European Annals of Dental Sciences

Official Publication of Ankara University Faculty of Dentistry

e-ISSN: 2757-6744

Volume 52 Issue 1, April 2025

# European Annals of Dental Sciences

*Year: 2025 Volume: 52 Issue :1*

The official journal of Ankara University, Faculty of Dentistry

Published electronically three times a year

Publication language is English

Owner on behalf of Ankara University, Faculty of Dentistry; Prof. Dr. Kaan ORHAN (Dean)

## EDITOR-IN-CHIEF



## ASSOCIATE EDITORS

# Editorial Board



# Scientific Advisory Board

European Annals of Dental Sciences

Year: 2025 Volume: 52 Issue :1

# Contents

## Original Research Articles



## Case report articles

European Annals of Dental Sciences
Official Publication of Ankara University, Faculty of Dentistry

*EADS*, 2025, 52 (1), 1–9

e-ISSN : 2757-6744
doi : 10.52037/eads.2025.0001

Article Received/Accepted : July, 23 2024 / December, 29 2024
Ethical Committee No : 36290600/96/2017

ORIGINAL RESEARCH ARTICLE

# Machine Learning Based Software to Predict the Type of Gingival Recession Surgery

Burak Karagöz [1], Batuhan Bakirarar [2], Canan Önder [3,*], Elif Ünsal [3] and Mehmet Tatlıcıoğlu [4]

[1]Institute of Health Sciences, Ankara University, Ankara, Türkiye and [2]Department of Biostatistics, Faculty of Medicine, Ankara University, Ankara, Türkiye and [3]Department of Periodontology, Faculty of Dentistry, Ankara University, Ankara, Türkiye and [4]Microsoft, 1 Microsoft Way, Redmond, WA, 98052, USA

*Corresponding Author; gulec_canan@yahoo.com

## Abstract

**Purpose:** The goal of this study is to identify the most important variables affecting gingival recession and to develop a machine learning -based software system using these variables.
**Materials and Methods:** 132 mandibular/maxillary right/left teeth #1, #2, #3, #4, and #5 were included in the study. Recession depth, recession width, width of keratinized gingiva, plaque index, buccogingival tissue thickness, frenulum position, and mobility were recorded before and 6 months after surgery. One of the following methods has been selected: Gingival unit graft, coronally advanced flap, coronally advanced flap+connective tissue graft, and coronally advanced flap+platelet-rich fibrin. Software system was developed to predict the type of gingival recession surgery.
**Results:** While the gingival unit graft group had the highest pre- and post-recession depth values, the coronally advanced flap group had the highest pre-recession width, pre-width of the keratinized gingiva, and post-width of the keratinized gingiva values. A significant difference was found between surgical type categories for all variables except gender, post-buccogingival tissue thickness, and post-frenulum position ($p<0.05$). Random Forest was found to be the best-performing method both for surgery categories and overall based on accuracy and F-measure. The accuracy value was found to be 90.0% for the gingival unit graft, 62.5% for the coronally advanced flap, 71.4% for the coronally advanced flap+connective tissue graft, and 97.8% for the coronally advanced flap+platelet-rich fibrin.
**Conclusions:** The machine learning software system could evaluate the data accumulated in the database using the decision trees method and predict the prognosis of surgical techniques to treat gingival recession. The software system developed will help physician determine the optimal treatment approach.

**Keywords**: Decision trees; Gingival recession; Machine learning; Mucogingival surgery; Predictive decision model

## Introduction

Mucogingival deformities are a group of conditions that affect a large number of patients. Among the mucogingival deformities, lack of keratinized tissue and gingival recession are the most common problems.[1] Marginal tissue recession is characterized as the displacement of the soft tissue margin apical to the cementoenamel junction (CEJ).[2]

Numerous variables, like inflammation, trauma, tooth alignment, age, calculus deposition, and smoking, are believed to contribute to this disease. The absence of keratinized tissue is also considered a risk factor for gingival recessions and inflammation.[3] Several aspects of gingival recession make it clinically significant.[4–6] The presence of recession is esthetically unacceptable for many patients; dentin hypersensitivity may occur, the denuded root surfaces are exposed to the oral environment, and may be associated with carious and non-carious cervical lesions, such as abrasions or erosions.

