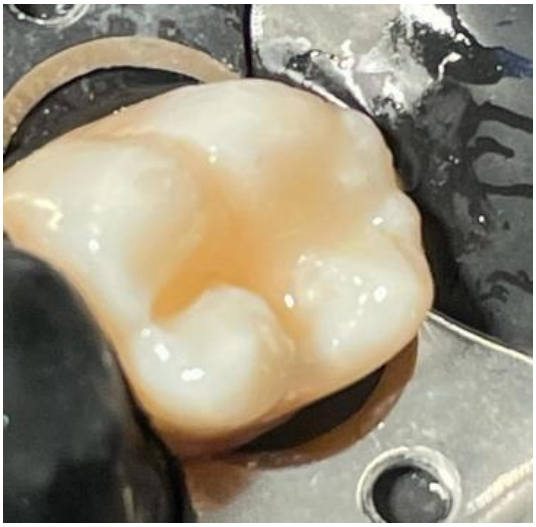

Figure 20. Applying the adhesive system.

In a context involving the detection of compromised structural integrity at tooth 4.6, clinical examination showed a fracture of the physiognomic restoration, with evident material loss affecting the occlusal surface (Figure 19).

Because the filling showed infiltration at the marginal contour, we preferred to remove the entire filling and prepare a class I A cavity (Figure 20).

Figure 21. Light curing of the adhesive system.

By following the isolation and filling steps mentioned in the Material and Method chapter, the cavity was filled, restoring the coronal morphology (Figure 21).

4. Discussion

The American Dental Association states that a restorative material intended for posterior teeth should have a success rate of at least 90% after 18 months of application [15]. Two-year results from a multicenter clinical study reported similar survival rates for restorations performed with glass ionomer cement (GIC) and resin-modified nanohybrid composites, at 93.6% and 94.5%, respectively, when evaluating Class II two-surface restorations in molars [16].

Similarly, other studies have reported comparable clinical performance for restorations using GIC and microfilled hybrid composites in extensive Class II cavities over a 24-month evaluation period [17]. A survival rate of 98% was observed for GIC restorations in hypomineralized permanent molars [18]. However, a longitudinal study reported a significantly lower survival rate for hybrid glass ionomer Class II restorations compared to conventional GIC and bulk-fill composites [19].

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Oz et al. compared Cention N (CN) with a resin-enhanced composite for the restoration of Class II cavities. After one year, three CN restorations failed, and seven (18%) presented marginal adaptation issues [20]. Cieplik et al. compared the one-year performance of a new self-adhesive bulk-fill restorative material (SABF) with a conventional bulk-fill resin composite for Class II restorations. They concluded that both materials were clinically acceptable according to FDI criteria. However, SABF showed reduced surface gloss, color changes, decreased translucency, and more pronounced marginal discoloration [21].

Some studies indicate that GIC and composites demonstrate similar clinical performance for most evaluated criteria, except for the presence of secondary carious lesions, where GIC especially resin-modified GIC combined with rubber dam isolation performed better [22].

The choice of restorative material depends on the depth of the carious lesion and the condition of the dentin at the pulpal wall. Traditionally, caries management involved complete removal of demineralized dentin before placing the restoration. However, the benefits of complete removal of affected dentin have been questioned due to concerns about potential adverse effects on the dental pulp. Several studies have challenged this approach, testing different techniques for managing carious dentin. Stepwise excavation involves removing dentin in stages over two visits, allowing the dental pulp time to deposit reparative dentin. Partial removal preserves a portion of the affected dentin and seals the carious lesion in permanent teeth. Another approach involves not removing carious dentin before sealing or restoring, relying on sealing to arrest lesion progression [23,24].

Proximal dental lesions confined to dentin have traditionally been managed through invasive means, including surgical intervention and restoration. Non-invasive alternatives, such as sealants, fluoride varnish applications, or floss impregnated with fluoride, could potentially prevent enamel demineralization; however, their effectiveness depends on the patient's caries risk. Recently, micro-invasive approaches have been attempted for the management of proximal carious lesions. These interventions involve creating a barrier either above (sealing) or within (infiltration) the lesion. Various methods and materials are currently available for micro-invasive treatments, including resin-based sealants (e.g., polyurethane), patch/strip systems, glass ionomer cements (GIC), or adhesive resin infiltration [25].

However, non-invasive alternatives are applicable only to lesions confined to enamel, while lesions extending beyond the enamel–dentin junction have not yet been fully evaluated in terms of the potential for remineralization of the affected dental hard tissues [26,27]. Several studies have indicated that radiographically visible lesions extending into outer dentin represent either a contraindication for resin infiltration techniques or a clear indication for surgical treatment [28,29].

The depth of the lesion observed radiographically correlates with the level of bacterial infection, which applies equally to both non-cavitated and inactive lesions, as well as with the accumulation of proteins, microbial metabolic products, lipids, polysaccharides, and/or other salivary or

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dietary infiltrates. All these factors have a negative impact, likely hindering complete remineralization [30-37].

Dentin caries can be removed via an occlusal approach, while enamel caries may be remineralized through infiltration both from within the cavity and from the proximal site, thereby occluding the porous enamel lesion areas through capillary infiltration. Remineralization could lead to stabilization of weakened proximal enamel and should result in increased clinical success rates [28,29].

A Class II cavity can be prepared in several ways. Tunnel preparation offers greater mechanical advantage compared to conventional Class II cavity preparation or drop/slot preparation methods, thereby protecting the restored tooth from potential fracture. Combining tunnel preparation with resin infiltration could further enhance tooth strength while still representing a minimally invasive approach for managing proximal caries. Undoubtedly, the biomechanical performance of the restored tooth would be improved by employing this method [38].

Composite restorations for Class II cavities are more frequently placed subgingivally, at the cement–enamel junction, and those placed in dentin are more prone to bacterial microleakage [39]. One of the major disadvantages of restoring posterior teeth with resin composites is the lack of adaptation of the material to the tooth structure, particularly at the gingival floor [40].

Especially when the bond to dentin is weaker, polymerization shrinkage of the material can result in the formation of a gap between the cavity walls and the composite resin. This gap facilitates bacterial microleakage, allowing the infiltration of bacteria and oral fluids from the oral cavity. Bacterial microleakage can lead to postoperative sensitivity, pulpal inflammation, and secondary caries [41].

Recently, a new category of composites called nanocomposites has been developed [42]. Restorative composite systems utilizing nanotechnology offer high translucency and improved polishability [43,44]. Clinically, nanocomposites exhibit adequate strength in high-stress areas typical of posterior teeth, making them as durable as hybrid and microhybrid composites [43-45].

Flowable composites have been recommended for application beneath paste-type resin composites due to their low viscosity, elasticity, and improved infiltration into dentin. These application characteristics, combined with a syringe delivery system, make flowable composites an ideal choice for use in the sandwich technique. They are placed on the gingival floor of proximal Class II restorations as a liner, improving final marginal adaptation and resulting in reduced microleakage and postoperative sensitivity [43-47].

Composites have a relatively high modulus of elasticity, and it has been suggested that this rigidity contributes to their inability to compensate for polymerization shrinkage stress. This may lead to failure of the composite-tooth bond or fracture of the tooth structure, resulting in bacterial microleakage and postoperative sensitivity. The use of an intermediate layer of flowable composite, with a lower modulus of elasticity, can compensate for some of the polymerization shrinkage stress. Some in vitro studies have shown that the use of flowable composites reduces the risk of bacterial

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microleakage and the occurrence of secondary caries [48,49].

Flowable compomers are resin-modified composites with polyacid additives, possessing the characteristics of both flowable composites and glass ionomer cements. Flowable compomers are claimed to improve adhesive properties and release fluoride similarly to conventional glass ionomer cements. These materials are also indicated for use at gingival floors, reducing polymerization shrinkage stress in Class II restorations, with properties similar to those of flowable composites, and thereby improving the C-factor [50,51].

The use of nanocomposites allows the creation of aesthetic restorations with adequate strength for direct application in posterior teeth. In a clinical study, Filtek Supreme demonstrated good performance in posterior teeth, similar to the results observed in our study. Although no statistically significant difference in bacterial microleakage was observed between Universal Filtek Supreme XT and Filtek Z250 with or without the addition of flowable composite at the gingival floor, Universal Filtek Supreme XT showed better results than Filtek Z250 in each similar subgroup [42,45,51-54].

Many new techniques and materials have been introduced to reduce polymerization shrinkage stress, such as the incremental layering technique, multi-angle polymerization, and the use of low-elasticity composites as an intermediate layer between the restoration and the tooth structure [55-57].

The dentin replacement material (SDR) is a recently introduced flowable composite that can be used as a liner in Class I and Class II restorations. SDR resin provides an approximate 20% reduction in volumetric shrinkage and an 80% reduction in polymerization stress compared to a conventional resin composite system [58].

The material GC Fuji II LC, a resin-modified glass ionomer, can be used as a liner beneath composite restorations to partially reduce polymerization shrinkage stress of composite restorations. In practice, these cements, whether traditional glass ionomers or resin-modified glass ionomers, ensure better adaptation and act as a flexible stress-absorbing layer between the restoration and the tooth [59].

Numerous studies have tested restorations made with different types of posterior composites using various adhesive techniques and tested composites, such as PRODIGY, Filtek Z250, and Filtek Supreme XT, concluding that there is no significant difference in the clinical performance of composites in posterior restorations [54,59-62].

The findings of the present study indicated that the clinical parameters associated with restorations-including secondary caries, postoperative sensitivity, marginal adaptation, marginal discoloration, color matching, anatomical form, and surface roughness-were clinically acceptable for composite restorations. These results are consistent with those reported in other studies [63-69].

The adaptation of resin-based composite restorations in Class I cavities has been evaluated through marginal microleakage, as it is more challenging for the restorative material to adapt to the deepest areas of the cavity compared to other interface locations [70]. Nevertheless, very good results were

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also observed in Class I cavities compared to Class II cavities.

5. Conclusions

Clinical findings indicate that direct light-cured resin composite restorations in posterior teeth demonstrate a high rate of clinical success and a favorable long-term survival time, supporting their use as a material of choice for medium to extensive, and in certain clinical situations, large cavity preparations in posterior teeth. The conducted research revealed that patient gender significantly influences restoration outcomes, particularly in terms of marginal adaptation and the need for repair or complete replacement. Specifically, a higher incidence of restorations requiring repair was observed in female patients compared to male patients.

Repairs were more frequently associated with cases involving dental abrasion and secondary caries, whereas fractures and dental erosion were less common indications for repair. Restoration replacement was most often necessary in cases with secondary caries or dental erosion.

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Author contributions

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The authors declare no conflicts of interest concerning this study.

Data availability statement

Will be provided on request.

Ethics statement

This study was approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova (approval data no. 412/04.11.2025).

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ORIGINAL ARTICLE

EXPERIMENTAL GINGIVITIS IN TYPE 1 DIABETIC PATIENTS: A CONTROLLED CLINICAL AND MICROBIOLOGICAL STUDY

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Abstract: *Background*: Type 1 diabetes mellitus (T1DM) is a chronic autoimmune disorder that alters the host's immune and inflammatory responses, potentially enhancing susceptibility to periodontal inflammation and disease. Experimental gingivitis models offer a controlled framework to evaluate host–microbiota interactions under plaque-induced challenges. Aim: This study aimed to evaluate and compare the clinical and microbiological responses to experimentally induced gingivitis between individuals with well-controlled type 1 diabetes and non-diabetic controls. *Materials and Methods*: A total of 155 volunteers (78 diabetics, 77 non-diabetics), aged 18–35 years, were enrolled in a 35-day controlled clinical trial. Following a 3-week period of no oral hygiene (Days 0–21) and a 2-week period of resumed hygiene (Days 21–35), clinical indices (Plaque Index—PI, Gingival Index—GI, and percentage of bleeding sites with GI ≥ 2) were recorded at six sites per tooth. Subgingival plaque samples were collected and analyzed for bacterial complexes using checkerboard DNA–DNA hybridization. *Results*: Both groups exhibited significant increases in PI and GI during plaque accumulation. However, diabetics developed an earlier and more pronounced inflammatory response ($p < 0.01$), with higher percentages of bleeding sites at Days 7 and 21. Red and orange bacterial complexes increased significantly during plaque accumulation, then decreased after oral hygiene reinstitution. *Conclusion*: Type 1 diabetic patients exhibited a hyperinflammatory response to bacterial plaque challenge compared with non-diabetic controls, despite similar plaque levels. These findings reinforce the critical importance of meticulous oral hygiene in diabetic individuals to mitigate periodontal risk.

Keywords: experimental gingivitis, type 1 diabetes mellitus, gingival inflammation, host response, subgingival microbiota

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1. Introduction

Periodontal diseases are chronic inflammatory conditions initiated by bacterial biofilms but significantly modified by the host's immune response. While plaque accumulation serves as the primary etiologic factor, the severity and rate of disease progression are largely dependent on host susceptibility. Among systemic conditions influencing periodontal health, diabetes mellitus has emerged as one of the most influential.

Type 1 diabetes mellitus (T1DM) is characterized by autoimmune destruction of pancreatic β-cells, resulting in insulin deficiency and hyperglycemia. The resulting metabolic imbalance contributes to oxidative stress, accumulation of advanced glycation end-products (AGEs), and upregulated pro-inflammatory cytokine expression (IL-1β, TNF-α, IL-6), which may amplify gingival inflammation.

Several epidemiological studies have demonstrated an increased prevalence and severity of periodontal diseases among diabetic individuals (Hugoson et al., 1989; Grossi et al., 1994). However, results have varied, particularly when considering differences in metabolic control, age, and study design. The experimental gingivitis model, introduced by Löe et al. (1965), provides a unique opportunity to observe the cause–effect relationship between plaque accumulation and gingival inflammation in a controlled manner.

The current study aimed to evaluate clinical and microbiological changes during experimental gingivitis in type 1 diabetic subjects compared with non-diabetic controls, using a standardized 35-day protocol. The study hypothesized that diabetic subjects would exhibit an earlier and more pronounced inflammatory response to a comparable bacterial challenge.

