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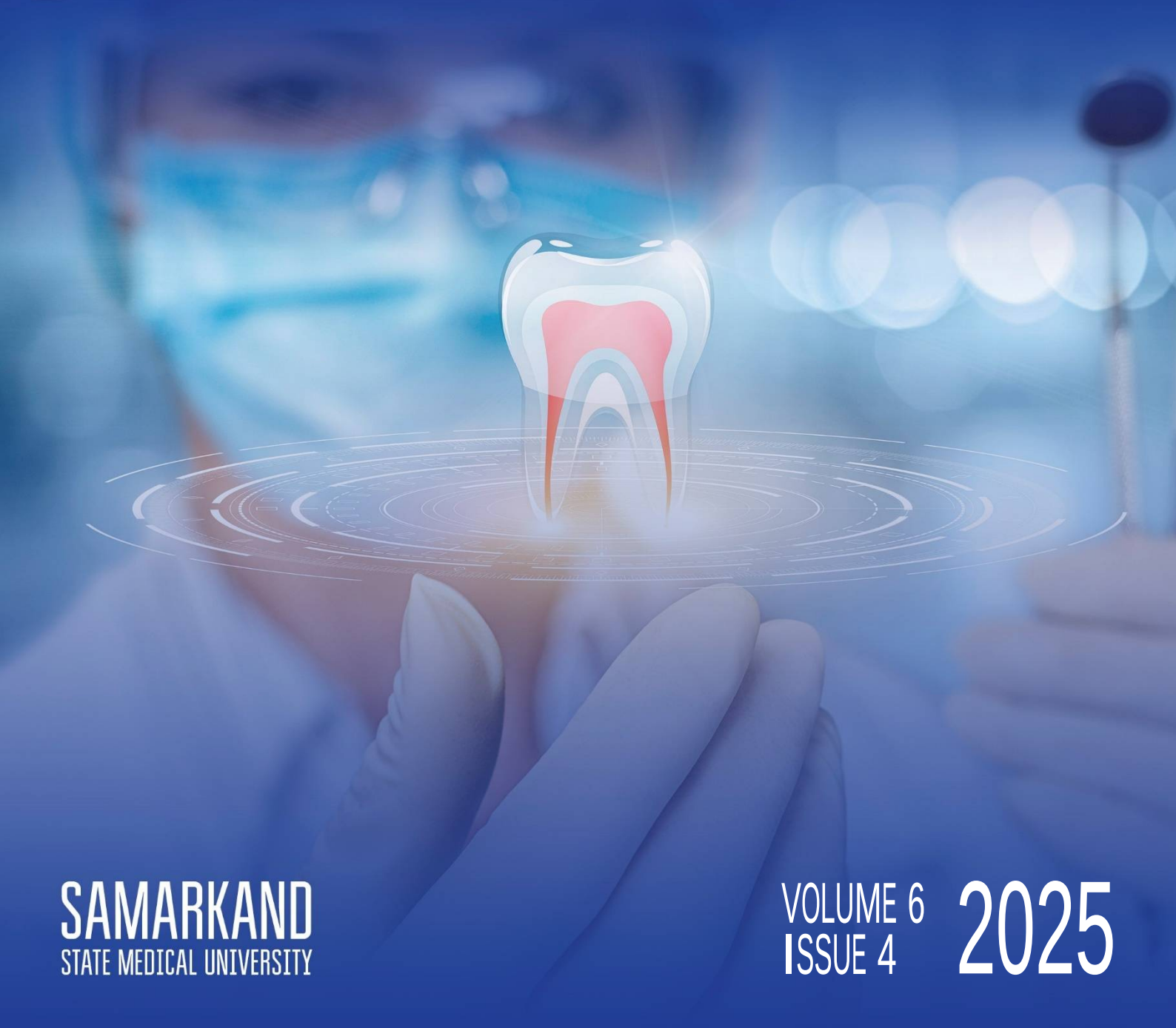

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DIGITAL MONITORING OF TOOTH COLOR CHANGES IN THE TREATMENT OF DENTAL DISCOLORATION IN ADOLESCENTS

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ANNOTATION

Dental discoloration in adolescents represents one of the most common esthetic problems in modern dentistry and significantly affects psychosocial well-being and quality of life. According to **Joiner (2004, 2006)**, even minor changes in tooth color are visually perceptible and influence patient satisfaction, while **Paravina and Powers (2008, 2012)** emphasize that objective, scientifically validated methods are required for reliable color assessment.