For an accurate treatment strategy, the severity of gingival recessions should always be determined. Cairo et al. presented a treatment-oriented classification based on the interdental clinical attachment loss (CAL) score: Cairo Recession Type 1 (RT1), RT2, and RT3.[7] Various periodontal plastic surgical strategies have been introduced in gingival recession treatment. These include free gingival grafts (FGG), connective tissue grafts (CTG), guided tissue regeneration, and pedicle grafts. Even though nearly all of them de-

livered positive clinical changes, different rates of success and consistency have been reported both between and within these procedures.[8,9] Numerous factors, including the width of the keratinized gingiva, cervical lesions, depth and width of gingival recession, buccal bone thickness, dental plaque, patient-related factors (such as age, gender, and smoking), gingival thickness, high frenulum attachment, and tooth mobility, influence the treatment outcome of gingival recessions.[10–15] Too many variables can induce gingival recession, making it difficult to predict the prognosis of recession surgery.

Machine learning refers to the process of extracting new, valuable, and undiscovered information from data sets. It is a joint effort of humans and computers.[16] It is also defined as the process of extracting previously unknown, potentially useful, and interesting information from large and often different data sources.[17,18] In practice, the most important purpose of machine learning is to make predictions. Prediction involves using variables in the dataset to predict unknown values of the dependent variable.[19]

To date, no studies have used machine-learning-based software to assess gingival recession and surgical approaches. The hypothesis of the study is that models created using machine learning are more successful in predicting the prognosis of recession surgery than classical statistical methods. The aim of this study is to determine the most important variables that affect gingival recession and to develop a machine-learning-based software system using these variables. The system has a dual purpose of serving as a database for patient information and as a decision support system for foreseeing the type of gingival recession surgery.

## Material and Methods

### Study Population and Study Design

This cross-sectional study included systemically healthy individuals who attended to Ankara University Faculty of Dentistry Department of Periodontology for gingival recession treatment and were scheduled for root closure surgery after the periodontal examination. The research was carried out in accordance with the Declaration of Helsinki of 1975, as revised in 2013, and the study design was authorized by the Ankara University Faculty of Dentistry Clinical Studies Ethics Committee (ethical approval number 36290600/96). This clinical investigation has been filed with Clinical Trials.gov (NCT04045808). All patients included in the study provided their consent after being fully informed.

The study included systemically healthy adult patients $\geq$18 years old who have incisors, first and second premolars in both jaws. Women who were pregnant or nursing, patients who were taking any medications that may affect periodontal tissues, and patients who had previously undergone periodontal surgery in the relevant region were excluded from the study. The research involved 132 teeth. Each patient underwent an initial phase of therapy, which included oral prophylaxis, root planing, oral hygiene instructions, and occlusal adjustment. Upon the completion of the initial examination and during Phase I periodontal therapy, the selected sites were randomly assigned to each one of the groups, 1, 2, 3, and 4, in accordance with a randomization list. The establishment of treatment groups, in which each patient receives a specific treatment choice, was conducted as follows:

1. Gingival unit graft (GUG) (Conventional free palatal graft modified with the involvement of marginal gingiva and papillary tissue). 2. Coronally advanced flap (CAF). 3. CAF+CTG. 4. CAF+platelet-rich fibrin (PRF).

### Data Collection

All surgical procedures were carried out by either associates or PhD candidates. A single investigator blinded to the procedures conducted all of the measurements. At the baseline, the teeth and the type of recession were recorded. The research included central and lateral incisors, canines, and the first and second premolars. The classification method used in this manner by Cairo et al.[7] was utilized for recessions and graded as RT1: Gingival recession with no loss of interproximal attachment. RT2: Gingival recession associated with loss of interproximal attachment. The amount of loss of interproximal attachment was less than or equal to the buccal attachment loss. RT3: Gingival recession associated with loss of interproximal attachment. The amount of interproximal attachment was higher than the buccal attachment loss.

The following periodontal variables were recorded before and 6 months after surgery by a periodontal probe . Recession depth (RD) was measured as the distance between CEJ and the most apical point of the gingival margin at the mid-buccal point of the teeth involved. Recession width (RW) was measured at the CEJ mid-facially, and values were recorded in mm. The distance between the mucogingival line and the gingival margin was measured for the width of the keratinized gingiva (WKG). With the help of a periodontal probe, the mobile alveolar mucosa was moved towards the keratinized gingiva, and the mucogingival line was determined (Roll technique). Plaque index (PI) was recorded from the mid-buccal, mesiobuccal, and distobuccal regions of each tooth undergoing periodontal surgery, and average values were recorded.[20] Buccogingival tissue thickness (BTT) was measured with the TRAN (probe transparency) method; the gingival biotype was considered thin if the outline of the probe was visible through the gingival margin from the sulcus and thick if the probe was not visible through the sulcus.[21] Frenulum position was named according to its location as a mucosal attachment, gingival attachment, or papillary attachment. Mobility was detected by using an instrument (e.g., a mirror handle) on either side of the tooth after applying a controlled force and was scored on a scale of 0–3.[22]

### Software Methodology

The creation of a decision support system based on the best-performing machine learning method was planned. The developed software system calculates an estimated success rate for each criterion based on the type of surgery for the 132 tooth regions, aligned with the specified pre- and post-operative data. At the same time, it aims to estimate the success rate and percent closure of the surgery for each selected type of surgery. With the developed system, it is planned to record patient data and thus create a global database for use in future research. It is thought that the performance of the system will increase by adding the post-surgical data to the model in addition to the pre-surgical data.