2. Materials and method

2.1 *Study design*

A controlled 35-day experimental gingivitis protocol was implemented, consisting of:

- Days 0–21: abstention from all oral hygiene (plaque accumulation phase)
- Days 21–35: reinstitution of optimal oral hygiene (healing phase)

All clinical and microbiological assessments were performed at baseline (Day 0), during the accumulation phase (Days 7, 14, 21), and after healing (Day 35).

2.2 *Participants*

A total of 155 volunteers (78 type 1 diabetics, 77 non-diabetic controls) were recruited.

Inclusion criteria: 18–35 years old, ≥ 24 teeth, probing depth < 4 mm, good systemic health, and for diabetics, HbA1c ≤ 8.5 %.

Exclusion criteria: smoking > 5 cigarettes/day, antibiotic use within 3 months, pregnancy, chronic medication influencing gingival status, or active caries.

Ethical approval was obtained from the Institutional Ethics Committee of UMF Craiova Nr.411/04.11.2025. Written informed consent was secured from all participants.

2.3 *Clinical assessments*

Description of Clinical Indices Used

The Plaque Index (PI) used in this study followed the Silness and Löe criteria, evaluating the thickness of dental plaque at the

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cervical third of the tooth. Scores ranged from 0 (no plaque) to 3 (abundance of soft deposits visible to the naked eye).

The Gingival Index (GI) was recorded according to the Löe and Silness system, assessing gingival color, edema, and bleeding tendency after gentle probing. GI values ranged from 0 (normal gingiva) to 3 (severe inflammation with a tendency to spontaneous bleeding).

Additionally, the percentage of gingival sites with GI ≥ 2 was calculated at each time point to quantify the extent of clinically significant bleeding inflammation.

These indices were recorded at six sites per tooth, using standardized probing techniques with a UNC-15 periodontal probe.

PI and GI were measured at six sites per tooth using calibrated probes (UNC-15). Inter-examiner reliability ($\kappa > 0.85$) was established before the study. The percentage of sites with GI ≥ 2 was used to quantify the extent of bleeding inflammation.

2.4 *Microbiological sampling*

Subgingival samples were collected from distolingual sites of first molars in each quadrant using sterile Gracey curettes. Samples were pooled and analyzed for 40 bacterial species by checkerboard DNA–DNA hybridization, focusing on:

- Red complex (Porphyromonas gingivalis, Treponema denticola, Tannerella forsythia)
- Orange complex (Fusobacterium nucleatum, Prevotella intermedia)
- Blue complex (Actinomyces naeslundii, Streptococcus mitis)

2.5 *Statistical analysis*

Data were analyzed using SPSS v27. Continuous variables were expressed as mean ± SD. Within-group changes were evaluated using paired t-tests; between-group differences were tested with unpaired t-tests and Mann–Whitney U tests. The significance level was set at $p < 0.05$.

3. Results

Table 1 presents the demographic characteristics of the study population. The diabetic and control groups were well balanced with respect to age, sex distribution, and number of teeth present, with no significant differences between groups. As expected, HbA1c levels were significantly higher in the diabetic group ($p < 0.001$), confirming distinct metabolic profiles between the cohorts

Table 1. Demographic characteristics.

Variable	Diabetics (n = 78)	Controls (n = 77)	p-value
Age (years, mean ± SD)	26.4 ± 4.8	25.9 ± 5.2	0.57
Sex (M/F)	32/46	31/46	0.94
HbA1c (%)	8.1 ± 0.7	5.3 ± 0.4	< 0.001
Teeth present	27.2 ± 1.3	27.4 ± 1.2	0.63

No significant baseline differences were found between the groups except for HbA1c levels.

Table 2 illustrates the evolution of plaque accumulation and gingival inflammation over the 35-day study period. Both groups

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exhibited sharp increases in PI and GI during the no-hygiene phase (Days 0–21). However, diabetic participants consistently demonstrated higher GI values and a greater percentage of bleeding sites from Day 7 onward ($p < 0.05$). After reintroduction of oral hygiene (Day 35), all indices returned near baseline levels.

Table 2. Mean Plaque Index (PI) and Gingival Index (GI).

Day	Group	PI (mean ± SD)	GI (mean ± SD)	% GI ≥ 2 ± SD
0	Diabetics	0.18 ± 0.10	0.25 ± 0.11	1.5 ± 1.0
	Controls	0.17 ± 0.08	0.22 ± 0.09	1.1 ± 0.8
7	Diabetics	0.85 ± 0.23	0.90 ± 0.20	12.5 ± 4.3
	Controls	0.80 ± 0.20	0.78 ± 0.22	8.3 ± 3.6
14	Diabetics	1.40 ± 0.27	1.30 ± 0.25	27.8 ± 8.5
	Controls	1.32 ± 0.29	1.10 ± 0.24	19.2 ± 6.7
21	Diabetics	2.05 ± 0.21	1.55 ± 0.28	41.0 ± 9.8
	Controls	1.92 ± 0.25	1.28 ± 0.23	26.2 ± 7.9
35	Diabetics	0.20 ± 0.10	0.30 ± 0.12	1.9 ± 0.9
	Controls	0.18 ± 0.09	0.25 ± 0.10	1.3 ± 0.8

Both groups showed significant PI and GI increases during plaque accumulation ($p < 0.001$). The diabetics demonstrated higher GI and bleeding percentages from Day 7 onward ($p < 0.05$).

Table 3 shows the relative proportions of major bacterial complexes at baseline, peak inflammation (Day 21), and recovery (Day 35). Both diabetics and controls showed significant increases in red and orange complexes during plaque accumulation, followed by reductions after oral hygiene reinstitution. Blue complex species decreased during inflammation and rebounded after hygiene, reflecting shifts between pathogenic and health-associated microbiota.

Table 3. Relative proportion of bacterial complexes.

Complex	Baseline (%)	Day 21 (%)	Day 35 (%)	Change ($p < 0.05$)
Red – Diabetics	5.2 ± 1.1	17.5 ± 3.2	6.0 ± 1.4	↑ Day 0–21; ↓ 21–35
Red – Controls	4.9 ± 1.0	14.2 ± 2.8	5.1 ± 1.3	↑ Day 0–21; ↓ 21–35
Orange – Diabetics	12.3 ± 2.4	24.1 ± 4.2	14.5 ± 3.0	↑ Day 0–21; ↓ 21–35
Blue – Both	22.1 ± 3.8	14.2 ± 2.5	23.8 ± 3.9	↓ Day 0–21; ↑ 21–35

The bacterial composition shifted toward pathogenic complexes during the plaque accumulation phase, followed by a return to health-associated flora after oral hygiene reinstitution.

Figure 1 illustrates the progressive increase in PI and GI during the 21-day plaque accumulation period, followed by a return toward baseline after oral hygiene was resumed. Diabetic subjects showed an earlier and more pronounced rise in GI relative to controls, indicating enhanced inflammatory susceptibility.

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Figure 2 depicts the percentage of gingival sites with bleeding (GI ≥ 2). The diabetic group exhibited significantly higher bleeding proportions at Days 7, 14, and 21 ($p < 0.01$), supporting the observation of a hyperinflammatory response even in the presence of similar plaque levels.

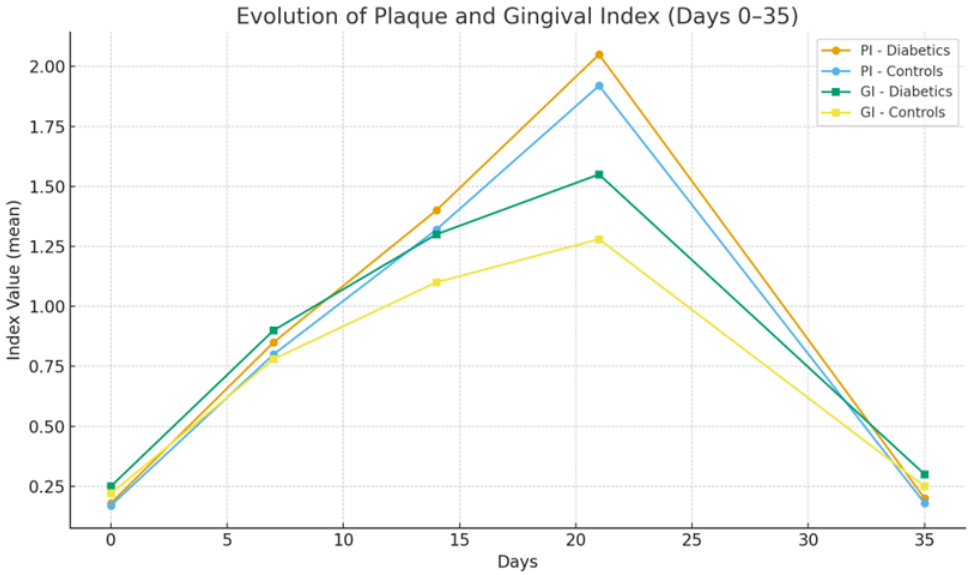

Figure 1. Evolution of Plaque and Gingival Index (Days 0–35).

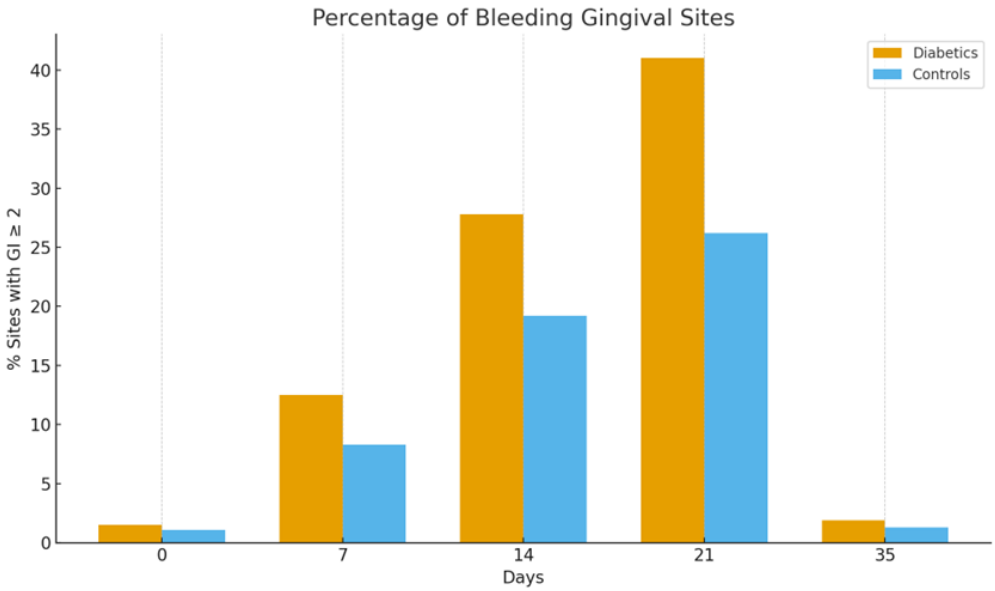

Figure 2. Percentage of Bleeding Gingival Sites.

Figure 3 shows the temporal changes in bacterial complexes within the diabetic group. During plaque accumulation, red and orange complexes increased substantially, consistent with a pathogenic shift. After reinstitution of hygiene, these levels decreased, while blue

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complex bacteria—associated with periodontal health—recovered.

Figure 4 presents a radar chart comparing key inflammatory parameters at Day 21 between diabetics and controls. Diabetic subjects displayed consistently higher values across all indices, corroborating their amplified inflammatory response to plaque challenge.

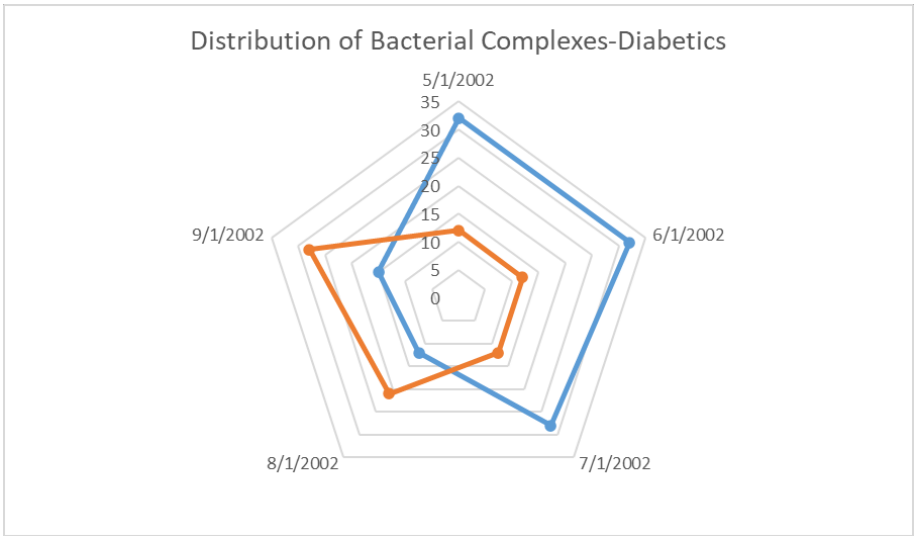

Figure 3. Distribution of Bacterial Complexes – Diabetic Group.

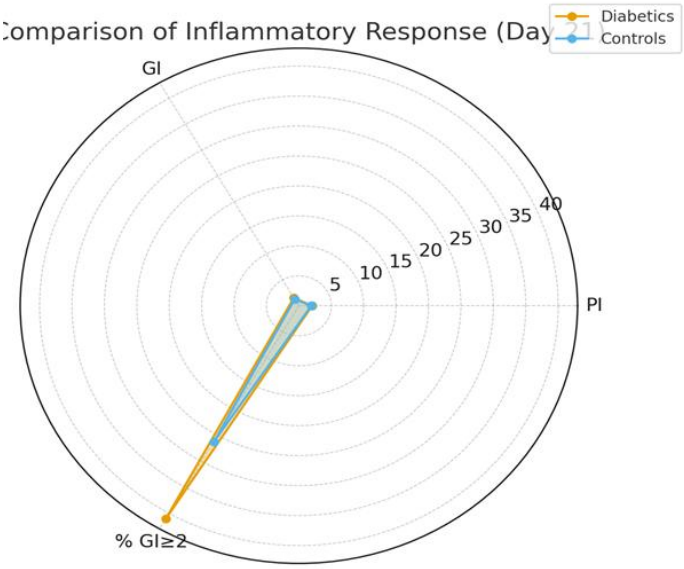

Figure 4. Radar Chart: Comparative Inflammatory Response at Day 21.

