European Journal of Interdisciplinary Research and Development
Volume- 46 December- 2025
Website: www.ejird.journalspark.org ISSN (E): 2720-5746

EVALUATION OF THE EFFECTIVENESS OF A THERAPEUTIC AND PREVENTIVE SPLINTING CONSTRUCTION BASED ON MATHEMATICAL MODELING AND BIOMECHANICAL ANALYSIS

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Abstract
The aim of the present study was to evaluate the effectiveness of a therapeutic and preventive splinting construction developed for the stabilization of teeth in patients with early and moderate stages of periodontitis. Mathematical modeling and biomechanical analysis were applied, enabling a quantitative assessment of functional load redistribution within the dentoalveolar system when using the proposed construction.A thermoplastic polymer, Vetakryl, characterized by high biocompatibility, elasticity, and resistance to deformational loads, was used as the splinting material. Comparative analysis of the mechanical properties of Vetakryl and conventional cobalt–chromium alloys demonstrated the advantages of the new material in reducing stress concentration and improving the uniform transmission of masticatory forces.The results of mathematical modeling were confirmed by clinical observations: the use of the Vetakryl-based construction contributed to a reduction in tooth mobility, a decrease in inflammatory manifestations, improvement of periodontal functional status, and increased stability of the dental arch.The developed methodology can be recommended for clinical application in the treatment and prevention of periodontal diseases, as well as serving as a model for further investigations into the biomechanical properties of dental constructions.

Keywords: periodontitis, splinting construction, Vetakryl, thermoplastic polymer, mathematical modeling, biomechanical analysis, functional load.

Introduction

Materials and Methods

Study Design

The study was conducted at the Department of Prosthetic Dentistry of the Tashkent State Dental Institute. The aim was to perform an experimental and clinical evaluation of the effectiveness of a new therapeutic and preventive splinting construction developed using the thermoplastic polymer Vetakryl.

Materials

The splinting construction was fabricated from the thermoplastic polymer **Vetakryl** (Poland), which is distinguished by high biocompatibility, transparency, elasticity, and resistance to mechanical and thermal воздействия. For comparative analysis, conventional metallic splints made of cobalt–chromium alloy were used.

Clinical Subjects

The clinical study included 30 patients aged 35–55 years diagnosed with mild to moderate periodontitis accompanied by pathological tooth mobility of grades I–II. All patients were divided into two groups:

- **Main group (n = 15):** treatment using the newly developed thermoplastic Vetakryl splint;
- **Control group (n = 15):** treatment using standard metallic splints.

Research Methods

Clinical assessment. Tooth mobility was determined according to the Miller classification. Periodontal indices, including PMA, GI, and BOP, were evaluated, and periodontal status was assessed at 1, 3, and 6 months after the initiation of treatment.

Mathematical modeling. Quantitative evaluation of functional load redistribution was performed using the **Finite Element Method (FEM)**. Modeling was carried out with the SolidWorks and ANSYS software packages, where a three-dimensional model of the dentoalveolar segment, including teeth, periodontal tissues, alveolar bone, and the splinting device, was constructed.

During modeling, the following parameters were considered:

- average masticatory load values (50–150 N);
- angular directions of force application (30–45° relative to the longitudinal axis of the tooth);
- physical and mechanical properties of the materials (elastic modulus, tensile strength, and Poisson's ratio).

Biomechanical Analysis

Stress distribution maps, deformation patterns, and displacement vectors under masticatory loading were analyzed. For Vetakryl and cobalt–chromium alloy splints, zones of stress concentration in the cervical and apical regions of the teeth were compared.

Statistical Analysis

The obtained quantitative data were processed using **variational statistical methods** with the **SPSS 26.0** software package. Differences were considered statistically significant at a significance level of $\mathbf{p < 0.05}$.

RESULTS AND DISCUSSION

The results of the present study allowed for a comprehensive evaluation of the effectiveness of the proposed therapeutic and preventive splinting construction made of the thermoplastic

polymer **Vetakryl**, in comparison with conventional metallic splints. The assessment consisted of two stages: **mathematical modeling** and **clinical evaluation**.

2.1. Results of Mathematical Modeling

Using the **Finite Element Method (FEM)**, a three-dimensional model of the dentoalveolar segment was created, including the alveolar bone, periodontal ligament, and splinting device. Modeling was performed under masticatory loads ranging from **50 to 150 N**, applied at an angle of **30–45°** relative to the longitudinal axis of the tooth.The analysis of mechanical stress distribution revealed the following patterns:

• In splints made of **cobalt–chromium alloy**, localized stress concentrations were observed in the cervical region of the abutment teeth, reaching **30–32 MPa**, which increases the risk of microtrauma to periodontal tissues.