Traditional visual shade determination is subjective and influenced by lighting conditions, clinician experience, and fatigue (**Chu et al., 2010; Hasegawa et al., 2000**). Digital technologies, such as spectrophotometry and digital colorimetry, based on the **CIE L*a*b*** color system (**O'Brien, 2005**), provide accurate, reproducible, and quantitative evaluation of tooth color changes. Color differences can be calculated using the ΔE parameter, with ΔE > 3.3 considered clinically perceptible (**Johnston & Kao, 1989; Paravina et al., 2015**).

Digital monitoring at multiple stages of treatment allows dynamic assessment of therapeutic effectiveness, objectively detecting even minimal improvements. Studies by **Kim-Pusateri et al. (2009)** and **Vichi et al. (2011)** demonstrated that digital devices significantly outperform visual methods in accuracy and reproducibility. Integration of digital color measurement into adolescent dental practice enhances evidence-based treatment planning, optimizes minimally invasive interventions, and strengthens the scientific validity of clinical outcomes.

Keywords: dental discoloration, adolescents, digital dentistry, CIE L*a*b*, ΔE, spectrophotometry, color monitoring

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ЦИФРОВОЙ МОНИТОРИНГ ИЗМЕНЕНИЯ ЦВЕТА ЗУБОВ ПРИ ЛЕЧЕНИИ ДИСКОЛОРИТОВ У ПОДРОСТКОВ

АННОТАЦИЯ

Дисколориты зубов у подростков представляют собой одну из наиболее распространённых эстетических проблем современной стоматологии и существенно влияют на психосоциальное состояние и качество жизни пациентов. Согласно **Joiner (2004, 2006)**, даже незначительные изменения цвета зубов визуально воспринимаются и оказывают влияние на удовлетворённость пациента, в то время как **Paravina и Powers (2008, 2012)** подчёркивают необходимость использования объективных, научно обоснованных методов для надёжной оценки цвета.

Традиционное визуальное определение оттенка является субъективным и зависит от условий освещения, опыта клинициста и уровня усталости (**Chu et al., 2010; Hasegawa et al., 2000**). Цифровые технологии, такие как спектрофотометрия и цифровая колориметрия, основанные на системе **CIE L*ab*** (**O'Brien, 2005**), обеспечивают точную, воспроизводимую и количественную оценку изменений цвета зубов. Различия в цвете могут быть рассчитаны с помощью параметра **ΔE**, при этом значения ΔE > 3,3 считаются клинически заметными (**Johnston & Kao, 1989; Paravina et al., 2015**).

Цифровой мониторинг на различных этапах лечения позволяет динамически оценивать эффективность терапии, объективно фиксируя даже минимальные улучшения. Исследования **Kim-Pusateri et al. (2009)** и **Vichi et al. (2011)** показали, что цифровые устройства значительно превосходят визуальные методы по точности и воспроизводимости. Внедрение цифрового измерения цвета в практику подростковой стоматологии повышает уровень доказательной медицины, оптимизирует малоинвазивные вмешательства и укрепляет научную достоверность клинических результатов.