4. Discussion

The present controlled experimental gingivitis study showed that young adults with type 1 diabetes mellitus (T1DM), despite good-to-moderate metabolic control, develop an earlier and more pronounced gingival

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inflammatory response to standardized plaque accumulation than non-diabetic controls, even in the presence of comparable plaque levels. Diabetic subjects exhibited higher Gingival Index (GI) values and a significantly greater percentage of bleeding sites from Day 7 onwards, while Plaque Index (PI) followed a similar trajectory in both groups. These findings support the concept that diabetes primarily acts as a modifier of the host response, rather than changing the quantity of bacterial challenge.

Our results are in line with previous experimental gingivitis models in T1DM. Salvi et al. (2005) reported that, under controlled plaque accumulation, diabetic patients developed more pronounced gingival inflammation and bleeding compared with non-diabetic subjects, confirming an exaggerated inflammatory response to a similar biofilm challenge. Likewise, Giannobile et al. (2010) observed elevated levels of pro-inflammatory biomarkers in gingival crevicular fluid during experimental gingivitis in T1DM patients compared with systemically healthy controls, further supporting the notion of a hyper-reactive periodontal inflammatory phenotype in diabetes. The present study corroborates these observations at the clinical level, showing that, from early time points, diabetic individuals cross the threshold into clinically evident inflammation and bleeding more rapidly than matched controls.

The clinical pattern observed here also aligns with epidemiological and clinical evidence indicating a higher prevalence and severity of periodontal disease in diabetes. Several recent reviews and umbrella analyses have reinforced the bidirectional relationship between periodontal disease and diabetes, highlighting diabetes as a major risk factor for gingivitis and periodontitis, and periodontal inflammation as a contributor to poorer glycemic control (Costa et al., 2023; Păunică et al., 2023; Di Domenico et al., 2023; "An Umbrella Review of the Association Between Periodontal Disease and Diabetes Mellitus," 2024; "Periodontitis: an often-neglected complication of diabetes," 2024). These works converge on the idea that even in relatively young populations, diabetes predisposes to an exaggerated periodontal inflammatory response, which is consistent with the present findings in 18–35-year-old participants.

From a microbiological perspective, both diabetics and controls in our study showed a shift toward a more pathogenic biofilm during plaque accumulation, with significant increases in red and orange complexes and a concomitant decline in health-associated blue complex species. After oral hygiene reinstitution, red and orange complexes decreased, while blue complex bacteria rebounded toward baseline.

This dynamic is comparable to earlier observations in experimental gingivitis models that demonstrated a transition from gram-positive, health-associated flora toward gram-negative anaerobes as plaque matures (Ximénez-Fyvie et al., 2000; Salvi et al., 2005). The key point is that, although the microbiological trends were broadly similar in diabetics and controls, the clinical inflammatory expression was consistently greater in T1DM subjects, strengthening the argument that the host response is the principal differentiating factor.

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Recent microbiome studies in children and adolescents with T1DM also support a pattern of dysbiosis associated with diabetes. Selway et al. (2023), Carelli et al. (2023), and Chakraborty et al. (2021) reported alterations in oral microbial communities and early markers of periodontal disease in young individuals with T1DM, often linked to glycemic control and inflammatory status. These studies indicate that T1DM may prime the oral environment for earlier and more pronounced inflammatory responses to plaque. Our data extend these findings to an adult population under standardized plaque challenge and suggest that, even with controlled experimental conditions and exclusion of overt periodontitis, diabetes still amplifies gingival inflammation.

The biological mechanisms underlying this hyperinflammatory gingival response in T1DM are multifactorial. Chronic hyperglycemia promotes formation of advanced glycation end products (AGEs) and engagement of the AGE–RAGE axis on endothelial cells and monocytes, enhancing NF-κB activation and upregulating pro-inflammatory cytokines such as IL-1β, TNF-α, and IL-6. Neutrophil chemotaxis and phagocytosis are frequently impaired, while oxidative stress is increased, and collagen turnover and repair are delayed. These mechanisms have been well documented in both experimental and clinical studies (Sereti et al., 2021; "Diabetes mellitus promotes susceptibility to periodontitis—novel insights," 2023; Duda-Sobczak et al., 2018). In the context of the present study, they offer a plausible explanation for why, under comparable plaque conditions, diabetic subjects progressed more rapidly to higher GI scores and higher proportions of bleeding sites than their non-diabetic counterparts.

Our findings are also consistent with the growing body of evidence that periodontal therapy can contribute to modest improvements in glycemic control. Several recent umbrella and systematic reviews reported that non-surgical periodontal treatment is associated with small but clinically relevant reductions in HbA1c levels in patients with diabetes (Di Domenico et al., 2023; "Effect of Periodontal Treatment in Patients with Periodontitis and Diabetes Mellitus," 2023; "The role of periodontal treatment on the reduction of hemoglobin A1c," 2025). In this context, the hyperinflammatory periodontal response observed in our T1DM group further supports the inclusion of periodontitis as a complication of diabetes and underscores the importance of periodontal care within comprehensive diabetes management.

Compared with cross-sectional and observational studies that often include broad age ranges and variable metabolic control, the strengths of the present investigation include a relatively homogeneous, young adult population, strict inclusion/exclusion criteria, and a well-controlled experimental gingivitis protocol with standardized plaque accumulation and healing phases. The use of validated clinical indices, calibrated examiners, and a microbiological assessment focusing on recognized bacterial complexes provides a robust framework for evaluating both clinical and microbial responses.

However, several limitations should be acknowledged. First, the study focused on young adults with relatively good-to-moderate metabolic control (HbA1c ≤ 8.5%),

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and the results may not be generalizable to older individuals, those with long-standing diabetes, or poorly controlled glycemia, where the inflammatory response may be even more pronounced. Second, the observation period was limited to 35 days, which captures short-term gingival changes but does not address long-term progression to periodontitis. Third, subgingival plaque sampling was restricted to specific molar sites and pooled for analysis, which may underestimate site-specific variability in microbial composition. Finally, no biochemical or molecular markers (e.g., cytokines, matrix metalloproteinases, oxidative stress markers) were collected, limiting the ability to directly correlate clinical findings with underlying immune and inflammatory mechanisms.

Future research should build on these findings by incorporating longitudinal designs that track periodontal and metabolic outcomes over longer periods, including patients with varying degrees of glycemic control and diabetes duration. Adding gingival crevicular fluid and serum biomarkers, as suggested by previous work (Giannobile et al., 2010; Sereti et al., 2021), would allow a deeper understanding of the molecular pathways linking T1DM and periodontal inflammation. Moreover, studies integrating detailed microbiome profiling and host-response analyses could help identify specific microbial–host signatures that characterize high-risk diabetic phenotypes.

From a clinical standpoint, the present results reinforce several key messages. First, even in young adults with T1DM and without established periodontitis, gingival tissues respond more aggressively to plaque accumulation, highlighting the necessity of meticulous daily oral hygiene and regular professional prophylaxis. Second, early identification and management of gingival inflammation in diabetic patients may help prevent progression to destructive periodontal disease and may contribute indirectly to better metabolic control. Third, the data support closer interprofessional collaboration between diabetologists and dental professionals, with routine periodontal screening and preventive counseling integrated into diabetes care pathways. Within the limitations of this study, it can therefore be concluded that T1DM significantly enhances susceptibility to plaque-induced gingival inflammation, confirming diabetes as a potent modifier of the periodontal host response. These findings complement and extend existing evidence, strengthening the rationale for recognizing periodontal disease as a relevant complication of diabetes and for prioritizing periodontal prevention and treatment in this population.

5. Conclusions

Within the limitations of this study, it can be concluded that both diabetic and non-diabetic individuals respond to bacterial plaque accumulation with gingival inflammation. However, patients with type 1 diabetes exhibit an earlier onset and greater severity of gingival inflammation, despite comparable plaque levels. The findings highlight diabetes as a potent modifier of host response, emphasizing the need for rigorous preventive and therapeutic periodontal care in this population.

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Author contributions

Authors read and approved the final manuscript. All authors have equally contributed to this work.

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Conflict of interest statement

The authors declare no conflicts of interest concerning this study.

Data availability statement

Will be provided on request.

Ethics statement

This study was approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova (approval data no. 411/04.11.2025).

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ORIGINAL ARTICLE

ASSESSMENT OF DENTAL STUDENTS' AND DENTISTS' KNOWLEDGE ON USING DIGITAL MODELS VS. PLASTER MODELS IN DENTISTRY

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Abstract: *Background*: In dentistry, study models are used for establishing comprehensive diagnosis, treatment planning, and evaluating post-treatment outcomes. Digitalization has become an indispensable component of the medical and dental fields, leading to the development of digital dental models. The present study aimed to investigate the knowledge of dental students and practitioners regarding the use of plaster models versus digital models for establishing dental diagnoses and treatment plans. *Methods*: The study was conducted on a representative sample of participants including students from the University of Medicine and Pharmacy of Craiova, Faculty of Dentistry and dental practitioners from Dolj County. The investigation of the students' and dentists' knowledge was carried out using a questionnaire-based method. The questionnaire included a set of 16 open-ended questions with single or multiple complementary responses, addressing several aspects. *Results*: Regarding the frequency of use of conventional plaster study models, 90% of respondents considered that they are still used in current clinical practice. Analysis of the responses regarding the comparison of the accuracy of digital models with that of plaster models indicated that 60% (n = 30) of participants stated that digital models have better accuracy. Regarding the use of study models in dental prosthesis design, 70% (n = 35) considered that designing is easier on digital models. *Conclusions*: The participants' opinions in the study highlighted that digital models provide greater accuracy of the information conveyed compared to gypsum models and also facilitate the design of prostheses more easily than gypsum models.

Keywords: digital model, plaster model, questionnaire

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1. Introduction

In dentistry, study models are used for establishing a comprehensive diagnosis, treatment planning, and evaluating post-treatment outcomes [1,2]. Thorough diagnosis and meticulous treatment planning enable the achievement of satisfactory and successful therapeutic results. Moreover, dental model analysis represents a valuable tool for examining occlusion and dentition in all three dimensions to assess the degree and severity of dental malposition and/or malocclusion for diagnostic and therapeutic purposes [3].

The gold standard for diagnostic measurements is the use of a caliper on gypsum models [4]. Conventional analyses of plaster models have been the most frequently employed form of model assessment from the past to the present due to the simplicity of the method [3].

Dental measurements performed on plaster models or photographs using a caliper are time-consuming [5] and prone to errors due to anatomical variations, individual factors, or factors related to tooth positioning and inclination [6]. Additionally, study models made of gypsum or dental cements are susceptible to damage and loss of accuracy caused by external factors [7].

In recent years, numerous advances in information technology have replaced traditional methods, offering modern and high-quality diagnostic tools at a reasonable cost [8]. Digitalization has become an indispensable component of the medical and dental fields, leading to the development of dental scanning techniques and the acquisition of digital dental models [9]. Digital models have become widely used in dental practices, with multiple options available for obtaining three-dimensional (3D) dental models [10].

The potential advantages of digital models arise from their ability to analyze dental and/or arch characteristics in a 3D manner, thereby eliminating the sources of measurement errors encountered in traditional methods [7]. Digital models offer numerous benefits, such as instant accessibility to 3D information without the need to retrieve plaster models from a storage area, reduced requirements for large storage spaces, faster analyses, the ability to share information online with other professionals, and objective (rather than subjective) evaluation of models according to the requirements for American Board of Orthodontics (ABO) certification [7,11]. The relationships between the maxillary and mandibular arches can also be visualized more clearly in occlusion, from multiple perspectives, in 3D images and software applications [12].

Digital models further allow for virtual treatment simulation and dental configuration planning [13]. 3D models can be processed to analyse individual teeth and estimate the axis or position of each tooth, providing a tridimensional prediction of tooth movement by superimposing dental changes on stable reference structures [7]. Additionally, digital models permit clinicians to use CAD/CAM applications (computer-aided design/ computer-aided manufacturing) for model analysis and for designing and fabricating appliances, particularly clear aligners [1].

Digital dental models can be obtained either by indirect scanning of impressions or plaster models using desktop laboratory scanners, or by directly scanning the dental

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arches with intraoral scanners [14,15]. Other methods for generating 3D digital models have also been proposed, such as those based on Con Beam Computer Tomograph data [16].

As a result of research and development in this field, Cadent (now Align Technology, San Jose, CA, USA) introduced in 1999 the first generation of OrthoCad™ software for "digital models" [3]. In 2006, the iTero Element intraoral scanner (Align Technology, San Jose, CA, USA) was launched, using parallel confocal imaging and point-by-point reconstruction to generate 3D computerized images [17].

This technology was later utilized for generating digital study models through various methods such as scanning alginate impressions or direct intraoral scanning, which may be more cost-effective and efficient, saving time and casting material compared with scanners used for plaster models [8].

Nevertheless, all these advantages can be considered valid only insofar as their accuracy and reliability are clinically demonstrated [3].

The scientific literature presents contradictory findings regarding the accuracy of dental measurements performed on digital models obtained by scanning plaster casts and offers limited data concerning digital models generated through impression scanning [3]. Previous reviews have confirmed that digital impressions obtained directly by intraoral scanning may be considered a viable alternative to alginate impressions in patients with a fully natural dentition [18,19].

In a recent systematic review, Alassiry stated that digital impressions may not be as precise as conventional ones, although intraoral scanners are considered clinically acceptable for orthodontic treatment planning, appliance fabrication, and clear aligner production [20].