• When using the **Vetakryl splint**, stress levels in the same regions were reduced by **35–40%**, and the load was more evenly distributed along the entire length of the splinting arch.

• Analysis of deformation vector maps demonstrated a reduction in peak loads on the abutment teeth and a more physiological orientation of force vectors.Thus, the thermoplastic material **Vetakryl** provides an optimal balance between strength and flexibility, contributing to dental arch stabilization and reducing traumatic effects on the periodontal tissues.

2.2. Clinical Results

Clinical trials were conducted in **30 patients** aged **35–55 years** diagnosed with mild to moderate periodontitis. The patients were divided into two groups:

• **Main group (n = 15):** splinting with a Vetakryl-based construction;

• **Control group (n = 15):** splinting with conventional metallic splints.

Clinical evaluation was based on the following indices: **tooth mobility (Miller classification)**, **PMA index**, **bleeding on probing (BOP)**, and **gingival index (GI)**.

Table 1. Dynamics of Clinical Parameters in the Main and Control Grou

Parametr	Group	Before treatment	**After 3 months.**	After 3 moths	**Δ (%)**	P- value
TOOTH MOBILITY	Main	1,86 ± 0,12	1,34 ± 0,10	**1,10 ± 0,08**	−40,9 %	< 0,05
	Control	1,82 ± 0,13	1,58 ± 0,11	1,41 ± 0,09	−22,5 %	< 0,05
INDEX PMA (%)	Main	42,3 ± 3,1	30,8 ± 2,4	**23,1 ± 2,0**	−45,3 %	< 0,05
	Control	41,7 ± 3,3	36,5 ± 2,8	32,9 ± 2,6	−21,1 %	> 0,05
INDEX BOP (%)	Main	38,5 ± 2,7	26,2 ± 2,3	**18,7 ± 1,9**	−51,4 %	< 0,05
	Control	37,9 ± 2,9	32,6 ± 2,4	28,4 ± 2,1	−25,0 %	> 0,05
INDEX GI	Main	1,73 ± 0,09	1,32 ± 0,08	**1,05 ± 0,07**	−39,3 %	< 0,05
	Control	1,70 ± 0,10	1,51 ± 0,09	1,36 ± 0,08	−20,0 %	> 0,05

The obtained results demonstrate a pronounced positive dynamic in the main group. After six months of treatment, a statistically significant reduction in tooth mobility and inflammatory manifestations was observed, indicating the restoration of functional periodontal

stability.Patients in the main group also reported a higher level of wearing comfort, absence of metallic taste, and better aesthetic adaptation of the splinting construction.

2.3. Discussion

Data analysis confirmed that the use of the thermoplastic material **Vetakryl** обеспечивает a more physiological redistribution of masticatory loads, reduces stress concentration, and thereby contributes to the restoration of periodontal biomechanical balance.

The close correlation between clinical findings and modeling results emphasizes the reliability of **mathematical modeling** as a predictive tool for assessing the effectiveness of dental constructions.

Comparative analysis also demonstrated that the flexibility and elasticity of the polymer allow the maintenance of physiological tooth mobility without excessive pressure on abutment elements—an outcome that cannot be fully achieved with metallic splints.

The obtained data are consistent with the findings of **Wilson (2019)**, **Lindhe (2022)**, and **Rizayeva (2023)**, who reported the advantages of polymer-based materials for long-term stabilization of the dental arch in patients with mild to moderate periodontitis.

CONCLUSIONS

The conducted study confirmed the high effectiveness of the developed therapeutic and preventive splinting construction made of the thermoplastic polymer **Vetakryl** in the treatment of patients with mild to moderate periodontitis.The application of **finite element modeling (FEM)** and biomechanical analysis enabled an objective assessment of functional load redistribution within the dentoalveolar system and revealed clear advantages of the proposed construction compared with conventional metallic splints.

According to the modeling results, the use of Vetakryl provides a **35–40% reduction in stress concentration** and a more uniform distribution of forces along the dental arch, thereby reducing traumatic effects on periodontal tissues.Clinical observations demonstrated a statistically significant reduction in tooth mobility (**40.9%**), a decrease in periodontal inflammatory manifestations, and improvement in oral hygiene indices in patients of the main group, indicating a pronounced therapeutic effect of the construction.

The Vetakryl-based construction is characterized by high biocompatibility, optimal elasticity, aesthetic properties, and wearing comfort, which increases patient compliance and improves quality of life.The obtained results confirm the feasibility of introducing next-generation thermoplastic polymers into the practice of **prosthetic and periodontal dentistry**. The combined use of clinical evaluation and numerical modeling may serve as a reliable tool for predicting the effectiveness of dental constructions and optimizing treatment protocols for periodontal pathology.

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