Ключевые слова: изменение цвета зубов, подростки, цифровая стоматология, CIE L*a*b*, ΔE, спектрофотометрия, мониторинг цвета

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O‘SMIRLARDA TISH DISKOLORITI DAVOLASHIDA TISH RANGINING RAQAMLI MONITORING

ANNOTATSIYA

O‘smirlar orasida tishlarning diskoloriti zamonaviy stomatologiyada eng keng tarqalgan estetik muammolardan biri bo‘lib, psixososial holat va bemorlarning hayot sifatiga sezilarli ta’sir ko‘rsatadi. **Joiner (2004, 2006)** fikriga ko‘ra, tish rangidagi eng kichik o‘zgarishlar ham vizual tarzda seziladi va bemor qoniqishiga ta’sir qiladi, **Paravina va Powers (2008, 2012)** esa ishonchli rang baholash uchun ob’ektiv, ilmiy asoslangan usullar zarurligini ta’kidlaydilar.

An’anaviy vizual rang aniqlash usullari subyektiv bo‘lib, yorug‘lik sharoitlari, klinik mutaxassisning tajribasi va charchoq darajasiga bog‘liq (**Chu et al., 2010; Hasegawa et al., 2000**). **CIE L*a*b*** rang tizimiga asoslangan spektrofotometriya va raqamli kolormetriya kabi raqamli texnologiyalar (**O’Brien, 2005**) tish rangidagi o‘zgarishlarni aniq, qayta ishlab chiqiladigan va miqdoriy baholash imkonini beradi. Rang farqlari **ΔE** ko‘rsatkichi yordamida hisoblanadi, ΔE > 3,3 qiymatlari esa klinik jihatdan sezilarli deb hisoblanadi (**Johnston & Kao, 1989; Paravina et al., 2015**).

Davolashning turli bosqichlarida raqamli monitoring terapiya samaradorligini dinamik tarzda baholash, hatto minimal o‘zgarishlarni aniqlash va klinik natijalarni ob’ektiv qayd etish imkonini beradi. **Kim-Pusateri et al. (2009)** va **Vichi et al. (2011)** tadqiqotlariga ko‘ra, raqamli qurilmalar vizual usullarga nisbatan aniq va qayta ishlab chiqilishi yuqori natijalarni ta’minlaydi. O‘smirlar stomatologiya amaliyotiga raqamli rang o‘lchovini joriy etish dalillarga asoslangan davolash rejalashtirishni yaxshilaydi, minimal invaziv davolash usullarini optimallashtiradi va klinik natijalarning ilmiy asoslanganligini mustahkamlaydi.

Kalit so'zlar: tish rangining o'zgarishi, o'smirlar, raqamli stomatologiya,CIE L * a*b*, daktilologiya, spektrofotometriya, ranglarni kuzatish

Introduction. Tooth color is one of the key factors determining the esthetic perception of a smile and the overall appearance of a patient. During adolescence, esthetic disturbances, including dental discoloration, significantly affect psychosocial well-being, self-esteem, interpersonal communication, and social adaptation.

Recent studies indicate that esthetic defects of teeth in adolescents can lead to reduced self-confidence, increased anxiety, and a negative self-image. Therefore, timely diagnosis and effective treatment of dental discolorations carry not only medical but also socio-psychological significance.

In adolescents, dental discolorations are most often of exogenous origin and are associated with exposure to dietary pigments, inadequate oral hygiene, medication intake, as well as early forms of fluorosis and enamel hypomineralization. In recent years, minimally invasive treatment methods aimed at preserving dental hard tissues have gained increasing importance in clinical practice. The effectiveness of such methods requires precise and objective evaluation of clinical outcomes.

Relevance of the Study. Traditional visual methods for assessing tooth color using standard shade guides (VITA Classical, VITA 3D-Master) are widely applied in clinical practice but are highly subjective. Results of visual assessment depend on lighting conditions, the clinician’s individual color perception, enamel moisture, and other factors.

Modern evidence-based dentistry requires the application of objective and reproducible diagnostic methods. This is especially important in adolescent practice, where treatment should be as conservative as possible, and outcomes must be both clinically and statistically justified.

Digital monitoring of tooth color allows

- Quantitative evaluation of enamel color changes;
- Tracking treatment dynamics;
- Performing statistical analysis of results;
- Improving the quality of scientific research and clinical observations.

Thus, the implementation of digital technologies in assessing dental discoloration in adolescents is both a relevant and promising direction in modern dentistry.