These reviews recommended further research to compare digital impressions produced with different scanners, using diverse scanning strategies, as well as comparisons with other conventional impression materials [18,20].

Numerous studies have confirmed the validity [21,22], reliability [3,23], and reproducibility [24] of measurements performed on digital models compared with those on plaster models in permanent dentition. Although statistically significant differences between methods have been reported, these measurement discrepancies have not been considered clinically relevant [25,26]. Studies have also verified that digital measurements are clinically acceptable and not inferior for treatment planning [27].

However, while the digital method represents a clinically acceptable alternative to the analogue standard for analyzing permanent dentition, no comparative studies have been available for digital versus analogue measurements in children with mixed dentition. These situations differ because, instead of measuring all teeth, it is necessary to analyze a limited number of permanent teeth together with the supporting area. Thus, longer distances must be measured when examining the supporting area, which may be more difficult to assess accurately.

The present study aimed to investigate the knowledge of dental students and practitioners regarding the use of plaster models versus digital models for establishing dental diagnoses and treatment plans.

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2. Materials and method

The study was conducted on a representative sample of participants including students from the University of Medicine and Pharmacy of Craiova, Faculty of Dentistry and dental practitioners from Dolj County. The present study was observational, non-interventional, and cross-sectional in design. The implementation and conduct of the study were approved by the Ethics and University Deontology Committee of the University of Medicine and Pharmacy of Craiova, under approval No. 305/10.07.2025.

The investigation of the students' and dentists' knowledge was carried out using a questionnaire-based method. The questionnaire included a set of 16 open-ended questions with single or multiple complementary responses, addressing several aspects: the first four questions assessed the participant category, the following question explored the respondents' sources of information, the next three questions examined the participants' knowledge regarding the use of study models, and the remaining nine questions investigated knowledge related to plaster dental models and digital dental models. The questionnaire was uploaded to the Google Forms application and distributed online between 7–11 July 2025 via social media platforms in the form of a link, under the title "Questionnaire on Plaster Dental Models versus Digital Dental Models". The questions included in the questionnaire were:

1 *Specify the professional category you belong to*: Dental practitioner; Dental student
2 *If you are a practitioner, indicate how many years of professional experience you have*: 0–5 years; 5–10 years; over 10 years
3 *Indicate your gender*: Male; Female
4 *Select the information sources you use frequently*: Specialty textbooks; Artificial intelligence; Congresses, Conferences, Workshops; E-books, Online Webinars; Others
5 *Do you consider that study models are important for establishing the diagnosis and treatment plan?* Very important; Less important; Not important
6 *Which of the following elements do you consider can be analyzed on study models?* Shape and dimensions of edentulous ridges; Topography of remaining teeth; Coronal lesions of remaining teeth; Apical lesions of remaining teeth
7 *Which elements identified on study models do you consider are taken into account in treatment planning?* Direction of inclination of remaining teeth; Position of remaining teeth; Dimension of missing teeth; Dimension of the edentulous ridge
8 *Based on your experience, do you consider that plaster models are still used nowadays?* Yes; No
9 *Which factors do you believe influence the accuracy of a plaster model?* Application of a correct impression technique; Type of impression material; Time interval between impression making and model pouring; Type of gypsum used for casting the model
10 *Do you consider that storage of plaster models is influenced by environmental temperature?* Yes; No

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11 *Based on your experience, how frequently are digital study models used?* Very frequently; Rarely; Very rarely

12 *Digital models can be obtained through:* Intraoral scanning; Scanning of plaster models; Scanning of dental impressions; Processing of CBCT data

13 *Have you participated in obtaining a digital model through intraoral scanning?* Frequently; Rarely; Never

14 *What do you consider to be the advantages of obtaining digital models through intraoral scanning?* Reduced time; Lower costs; Patient comfort; Additional digital training required for the practitioner

15 *Do you consider that the accuracy of digital models, compared with plaster models, is:* Approximately similar; Better; Worse

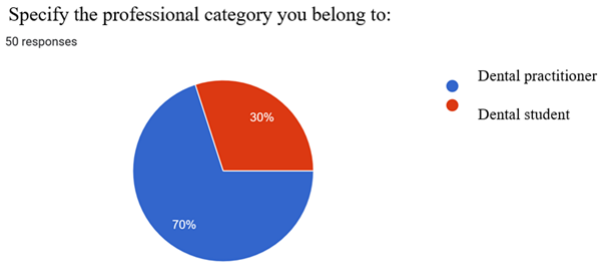
16 *Do you consider that designing a dental prosthesis is easier on:* Digital models; Plaster models

The results of the questionnaire-based study were processed using descriptive statistical analysis, and the data obtained from the case study were expressed numerically.

3. Results

The responses obtained from the questionnaire completed by the participating dental students and practitioners were analyzed. Analysis of the results obtained in the present questionnaire-based study

Following the centralization of the responses to the questionnaire distributed online, it was observed that responses were received from 50 participants, of whom 30% (n = 15) were students and 70% (n = 35) were dental practitioners (Figure 1).



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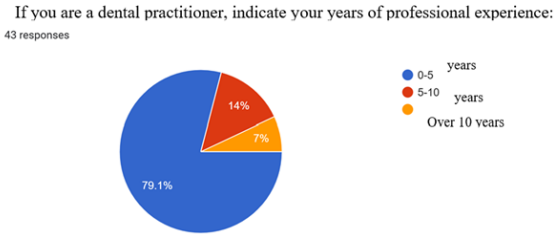

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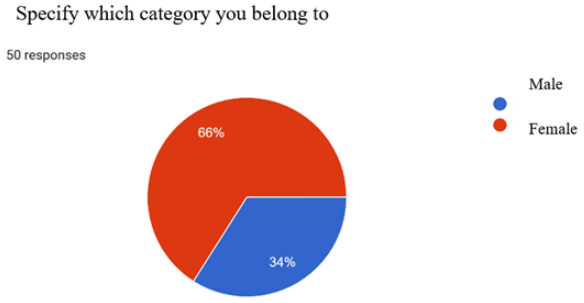

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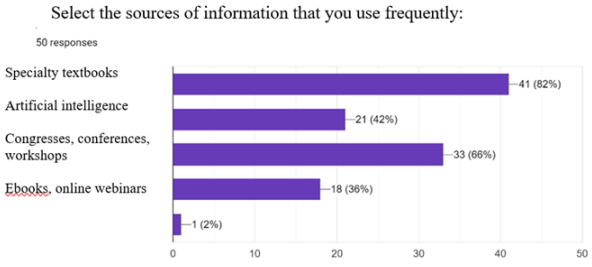

(Figure 4)

Figure 1. Distribution of study participants according to professional cate. **Figure 2.** Distribution of dental practitioner participants according to years of clinical experience. **Figure 3.** Distribution of participants by gender. **Figure 4.** Distribution of participants according to the information sources used.

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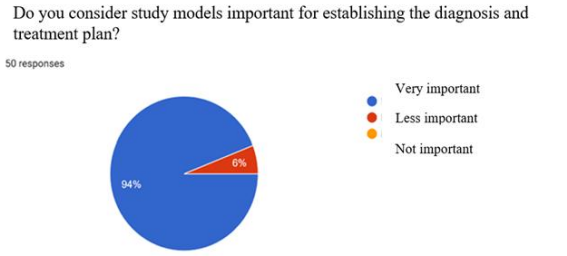
The next question investigated the number of years of professional experience among the participating dental practitioners. The results showed that 26 respondents had between 0–5 years of experience, 6 respondents had between 5–10 years of experience, and 3 respondents had more than 10 years of clinical experience (Figure 2). The third question explored the level of study of the participating dental students. Analysis of the responses showed that all 15 students were in their 6th year of study. Regarding the gender of the participants, the analysis indicated that 66% (n = 33) were male and 34% (n = 17) were female (Figure 3). Analyzing the participants' responses regarding the information sources they use, it was found that 82% (n = 41) reported that they most frequently use specialty textbooks, 66% (n = 33) indicated that their primary source of information is participation in congresses, conferences, and workshops, and the third most cited source was the use of artificial intelligence (42%, n=21) (Figure 4).



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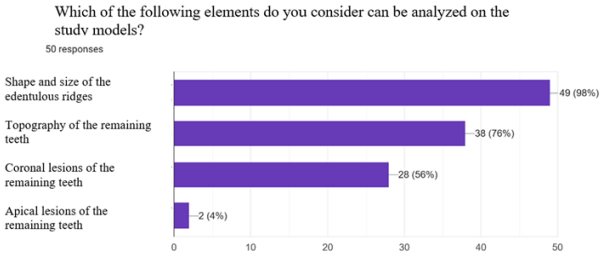

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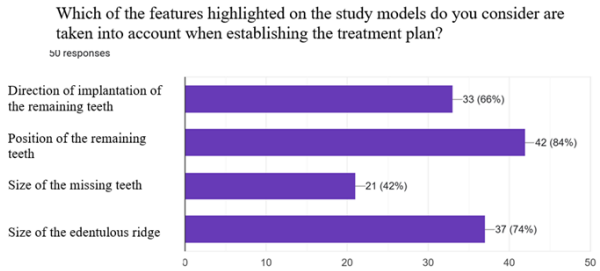

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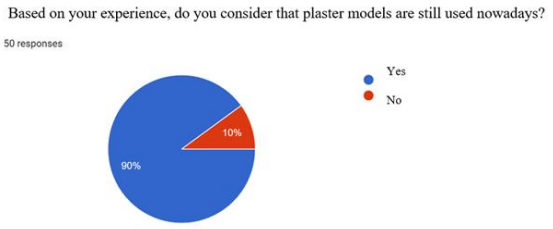

(Figure 8)

Figure 5. Distribution of participants according to their opinion on the importance of study models. **Figure 6.** Distribution of responses regarding the elements analyzed on study models. **Figure 7.** Distribution of responses regarding the factors that influence the treatment plan. **Figure 8.** Distribution of respondents according to their opinion on the frequency of plaster model use.

In response to the question regarding the importance of study models for establishing the diagnosis and treatment plan, 94% (n = 47) indicated that they represent very important tools in clinical practice, while 6% (n = 3) considered that study models are of lesser importance. None of the participants stated that study models are not important (Figure 5). Regarding the elements that can be analyzed on study models, 98% (n = 49) of participants mentioned the shape and dimensions of the edentulous ridges, 76% (n = 38) indicated the topography of the remaining teeth, and 28% reported that coronal lesions of the remaining

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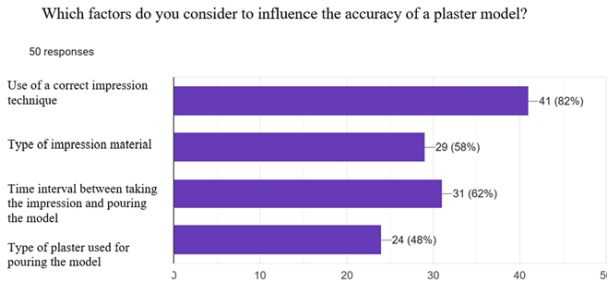
teeth can be analysed on study models (Figure 6). The investigation of knowledge regarding the elements highlighted on study models that influence the treatment plan yielded the following responses: 84% (n = 42) of participants mentioned the position of the remaining teeth, 74% (n = 37) indicated the dimension of the edentulous ridge, and 66% (n = 33) considered that the direction of inclination of the remaining teeth influences the treatment plan (Figure 7). Regarding the frequency of use of conventional plaster study models, 90% of respondents considered that they are still used in current clinical practice (Figure 8).



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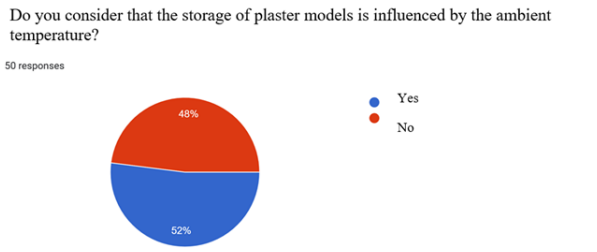

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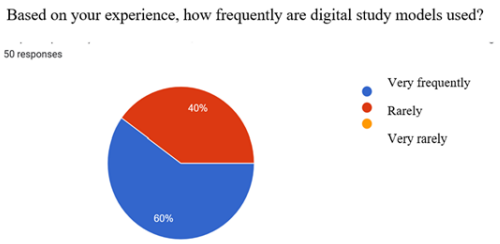

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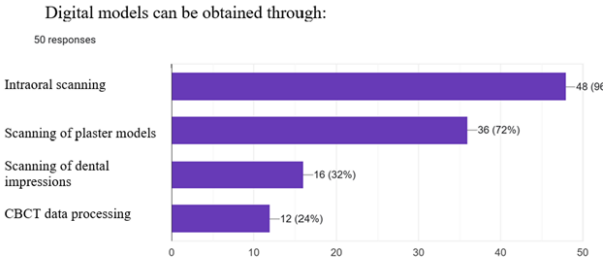

(Figure 12)

Figure 9. Distribution of responses regarding the factors influencing the accuracy of a plaster model. **Figure 10.** Distribution of participants according to their opinion on the storage of plaster models. **Figure 11.** Distribution of respondents according to their opinion on the frequency of digital study model use. **Figure 12.** Distribution of responses regarding the methods of obtaining digital study models.

The question regarding the factors that may influence the accuracy of a plaster model was a multiple-response item. The recorded responses highlighted that the use of a correct impression technique is the main factor affecting the accuracy of a plaster model (82%, n = 41), while the time interval between taking the impression and pouring the model was also considered an important factor (62%, n = 31) (Figure 9). In relatively equal proportions, 52% and 48% of the study participants considered that environmental temperature does, respectively does not, influence the storage of plaster models (Figure 10). The next question explored the participants' opinions regarding the frequency of use of digital study models. The analysis of the responses revealed that 60% and 40% of them reported very frequent and rare use of digital study models, respectively (Figure 11).