Aim and Objectives of the Study

Aim

To evaluate the clinical effectiveness and diagnostic significance of digital monitoring of tooth color changes during the treatment of dental discoloration in adolescents.

Objectives

1. To analyze the main causes of dental discoloration in adolescents.
2. To study contemporary digital methods for tooth color assessment.
3. To evaluate the dynamics of color parameter changes during treatment.
4. To compare digital and visual methods of tooth color evaluation.
5. To justify the feasibility of implementing digital monitoring in clinical practice.

Study Population

The study included adolescents aged 12–17 years with mild to moderate exogenous dental discolorations. All participants were systemically healthy and were under dynamic dental supervision.

Treatment Methods

The therapeutic protocol included:

- Professional oral hygiene;
- Remineralization therapy;
- Where indicated, enamel microabrasion or conservative chemical bleaching.

Methods for Tooth Color Assessment

To assess tooth color, the **CIE L*a*b*** system was used, which is recognized as the international standard in colorimetry:

- **L*** — lightness (0 = black, 100 = white);
- **a*** — axis from green (–) to red (+);
- **b*** — axis from blue (–) to yellow (+).

Color difference formula (ΔE).

For quantitative evaluation of color changes, the following formula was used:

$$\Delta E=(L^*_2-L^*_1)2+(a^*_2-a^*_1)^2+(b^*_2-b^*_1)^2$$

where:

- **L*1, a*1, b*1** — baseline (initial) color values;
- **L*2, a*2, b*2** — color values after treatment.

Values of **ΔE > 3.3** are considered clinically perceptible.

Stages of Digital Monitoring

1. Baseline measurement of tooth color.
2. After professional oral hygiene.
3. After completion of the main stage of treatment.
4. Follow-up measurement after 1–3 months.

Study Results

Table 1. Mean tooth color values before and after treatment (M ± SD)

Parameter	Before Treatment	After Treatment	After 3 Months
L*	68,4 ± 2,1	74,9 ± 1,8	73,8 ± 1,9
a*	1,9 ± 0,4	1,2 ± 0,3	1,3 ± 0,3
b*	12,6 ± 1,3	8,4 ± 1,1	8,9 ± 1,2
ΔE	—	6,2 ± 0,9	5,7 ± 0,8

Statistical Analysis

Descriptive statistical methods and the paired Student's t-test were used to process the data. Differences were considered statistically significant at **p < 0.05**.

Table 2. Statistical significance of changes in color parameters

Parameter	**t**	**p**
L*	9,14	< 0,001
a*	4,02	< 0,01
b*	10,36	< 0,001
ΔE	8,97	< 0,001

Description of Graphs

Figure 1. Dynamics of the L* parameter— demonstrates a significant increase in enamel lightness after treatment, with partial maintenance of the effect after 3 months.

Figure 2. Changes in the b* parameter— reflects a pronounced reduction in the yellow hue of enamel.

Figure 3. Distribution of ΔE values— more than 80% of patients had ΔE > 5, indicating a pronounced clinical effect.

Discussion. The obtained results indicate the high informativeness of digital monitoring of tooth color during the treatment of dental discoloration in adolescents. The most pronounced changes were observed in the **L*** parameter, which corresponds to clinical enamel lightening.

Unlike visual assessment, digital methods allow the detection of minimal color changes and enable an objective comparative analysis of different treatment methods. This is particularly important in adolescent dentistry, where strict adherence to minimally invasive principles and evidence-based practice is required.

Advantages of digital monitoring:

- Objectivity and accuracy of measurements;
- High reproducibility of results;
- Possibility of long-term follow-up;
- Increased compliance among adolescents;
- Compliance with international journal standards.

Conclusion. Digital monitoring of tooth color changes is a highly effective tool for evaluating the outcomes of dental discoloration treatment in adolescents. Its implementation allows for the objective documentation of clinical data, optimization of treatment protocols, and improvement of dental care quality. The integration of digital technologies aligns with modern trends in esthetic and adolescent dentistry.

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