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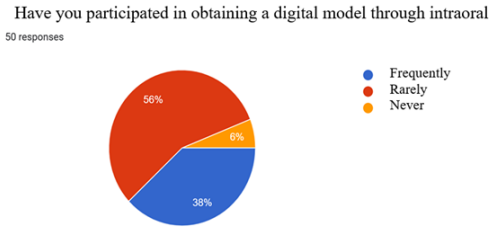
Analyzing the methods for obtaining digital models, the study results highlighted that 96% (n = 48) of participants mentioned intraoral scanning as a means of obtaining a 3D model. Another frequently used method for obtaining digital study models was considered to be scanning of plaster models, with 72% (n = 36) of participants indicating this method (Figure 12). Among the 50 study participants, 56% (n = 29) reported that they had rarely participated in obtaining a digital model through intraoral scanning, 38% (n = 19) stated that they had participated frequently in such a procedure, and 6% (n = 3) mentioned that they had never participated (Figure 13).

The main advantage of obtaining digital models through intraoral scanning was considered to be the reduction of working time, mentioned by 92% (n = 46) of participants. Other advantages reported by participants included patient comfort (74%, n = 37) and lower costs (38%, n = 19) (Figure 14). Analysis of the responses regarding the comparison of the accuracy of digital models with that of plaster models indicated that 60% (n = 30) of participants stated that digital models have better accuracy, 36% (n = 18) reported that the accuracy of the two types of models is similar, and 4% (n = 2) considered that the accuracy of digital models is inferior to that of plaster models (Figure 15). Regarding the use of study models in dental prosthesis design, 70% (n = 35) considered that designing is easier on digital models, while 30% (n = 15) indicated that designing a dental prosthesis is easier on plaster models (Figure 16).



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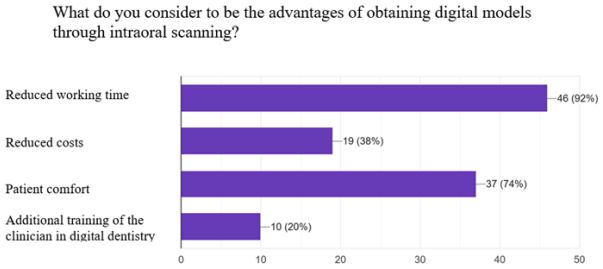

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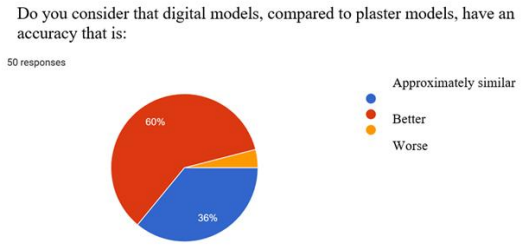

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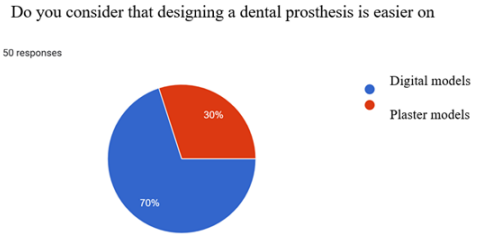

(Figure 16)

Figure 13. Distribution of participants according to their participation in obtaining a digital model through intraoral scanning. **Figure 14.** Distribution of responses regarding the perceived advantages of intraoral scanning. **Figure 15.** Distribution of responses regarding the accuracy of digital and plaster study models. **Figure 16.** Distribution of responses regarding the methods of obtaining digital study models.

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4. Discussion

The present study investigated the knowledge of dental students and dentists regarding the use of gypsum study models compared with digital models. Among the 50 respondents, 70% were dentists, indicating a greater interest among practitioners in the type of study models used in prosthodontics. The results are consistent with the findings of Hall et al., who reported that 28.6% of participants were postgraduate students, while the remaining respondents were practicing clinicians from various specialties [28].

The results of the current study also showed that interest in this topic was higher among female participants (66%), similar findings being reported by Schott et al., who noted that more than 70% of participants in a comparable study were also female [29].

This aspect is further supported by the fact that 94% of participants stated that the study model is highly useful for establishing the diagnosis and designing the therapeutic steps. Moreover, these results indicate that, regardless of the technology used to obtain it, the study model is perceived as an indispensable tool in dentistry.

Physical dental casts remain integral across all branches of dentistry, including orthodontics, prosthodontics, implantology, and oral and maxillofacial surgery, as they constitute essential diagnostic tools. They play a pivotal role in treatment planning, communication with patients and dental technicians, the fabrication of various appliances, preoperative simulation and training, as well as educational activities [30,31,32]. The use of these digital model–acquisition methods may facilitate the replacement of physical dental casts, thereby enhance cost-effectiveness and minimizing the need for storage space [33-35].

The study demonstrated that the use of study models in routine clinical practice holds significant importance, as these models enable the assessment of prosthetically relevant features that support prosthesis design. The participants identified the following elements as prosthetically significant: the position of the remaining teeth (84% of respondents), the dimensions of the edentulous ridge (74% of respondents), and the angulations of the remaining teeth (66% of respondents).

In the present study, 90% of respondents reported that gypsum study models are still used in clinical practice, while at the same time, 60% indicated very frequent use of digital models. These findings align with the results of Husain et al., who showed that practicing dentists preferred both digital and conventional study models, whereas dental graduates favored digital models to a greater extent than conventional ones [36].

The analysis of the responses regarding the accuracy of gypsum models reveals a high level of theoretical awareness among the participants. Both dentists and students correctly and frequently identified the main factors that may compromise the final accuracy of the model. Options such as “Applying a correct impression technique,” “Type of impression material,” “Time interval between impression taking and model pouring,” and “Type of gypsum used for model fabrication” were commonly selected, demonstrating a solid understanding of the analog procedural chain. Moreover, the nearly equal distribution of opinions concerning the

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influence of ambient temperature on the preservation of gypsum models indicates recognition of the material's dimensional instability—an intrinsic vulnerability. However, findings from the study conducted by Ovsenik et al. showed that a gypsum model can still be stored, handled, and analyzed effectively when proper lighting and suitable measuring instruments are used [37].

Regarding the possibilities for obtaining digital study models, in the present study most respondents indicated intraoral scanning (92%) and scanning of gypsum models (72%). Only 32% mentioned impression scanning, and 24% noted that CBCT data can also be processed to generate digital models. Similar results were reported by Husain et al., who found that 80% of participants identified intraoral scanning as the primary method for acquiring 3D models [36].

Other studies have highlighted that dentists' opinions concerning the use of digital technologies, as well as the factors that motivate their professional activities, vary according to the level of technology implemented [38].

In the present study, several advantages of digital models were identified in descending order of frequency, namely: reduced working time, improved patient comfort, and lower costs.

Similarly, in the study conducted by Schott et al. [29], nearly 100% of participants reported reduced working time and increased patient tolerance with respect to handling the intraoral scanner as the main advantages.

Regarding the accuracy of the information provided by the two types of models—digital and plaster, the respondents indicated that digital models offer more reliable and accurate information compared with plaster models. Similarly, the findings of the study conducted by Abizadeh N., 2012 highlight that digital models represent a valid and efficient alternative for clinical diagnosis; however, plaster models may still be preferred in certain scientific research contexts where a higher level of precision and fewer discrepancies in occlusal analysis are required.[39].

Regarding the ease of designing dental prostheses using digital models versus plaster models, 70% of the study participants preferred the use of digital models. The results are consistent with those reported by Ahmed et al., 2018, who stated that digital technology can make the planning and execution of restorations more efficient and faster ("streamlined and efficient"), although they noted that the outcomes are not always more accurate than those obtained with conventional methods. The authors also mentioned that in surveys involving dentists, many acknowledge the significant role of CAD/CAM, but its adoption in routine clinical practice is limited by barriers such as cost [40].

The limitations of this study arise from the small number of respondents included in the two participant categories. Moreover, the respondents were students or graduates of the same university center; therefore, their knowledge regarding the acquisition and use of digital and plaster models was limited to the information provided during their training at that institution.

The questionnaire did not assess detailed knowledge about the procedures involved in obtaining and using the two types of study models.

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5. Conclusions

1. Study models are routinely used in dental practice for establishing diagnoses, treatment planning, and post-therapeutic evaluation, allowing the analysis of multiple factors.

2. The results of the questionnaire-based study highlighted greater interest in the topic among dental practitioners with fewer years of experience compared to students. Analysis of the responses indicated concurrent use of both plaster and digital study models, awareness of the advantages and disadvantages of each type, as well as understanding of their potential applications in dental prosthesis design.

3. The study showed that the participants demonstrated knowledge of obtaining digital models through intraoral scanning and scanning of study models.

4. The participants' opinions in the study highlighted that digital models provide greater accuracy of the information conveyed compared to gypsum models and also facilitate the design of prostheses more easily than gypsum models.

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ORIGINAL ARTICLE

KNOWLEDGE ASSESSMENT ON THE IMPORTANCE OF RESTORING AESTHETICS USING REMOVABLE PARTIAL DENTURES

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Abstract: *Background*: Esthetic rehabilitation represents an essential goal of modern prosthetic therapy. With the increasing demand for esthetic treatments, both dental students and practitioners must understand the factors influencing the esthetics of removable partial dentures (RPDs). *Objective*: The aim of the study was to assess the level of knowledge among students and dentists regarding the importance of restoring aesthetics using composite prosthetic rehabilitation in patients with partial edentulism. *Materials and Methods*: A cross-sectional study was conducted using an online questionnaire consisting of 13 questions, applied to 97 participants (students from the Faculty of Dental Medicine in Craiova and dentists from Dolj County). Data analysis was descriptive, using percentages and distributions. *Results*: Most respondents were students (73.2%), and 56.8% considered that cast RPDs with special attachments provide the best esthetics. Factors perceived as determining the shape, color, and size of artificial teeth included VDO, facial type, age, coffee/smoking habits, and the size of edentulous ridges. *Conclusions*: Students and practitioners show a high level of interest in esthetic restorations using RPDs, considering that special attachment systems offer the best esthetic outcomes. Prosthetic education and the integration of digital tools can significantly improve understanding and clinical application.

Keywords: removable partial denture, dental esthetics, special attachments, composite prosthetic rehabilitation, partial edentulism

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1. Introduction

The increase in life expectancy represents one of the greatest public health challenges, both in developed countries and worldwide [1]. Tooth loss is considered a chronic disability that creates difficulties in performing essential functions of the dento-maxillary system, such as food trituration, swallowing, and breathing. Facial aesthetics may also be affected as a result [2]. The management of patients with partial edentulism always represents a major challenge for dental practitioners [3].

Although digital technologies have evolved steadily and implant-prosthetic techniques in dentistry have undergone significant development, the removable partial denture (RPD) continues to be used in the treatment of patients with various forms of partial edentulism resulting from tooth loss. These RPDs address specific clinical needs for patients who cannot be adequately rehabilitated through other methods [4].

The design of partial dentures is oriented toward fulfilling essential mechanical requirements, namely retention, support, and stability. In recent years, the esthetic component has become equally important, being increasingly integrated into the conception of these restorations. Esthetics represents an important factor that influences patient satisfaction [5].

Considerations and evaluation of facial esthetics should begin as soon as the patient enters the dental office. A good clinician should possess excellent observation and listening skills to accurately interpret these elements and arrive at a precise diagnosis.

Aim: The present study aimed to evaluate the knowledge of both dental students and dental practitioners regarding the importance of restoring the esthetic function in the treatment of partial edentulism using RPD.

2. Materials and method

For this study, the analyzed material consisted of the responses provided by the participants to an online questionnaire. This was a non-interventional cross-sectional study. The study was approved by the Ethics and Deontology Committee of the University of Medicine and Pharmacy of Craiova, approval no. 8/10.01.2025. The study participants included fourth- to sixth-year students from the Faculty of Dentistry in Craiova, as well as dental practitioners from Dolj County.

The study method used was the questionnaire method. The questionnaire was created using Google Forms and included 13 questions addressing the following aspects: belonging to a specific social or professional category, questions about sources of information, and questions about restoring facial esthetics using RPDs. The questions included in the questionnaire were as follows:

1. *What is your professional level?*
   - Student
   - Dentist

2. *If you are a dentist, please specify your years of experience*:
   - 0–5 years
   - 5–10 years
   - More than 10 years

3. *If you are a student, please specify your year of study:*
   - IV
   - V
   - VI

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4. *Please specify your category:*
- Female
- Male

5. *Please specify the sources of information you use:*
- Specialty textbooks
- Artificial Intelligence
- Congresses, Conferences, Workshops
- E-books, Online Webinars
- Others

6. *Have you ever assisted in the fabrication of an RPD?*
- Yes
- No

7. *Which of the following RPD methods is used most frequently?*
- Cast RPD with clasps
- Cast RPD with precision attachments
- Others

8. *Which type of RPD do you consider to be more esthetic?*
- Acrylic RPD
- Cast RPD with clasps
- Cast RPD with precision attachments

9. *Which of the following prostheses do you consider achieves better esthetic rehabilitation for a Kennedy Class IV edentulism?*
- Acrylic RPD
- Cast RPD with clasps
- Cast RPD with precision attachments

10. *Which factors influence the selection of artificial teeth shape in an RPD?*
- Facial type
- Gender
- Age
- Vertical dimension of occlusion (VDO)
- Systemic diseases

11. *Which factors influence the selection of artificial teeth color in an RPD?*
- Facial type
- Smoking habits
- Excessive consumption of coffee or chocolate
- Age

12. *Which factors do you consider influence the selection of artificial teeth size in an RPD?*
- Facial type
- Body height
- Body weight
- Systemic diseases
- Size of the edentulous ridges
- Size of the remaining teeth

13. *Which factors influence the arrangement of artificial teeth in an RPD?*
- Size and shape of the edentulous ridges
- Position of the remaining teeth
- Achieving ideal occlusal relationships
- Achieving stable and functional occlusal relationships

The answers to the questionnaire were centralized and statistically processed using descriptive statistical analysis.

3. Results

A total of 97 participants responded to this study. The first question investigated the professional category of the participants. The results showed that 73.2% of the participants were students (Fig. 1a).

Regarding the distribution of the participating dentists according to years of experience, those with 0–5 years of experience represented the largest group (68.3%), while dentists with more than 10 years of experience represented only 9.8% of the total dentist respondents (Fig. 1b).

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Among the student participants, most were in their 6th year of study, representing 57.7%. Students in the 4th and 5th years showed approximately equal percentages, as follows: 19.7% for the 4th year and 22.5% for the 5th year (Fig. 1c).

Regarding the gender distribution of the participants, the statistical analysis indicated that the respondents were almost evenly divided between female and male (49.5% male, 50.5% female) (Fig. 1d).

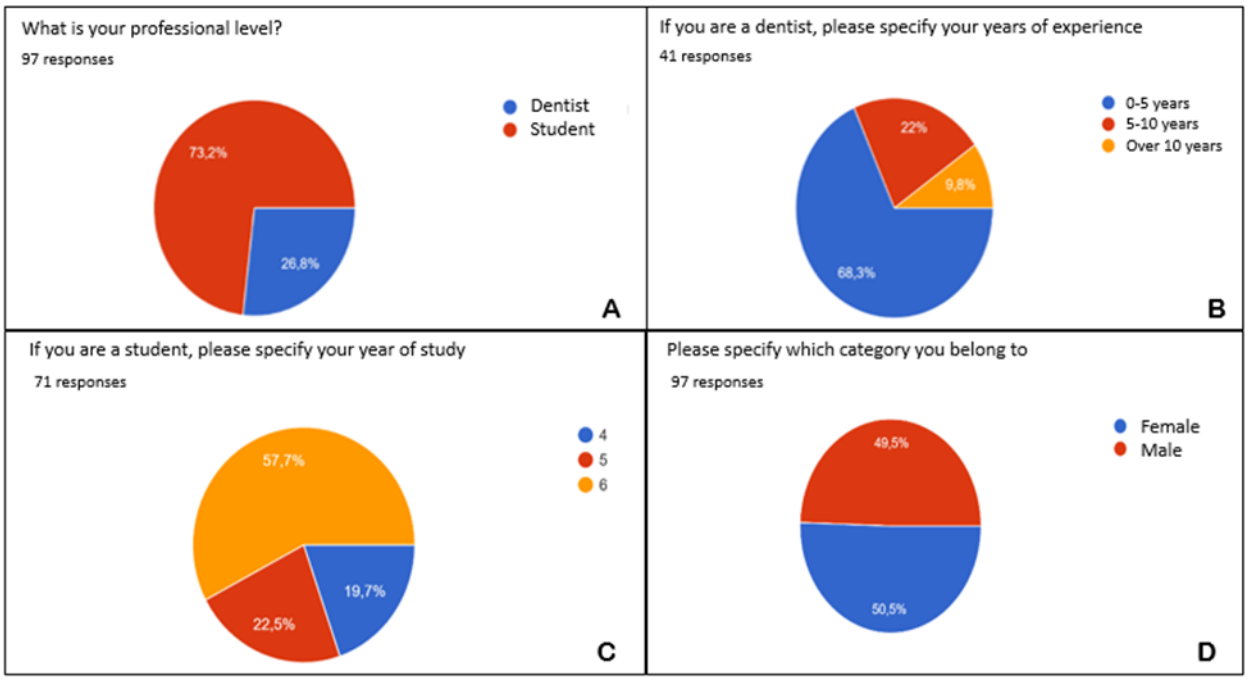

Figure 1. Distribution according to professional level (1A), Distribution according to the number of years of clinical experience (1B), Distribution of students according to year of study (1C), Gender distribution (1D).

In our study, it was highlighted that most participants used specialty textbooks as their primary source of information (61.9%). Other preferred sources of information included congresses, conferences, and workshops, while a high percentage was also observed regarding the use of artificial intelligence (Fig. 2a).

Regarding participation in the fabrication of an RPD, 61.9% of the respondents stated that they had taken part in the fabrication of a removable partial denture (Fig. 2b).

The investigation of respondents' opinions on the frequency of using different types of RPDs showed an approximately equal distribution of answers between prosthetic rehabilitation with clasp-retained RPDs and prosthetic rehabilitation with RPDs using precision attachments (Fig. 2c).

A total of 56.8% of the study participants considered that the RPD with precision attachments represents the most aesthetic treatment option among removable prostheses (Fig. 2d).

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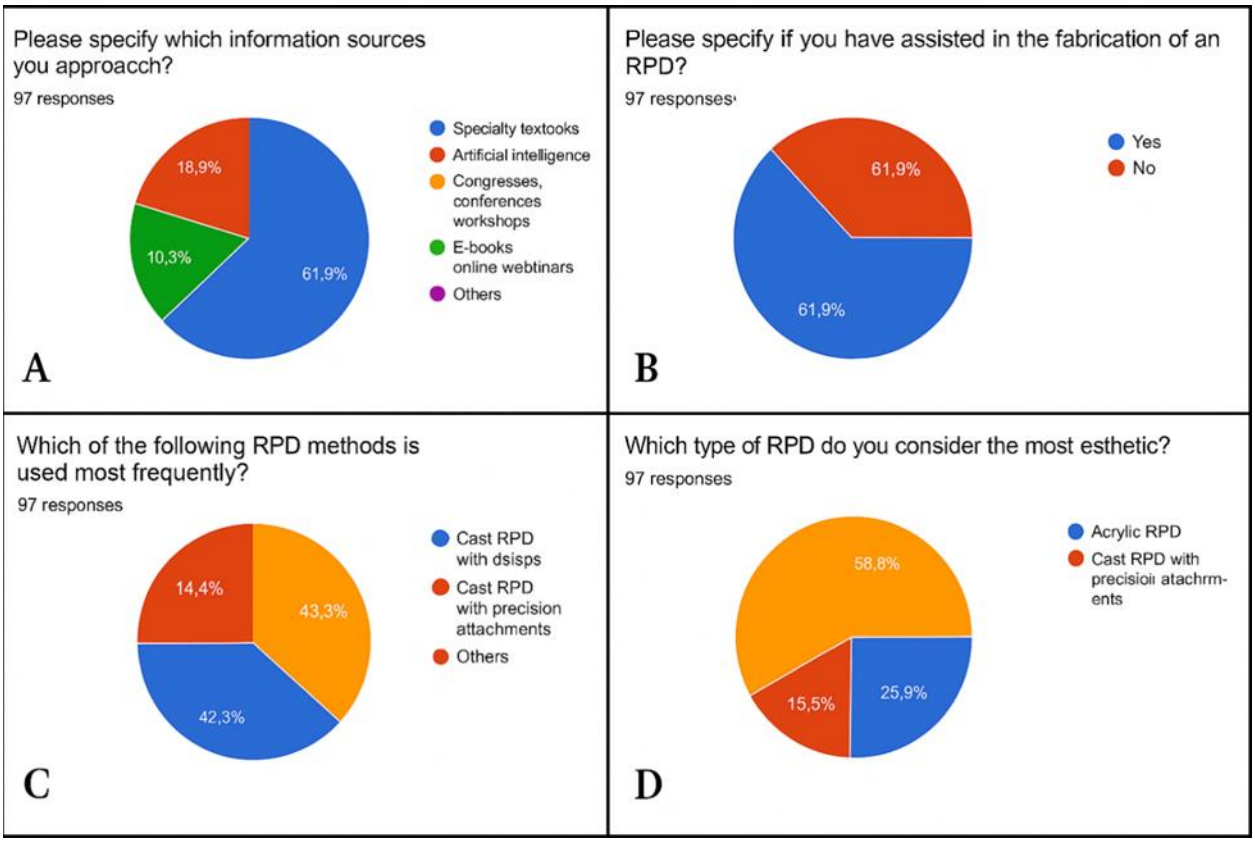

Figure 2. Sources of information used (2A). Participation in the fabrication of an RPD (2B). Type of RPD considered to be most frequently used (2C). Type of RPD considered being the most aesthetic (2D).

According to the results of the present study, the factors that may influence the selection of artificial tooth color included age, smoking habits, and excessive consumption of coffee and chocolate. Among the responses obtained, the highest percentage was represented by those referring to age, accounting for 46.4% (Figure 3).

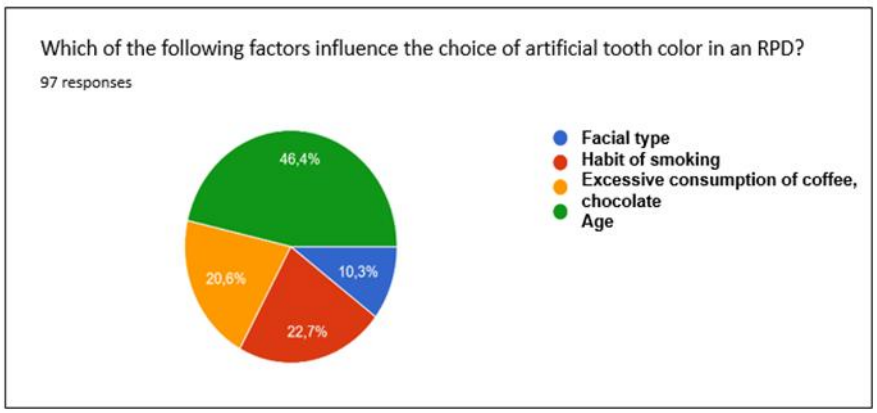

Figure 3. Choosing artificial teeth colors in making a PPM.

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The following question addressed the aesthetic rehabilitation of Kennedy Class IV edentulism using a RPD. The largest percentage (48.5%) corresponded to those who stated that Kennedy Class IV edentulism can be more aesthetically rehabilitated with a RPD using precision attachments (Fig. 4a).

According to the responses provided by the study participants, the factors influencing the selection of artificial tooth shape included the vertical dimension of occlusion (VDO), facial type, and age (Fig. 4b).

Regarding the main factors influencing thechoice of artificial tooth size, the most frequently selected options were: the size of the remaining natural teeth (30.9% of responses), the facial type (29.9%), and the size of the edentulous ridges (21.6%) (Fig 4c)

According to the conducted study, 41.2% of the participants considered that achieving stable and functional occlusal relationships, and 30.9% believed that the position of the remaining teeth, represent factors influencing the arrangement of artificial teeth. Additionally, smaller percentages of responses referred to the size and shape of the edentulous ridges as factors that may influence the arrangement of artificial teeth (Fig. 4d).

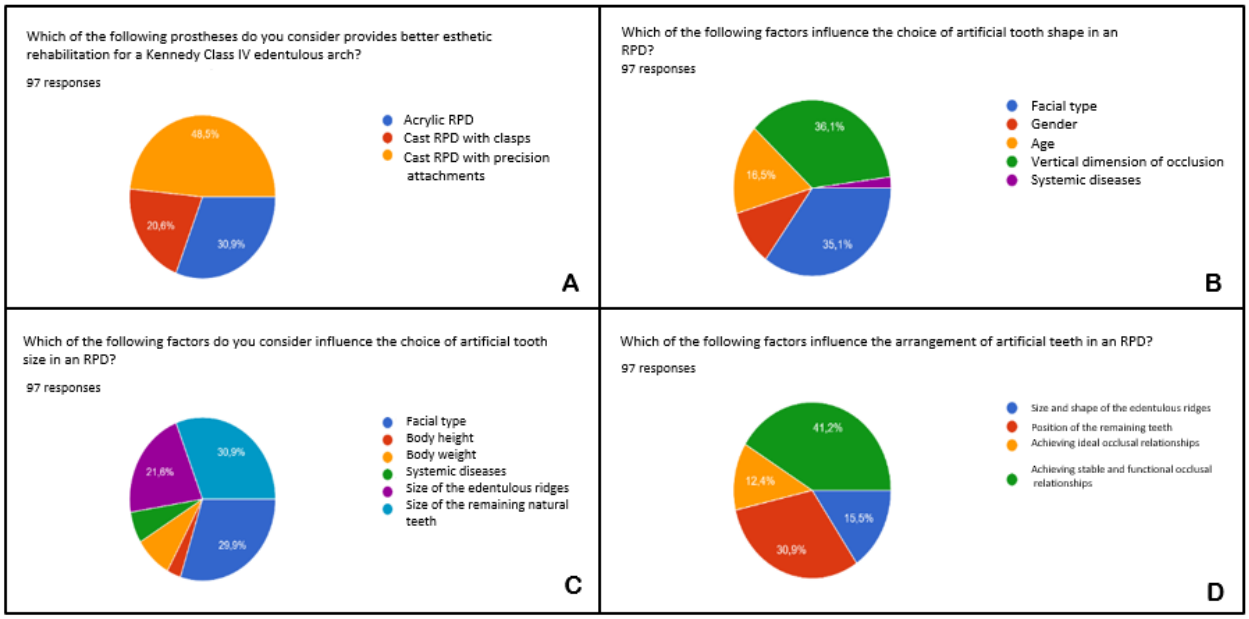

Figure 4. Aesthetic rehabilitation of Kennedy Class IV edentulism (4A); Factors influencing the shape of artificial teeth (4B); Factors influencing the color of artificial teeth (4C); Factors influencing the size of artificial teeth (4D).

4. Discussion

The findings of this study demonstrate a strong interest in esthetic rehabilitation using RPDs, particularly among dental students in advanced clinical years. This is consistent with previous research showing that students and young practitioners express a growing awareness of RPD design principles and improved confidence in applying contemporary prosthodontic concepts as their clinical exposure increases [6, 7]. Such alignment with existing literature highlights the importance of continuous and structured

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prosthodontic education. Participants in this study reported using traditional prosthodontic textbooks as their main learning resource; however, a notable proportion also relied on digital content and artificial intelligence tools. This shift mirrors recent reports indicating that technology-enhanced educational platforms—especially artificial intelligence—positively influence knowledge acquisition and critical reasoning within prosthodontic training [8]. The combination of classical sources with modern interactive tools reflects a global transition toward hybrid learning models in dental education.

More than half of the respondents had previously participated in the fabrication of an RPD, which reflects moderate clinical exposure. Similar studies have demonstrated that although theoretical understanding of RPD design is generally adequate, students frequently report limited hands-on training and insufficient opportunity to apply design principles clinically [6,7]. This suggests a need to strengthen the clinical component within prosthodontic curricula to better support the transition from theoretical knowledge to practical competence.

A significant outcome of this study was the respondents' preference for precision-attachment RPDs over clasp-retained designs when esthetics was the primary concern. This corresponds with the literature showing that attachment-retained RPDs provide superior esthetic outcomes by eliminating visible metal clasps and enhancing smile harmony [9-11]. Studies have reported higher patient satisfaction, improved retention, and better overall acceptance of attachment-retained RPDs, particularly in the anterior esthetic zone, where visibility is critical [9-11]. These findings are in line with the responses obtained for Kennedy Class IV cases in the present study.

The selection of artificial tooth shape was influenced predominantly by the VDO, facial morphology, and age. These determinants are widely supported in prosthodontic literature, where anterior tooth selection guidelines emphasize facial-type matching, age-related esthetic considerations, and the importance of dento-facial harmony [12–14]. Furthermore, maintaining an appropriate VDO has been shown to affect both esthetics and function, reinforcing its relevance in prosthetic planning [12].

Artificial tooth color selection was most strongly associated with age, smoking, and dietary staining factors such as coffee and tea consumption. These associations are corroborated by studies demonstrating that natural tooth shade tends to darken with age and that both tobacco use and pigmented beverages significantly contribute to extrinsic discoloration [15–17]. Such evidence aligns with the respondents' understanding of factors influencing shade selection for prosthetic restorations. Regarding tooth size, respondents highlighted the dimensions of remaining natural teeth, facial morphology, and ridge anatomy as the most influential factors. These considerations reflect established prosthodontic principles indicating that tooth size must be adapted to facial proportions, arch form, and available prosthetic space to achieve an esthetically and functionally harmonious result [13, 14, 18]. Research also demonstrates that the morphology and volume of the edentulous ridge directly affect tooth placement and may require modifications in tooth size or

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arrangement to maintain prosthesis stability [18]. Finally, respondents correctly identified occlusal stability, the position of remaining teeth, and ridge morphology as key determinants of artificial tooth arrangement. These findings are strongly supported by Goodacre [19], who emphasized that RPD occlusion must exhibit bilateral posterior contacts, absence of deflective interferences, and physiologic distribution of occlusal forces. Their review also highlights the importance of respecting ridge anatomy, occlusal plane orientation, and the patient's existing occlusal scheme to optimize function and long-term prosthesis performance [19]. The high concordance between participants' responses and established occlusal recommendations suggests a solid conceptual understanding of functional design principles among the surveyed population.

Overall, the results align with international trends emphasizing esthetic-driven prosthetic rehabilitation, increased preference for precision attachments, and a comprehensive approach to artificial tooth selection and occlusal planning. Enhancing clinical training opportunities and integrating digital learning tools may further strengthen competence among dental students and young practitioners.

Limitations: Because the study relied on self-reported data from a geographically restricted sample, results may not fully represent all educational environments. Future studies should incorporate broader populations and objective clinical assessments.

5. Conclusions

The questionnaire-based study revealed that most participants were students, indicating a high level of interest in composite prosthetic rehabilitation using fixed prostheses and removable partial dentures (RPDs).

The evaluation of participants' knowledge regarding the factors influencing facial aesthetics through composite prosthetic rehabilitation showed that the majority considered that cast RPDs with precision attachments provide a more aesthetic rehabilitation.

The combination of fixed and removable restorations represents a very good treatment option for partially edentulous patients, especially for those with bilateral distal-extension edentulism, in whom implant-prosthetic treatment options are limited, offering very good masticatory efficiency.

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ORIGINAL ARTICLE

EVALUATING THE CLINICAL APPLICABILITY OF THE INJECTION TECHNIQUE IN THE MANUFACTURING OF FLEXIBLE REMOVABLE PARTIAL DENTURES

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Abstract: *Background*: In the current context of dental technology development, modern methods for manufacturing removable partial dentures hold an essential place in the current practice of the dental technician. The aim of the study was to evaluate the clinical applicability of the injection technique in the realization of elastic removable partial dentures. *Methods*: The study was conducted on a total of 90 clinical cases documented in the dental technique laboratory. Inclusion criteria in the study regarded patients with unilateral or bilateral, maxillary or mandibular partial edentulism, clear indication for the realization of an injected elastic prosthesis. *Results*: The injection technique in the realization of dental prostheses has demonstrated high versatility and effective adaptation to a variety of clinical situations, for both complete and partial dentures. *Conclusions*: The results obtained in this study support the idea that the injection method represents a viable and modern alternative to classical techniques, especially when applied in a well-controlled technical context and with efficient collaboration between the dentist and the dental technician.

Keywords: removable partial denture, injection technique, flexible materials

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1. Introduction

In the current context of dental technology development, modern methods for manufacturing removable partial dentures hold an essential place in the current practice of the dental technician.

The injection of flexible materials, such as thermoplastic PMMA, allows for obtaining prostheses with precise adaptation, reduced weight, and superior aesthetics. In addition, the increased comfort and biocompatibility of these materials contribute to a better acceptance of the prosthetic treatment by patients [1-4].

The injection technique is a modern procedure for manufacturing removable partial dentures, which consists of introducing a heated thermoplastic material under pressure into a negative space created by prior modelling. This method allows for obtaining excellent adaptation and a high level of detail, being frequently used in the fabrication of flexible dentures and aesthetic components [5-7].

The most commonly used materials for this technology are polyamides (nylon), polycarbonate, and flexible PMMA. These materials exhibit properties of elasticity, fracture resistance, biocompatibility, and superior aesthetics. Sabilex FlexiAcryl (Leopoldo Marechal, Buenos Aires, Argentina) is an example of flexible PMMA used in this technique, with favorable results regarding denture adaptation and patient comfort [1,8-10].

Among the major advantages of this technology are: precise adaptation to the prosthetic field, increased elasticity which offers comfort and stability, superior aesthetics through the elimination of visible metal clasps, long-term mechanical resistance, and the possibility of rapid repair in the laboratory [11,12]. The main benefit, however, lies in the biocompatibility of thermoplastic materials, which are well-tolerated by oral tissues, reducing the risk of irritation or allergic reactions [13].

Although the technique presents multiple benefits, there are also limitations, such as: the difficulty of subsequent modifications or repair to the prosthesis, the need for specialized equipment, the high cost of materials, and the technician's experience in correctly handling the system [6,12,14,15]. Another important aspect is the fact that thermoplastic resins can undergo deformation at high temperatures if not handled correctly, which requires strict adherence to the technological protocol [16-23]. Also, the lack of material rigidity can affect long-term functionality in cases with extensive edentulous spaces, where additional support is required [10].

Looking into the future, the development of hybrid injectable materials with improved biomechanical properties is recommended, which combine flexibility with superior structural strength. Also, optimizing digital CAD/CAM technologies for the design and modeling of injected prostheses can bring a higher standardization of the quality of the work [24,25].

Main purpose of this study is to evaluate the clinical applicability of the injection technique in the realization of elastic removable partial dentures and to highlight the advantages and limitations of the method, as well as to assess the degree of functional and aesthetic satisfaction of the prosthesis by

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performing a statistical analysis of the cases to determine the frequency of use of the method according to location (maxilla vs. mandible), extent of edentulous area, and other relevant clinical criteria and also to identify the limitations of this technique.

2. Materials and method

This study is retrospective and conducted by analyzing the results obtained in 90 clinical cases documented in the dental technique laboratory between October 2024 and June 2025.

Inclusion criteria in the study regarded patients with unilateral or bilateral, maxillary or mandibular partial edentulism, clear indication for the realization of an injected elastic prosthesis, in the absence of major contraindications, the possibility of complete photographic documentation of the laboratory stages and the application of a standardized technological protocol based on thermoplastic injection technology with a Sabilex 2AD device.

Cases not included in the analysis were the ones with incomplete information or insufficient photographic documentation and also prostheses obtained using mixed or conventional technologies.

All the prostheses were obtained in the dental laboratory using Sabilex FlexiAcryl flexible resin, dedicated insulation liquid for plaster and resin, Sabilex aluminum flask, 3rd class plaster for the plaster model and Sabilex 2AD injection device using the standard parameters: 280C temperature, 6 bar pressure and 25 minutes.

Each technological step was applied according to the equipment user manuals and the protocols recommended by the manufacturers [1,11]. The stages include wax modelling, mounting the model in the metal flask, applying the insulator, material injection, de-flasking, finishing, and final polishing of the prosthesis.

This method was chosen due to its efficiency in detail reproduction, the adaptability of the thermoplastic material, and the reduction of working time compared to classic methods [14,15].

The study was approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova, with no 65/29.01.2024.

3. Results

Demographic analysis of the study group

Distribution of patients by sex

The analysis of gender distribution among the 90 patients included in the study shows a predominance of the male sex, with a total of 55 male patients (61%), compared to the female sex (39%). The distribution was performed based on the cases selected during the analyzed period, without applying a criterion for balancing between sexes (Figure 1).

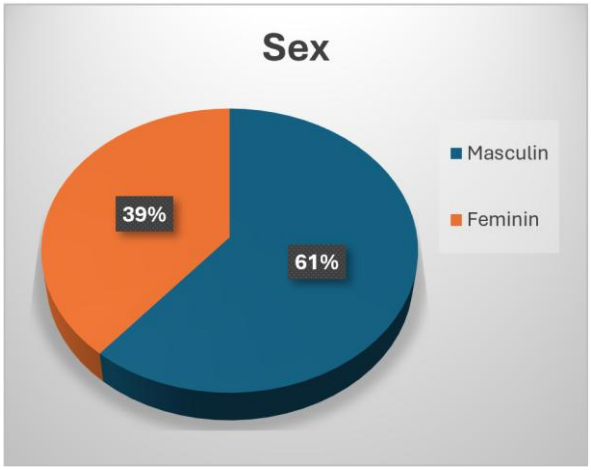

Figure 1. Sex distribution of patients.

Distribution of patients by age

The distribution by age group indicates that the predominant segment is between 40

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and 59 years old, represented by 13 patients (72%). Out of the total of 18 patients, 2 were aged between 30–39 years (11%), 6 between 40–49 years (33%), 7 between 50–59 years (39%), and 3 patients were over 60 years old (17%) (Figure 2).

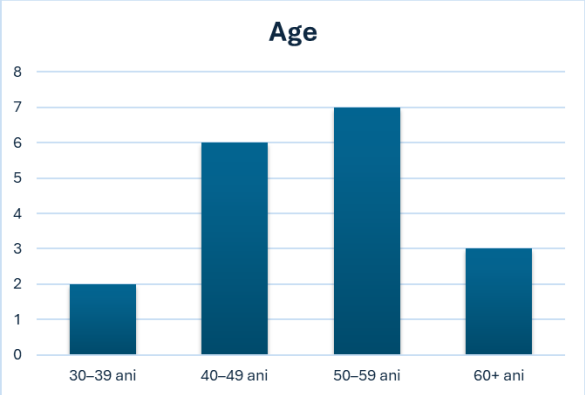

Figure 2. Age distribution of patients.

Technical aspects

Type of prostheses used

The distribution by type of prostheses shows that the majority of works made using the injection technique were full dentures (10 cases, 56%). Partial dentures represented 6 cases (33%), and injected partial frameworks were used in 2 cases (11%) (Figure 3).

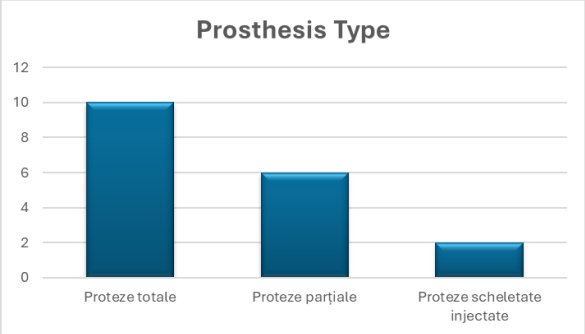

Figure 3. Types of prosthesis used.

Materials used for the injection technique

In the 90 analyzed cases, the materials used were: PMMA (45 cases, 50%), nylon (25 cases, 28%), acetal (15 cases, 17%), and PEEK (5 cases, 5%). The choice of material varied depending on clinical indications, peculiarities of the prosthetic field, and the preferences of the medical-technical team. (Figure 4).

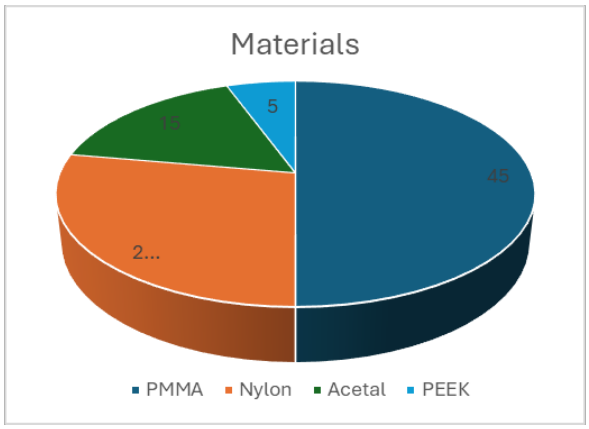

Figure 4. Materials used for the injection technique.

The duration of prosthesis manufacture

The execution time of the analyzed prosthetic works varied between 3 and 6 days, with a higher frequency for the intervals of 4 and 5 days (6 and 7 cases respectively). Fewer cases were completed in 3 days (10 cases) or 6 days (15 cases), with the overall average execution time being approximately 4.4 days (Figure 5).

Figure 5. The duration of prosthesis manufacture.

Post-insertion complications

Complications observed after the insertion of the injected prostheses were absent in 45 cases (50%). In 25 cases (28%), minor discomfort was reported, 15 cases (17%) required adjustments to improve retention,

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and in 5 cases (5%), a localized mucosal lesion was recorded (Figure 6).

The mucosal tolerance to the materials used was good, and the adjustments were limited, in most cases, to slight retouching performed in the laboratory. The low incidence of lesions or major discomfort validates the efficiency of the injection method from a clinical point of view.

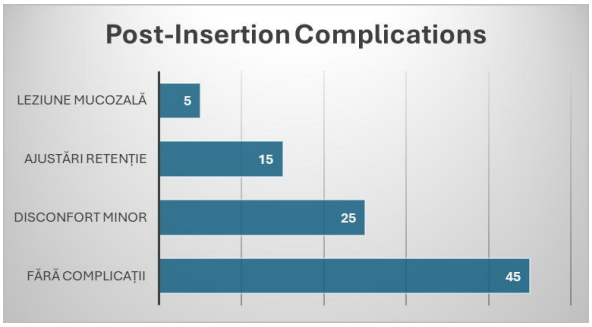

Figure 6. Post-insertion complications.

Number of adjustments necessary after insertion

The distribution of adjustments made after the insertion of dentures produced by the injection technique indicates that in 35 cases (39%), no intervention was necessary, and in 30 cases (33%), only a single adjustment was required. More extensive adjustments were reported in 15 cases (17%) which required two interventions, and in 10 cases (11%) where three or more adjustments were performed. These corrections primarily focused on improving retention and eliminating pressure points identified in the period immediately following the delivery of the prostheses (Figure 7).

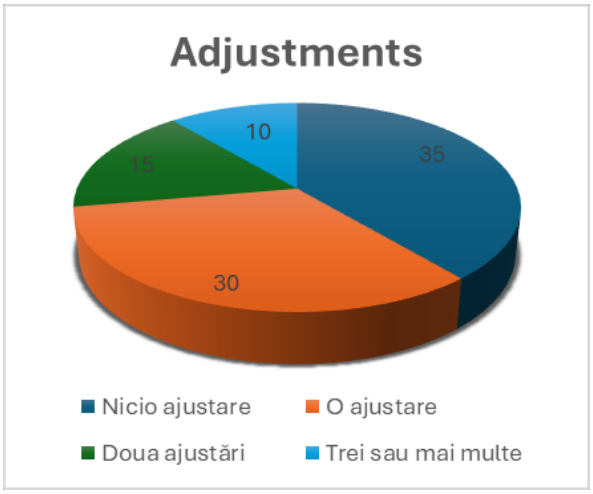

Figure 7. Number of adjustments necessary after insertion.

Prosthesis lifespan estimation

The estimated lifespan of the dentures was distributed as follows: under 1 year – 5 cases (6%), between 1–3 years – 55 cases (61%), and over 3 years – 30 cases (33%). The estimations were based on the type of material used, the predictable degree of wear, and the particular clinical conditions of each case (Figure 8).

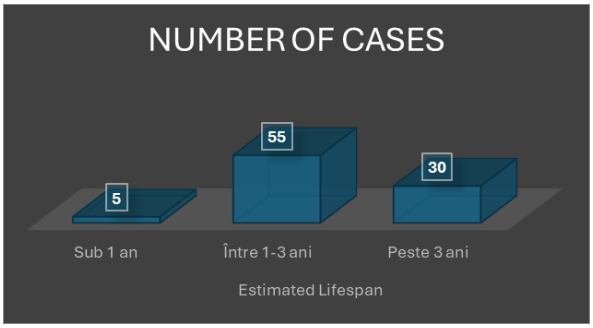

Figure 8. Prosthesis lifespan estimation.

Prosthesis cost

The estimated cost of the prosthetic works fell within the following ranges: under 1000 RON – 5 cases (28%), between 1000 – 1500 RON – 9 cases (50%), and over 1500 RON – 4 cases (22%) (Figure 9).

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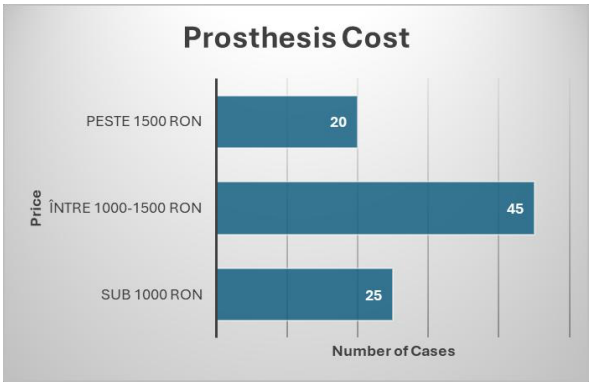

Figure 9. Prosthesis cost.

Patient satisfaction

The evaluation of patient satisfaction with dentures made using the injection technique was performed using a rating scale from 1 to 5, where 1 represented a very low level of satisfaction, and 5 a maximum level. The collected results showed that 40 patients (44%) gave a score of 5, 30 patients (33%) a score of 4, 15 patients (17%) a score of 3, and 5 patients (6%) gave a score of 2. No minimum scores (score 1) were recorded (Figure 10).

Figure 10. Patient satisfaction degree.

4. Discussions

The injection technique in the realization of dental prostheses has demonstrated high versatility and effective adaptation to a variety of clinical situations, for both complete and partial dentures. The analysis of the 90 prosthesis made using this method highlights a good clinical success rate, a short execution time, and increased patient satisfaction, especially in cases where modern materials such as acetal or PEEK were used. These results are consistent with the specialized literature, which emphasizes the advantages of injection concerning fitting precision and patient comfort [26,27].

One of the most notable benefits of the method is the optimal initial fit of the work, due to the precision of the impression taking and the constant pressure applied during injection. This contributed to reducing the number of post-insertion adjustments and limiting complications, confirming observations that modern methods of processing prosthetic materials significantly improve denture retention and stability. Recent studies indicate superior biological tolerance of injected materials, especially in cases of patients with fragile mucosa or difficult denture bearing areas [28].

However, the technique is not without limitations. The higher cost of high-performance materials (e.g., PEEK), the need for specific equipment, and the complexity of preparing the metal flask can limit the applicability of the method in some laboratories. Also, in cases with complicated anatomies or the need for frequent repairs, the technique may become more difficult to manage in the absence of corresponding experience.

The relatively small difference between the two groups of patients, males and females, may influence certain functional aspects [29] or adaptation, but it does not generate significant imbalances in the overall analysis. The relevance of this distribution lies in highlighting a demographic profile [30] which

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can contribute to the interpretation of other variables such as the degree of satisfaction, post-insertion complications, or the type of prosthesis produced.

Gender distribution may indirectly influence material choice [31], psychological adaptability to the prosthesis, or the level of collaboration during the clinical and technical stages. For example, some authors have highlighted a slight tendency for female patients to prioritize the aesthetic aspect [32], while male patients may place greater emphasis on functionality [25].

This distribution of patients by age highlights an increased frequency of extensive edentulism in the fifth and sixth decades of life, a period during which an intensification of demands for modern prosthetic treatments is observed [22]. At the same time, the group over 60 years old was less represented, possibly due to preferences for other types of work or limited access to new technologies.

The most frequent age range corresponds to a period of life where tooth loss becomes more common due to periodontal disease and cumulative complications [33]. Injected prostheses offer clear advantages from an aesthetic and functional point of view, adapting well even in complex cases, regardless of age.

Injectable PMMA was the most frequently used material, due to good mechanical characteristics, dimensional stability, and accessible cost [34]. It is easy to finish, repairable, and versatile for a wide range of clinical cases. Nylon was preferred in works where increased flexibility and superior aesthetic appearance were desired, but it is more difficult to adjust and polish, requiring special equipment.

Acetal was chosen for its increased resistance and adaptability in the clasp area, offering an aesthetic alternative to metallic elements, available in multiple shades. PEEK, a high-performance material with excellent mechanical properties and high biocompatibility, was used in only 5 cases, being rarely applied due to high costs and strict technical requirements [35].

The choice of injected material was dictated by both the clinical specifics of each case and the availability of equipment and materials in the dental technical laboratory.

Regarding the types of prosthesis used, the high frequency of full dentures can be associated with the increased demand for this type of treatment, especially in cases of complete edentulism [36]. Partial dentures were made in situations with stable remaining teeth, and injected partial frameworks were reserved for cases where an aesthetic and resistant solution, without visible metal, was desired.

The types of the prostheses obtained reflects both the clinical needs of the patients and the therapeutic orientation of the collaborating dentists involved in the treatment. Full dentures were often recommended in cases with atrophied maxillae or old edentulous areas, where stability and retention are priorities. Partial dentures were preferred for patients with healthy remaining teeth, offering a balance between functionality and the preservation of the oral structure. In contrast, injected partial frameworks, although used less frequently, were chosen for patients who presented favorable conditions for support and retention, but required a light design without visible metal components [26].

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This diversity of options demonstrates the adaptability of the injection technique depending on the specifics of each prosthetic case.

Complications observed after the insertion of the injected prostheses indicate an appropriate functional adaptation in most cases. Minor discomfort and the need for adjustments are considered normal post-insertion reactions, especially in the case of atrophied prosthetic fields [37]. The mucosal lesion was treated by recontouring the prosthesis, with no subsequent complications.

Although the complications were quantitatively reduced, they offer valuable information about the need for fine adjustment of the injected works, especially in areas with concentrated pressure or an irregular prosthetic field. In general, injected works tend to have a better initial adaptation compared to those made classically [38].

Regarding the duration of prosthesis manufacture, the distribution confirms the efficiency of the injection technique in obtaining rapid results while maintaining quality standards [6].

The short realization time is supported by the fact that the injection method involves a coherent and compact technological flow, with well-defined stages and a reduced rate of re-interventions. Especially in the case of using injectable PMMA, the homogeneity of the material and the precise adaptation to the model contributed to shortening the working time [39]. In situations where the duration exceeded the average, the determining factors were the need for additional impressions, technical adjustments, or delays related to patient scheduling. Overall, the execution time falls within an efficient range adapted to the work rhythm of the dental technical laboratory.

Patient satisfaction degree showed that no minimum scores (score 1) were recorded, which indicates a generally favorable perception among patients regarding the quality of the prosthetic work received [40].

The information regarding the patient satisfaction was obtained indirectly, through discussions and follow-up consultations conducted shortly after the insertion of the prostheses, without the application of standardized questionnaires. The high level of satisfaction scores reflects both the quality of the work carried out in the laboratory and the efficiency of the collaboration between the technical team and the dentist [37]. Among the most frequently mentioned positive aspects were comfort during speech and mastication, good denture retention, and harmonious aesthetic integration into the facial context.

Regarding the total cost of the prosthesis, the distribution reflects the differences generated by the materials used, the applied technology, and the complexity of the case. The most accessible dentures were those made with PMMA, while works with nylon or PEEK recorded higher costs [41].

The cost structure is influenced by both the material used and the complexity of the work (partial vs. complete denture) and the number of technological stages involved. The prostheses with costs under 1000 RON were, in general, simple, made from PMMA, without special aesthetic demands or special components.

In contrast, works that exceeded the 1500 RON threshold included either special materials (e.g., PEEK) or more complex

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configurations, with aesthetic clasps or personalized functional modifications. Cost remains an important variable in the patient's choice of the type of prosthetic work and must be correlated with the long-term functional and aesthetic benefits [6].

The distribution of adjustments made after the insertion of dentures produced by the injection technique reveals a good functional adaptation of the majority of the injected dentures, right from the first post-insertion stages. The quality of the adaptation is closely linked to the precision of the impression taking [42], the fidelity of the working model, and the careful control of the injection parameters. The fact that most dentures did not require additional adjustments or only needed minor modifications confirms the efficiency of the method and the stability of the prostheses [43].

The cases that involved multiple corrective interventions were generally associated with anatomical difficulties, such as atrophied alveolar ridges, mobile mucosa, or unstable denture bearing areas. Even in these situations, all adjustments were carried out in the laboratory, without requiring the complete remake of the work, which highlights the flexibility of the injection technique and its ability to offer tailored solutions even in more complex clinical conditions.

Most prostheses are expected to have a usage duration of between 1 and 3 years, especially those made with PMMA. Dentures made with materials such as acetal or PEEK showed a better prognosis regarding durability [44], due to their superior mechanical resistance and dimensional stability.

The durability of the dentures is influenced by several factors: the material used, oral hygiene conditions, the degree of functional wear, and the correct conformation of the prosthesis. In particular, poor hygiene or parafunctions (bruxism) can accelerate the degradation of the material, reducing the lifespan of the denture, regardless of its initial composition. In this context, educating the patient about the correct maintenance of the prosthesis has an essential role in extending its use.

Injected dentures made from modern materials, such as PEEK or acetal, have demonstrated superior performance in terms of fracture resistance and chemical aging [45]. However, the choice of these materials remains conditioned by the availability of adequate equipment and the patient's budget. The lifespan estimation, although theoretical, aligns with clinical observations in the specialized literature, which support an average usage of 2–3 years for injected dentures, with the possibility of extension under optimal usage conditions.

The injection technique has the potential to become a standard option in the realization of modern dentures, provided that the medico-technical teams are familiar with the correct application parameters and the specific indications of each material [46,47].

5. Conclusions

The results obtained in this study support the idea that the injection method represents a viable and modern alternative to classical techniques, especially when applied in a well-controlled technical context and with efficient collaboration between the dentist and the dental technician. The general recommendation is that the choice of method

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should be personalized according to the complexity of the case, available resources, and the patient's profile, with an emphasis on post-insertion comfort and the long-term stability of the prosthesis.

The injection method is notable for its flexibility and efficiency, but it involves a higher initial investment in equipment and good technical training. At the same time, the choice of material and the configuration of the prosthesis must be personalized according to the particularities of each case to ensure long-term prosthetic success.

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Author contributions

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Conflict of interest statement

The authors declare no conflicts of interest concerning this study.

Data availability statement

Will be provided on request.

Ethics statement

This study was approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova (approval data no. 65/29.01.2024).

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