### Sample Size

Since there is no similar study in the literature, the sample size is calculated based on the effect size. When the effect size of the difference between GUG, CAF, CAF+CTG, and CAF+PRF surgery types in terms of preoperative WKG is taken as 0.3, when the sample size is calculated using the One Way ANOVA test with a significance level of 0.05 and a power of 0.80, a minimum of 128 teeth was found sufficient for the study.

### Statistical Analysis

WEKA 3.7 and SPSS 11.5 were used to evaluate the data. Mean ± standard deviation and median (minimum-maximum) were used

**Table 1.** Descriptive statistics for quantitative variables according to the types of gingival recession surgery

| Variables | | Surgery Type | | | | p value |
|---|---|---|---|---|---|---|
| | | GUG | CAF | CAF+CTG | CAF+PRF | |
| **Age** | Mean ± SD | 30.69±7.95 | 46.75±12.48 | 39.78±11.72 | 45.29±10.82 | <0.001 |
| | Median | 29.00 | 50.00 | 35.50 | 50.00 | |
| | (Min-Max) | (18.00-46.00) | (27.00-58.00) | (21.00-60.00) | (18.00-59.00) | |
| **Pre-RD(mm)** | Mean ± SD | 3.85±1.43 | 2.07±0.51 | 3.11±1.09 | 2.23±0.95 | <0.001 |
| | Median | 4.00 | 2.00 | 3.00 | 2.00 | |
| | (Min-Max) | (1.50-7.00) | (1.00-3.00) | (1.00-6.00) | (1.00-4.00) | |
| **Post-RD(mm)** | Mean ± SD | 1.97±1.45 | 1.68±0.82 | 0.91±0.97 | 1.24±0.99 | <0.001 |
| | Median | 1.50 | 2.00 | 0.75 | 1.00 | |
| | (Min-Max) | (0.00-6.00) | (0.50-3.00) | (0.00-3.50) | (0.00-4.00) | |
| **Pre-RW(mm)** | Mean ± SD | 2.74±0.68 | 3.57±1.27 | 3.46±0.85 | 3.23±0.91 | <0.001 |
| | Median | 2.50 | 3.25 | 3.50 | 3.00 | |
| | (Min-Max) | (1.50-4.50) | (1.50-5.50) | (2.00-6.00) | (2.00-5.00) | |
| **Post-RW(mm)** | Mean ± SD | 1.87±0.98 | 2.86±1.57 | 1.84±1.35 | 2.13±1.21 | 0.150 |
| | Median | 2.00 | 3.00 | 2.00 | 2.00 | |
| | (Min-Max) | (0.00-4.50) | (0.50-5.50) | (0.00-4.00) | (0.00-4.00) | |
| **Pre-WKG(mm)** | Mean ± SD | 2.01±0.99 | 5.71±2.02 | 3.29±1.44 | 5.26±1.97 | <0.001 |
| | Median | 2.00 | 7.00 | 3.00 | 5.00 | |
| | (Min-Max) | (0.00-4.00) | (2.00-8.00) | (0.50-7.00) | (2.00-10.00) | |
| **Post-WKG(mm)** | Mean ± SD | 5.44±1.77 | 6.14±1.51 | 5.01±1.39 | 5.89±1.76 | 0.048 |
| | Median | 6.00 | 7.00 | 5.00 | 6.00 | |
| | (Min-Max) | (2.00-11.00) | (3.00-8.00) | (3.00-8.00) | (3.00-10.00) | |

Abbreviations: GUG, Gingival unit graft; CAF, Coronally advanced flap; CAF+CTG, Coronally advanced flap + connective tissue graft; CAF+PRF, Coronally advanced flap + platelet rich fibrin; Pre-RD, Preoperative recession depth; Post-RD, Postoperative recession depth; Pre-RW, Preoperative recession width; Post-RW, Postoperative recession width; Pre-WKG, Preoperative width of the keratinized gingiva; Post-WKG, Postoperative width of the keratinized gingiva. SD: Standard deviation, Min: Minimum, Max: Maximum.

for quantitative variables, and the number of cases (percentage) wasused for qualitative variables. The Kruskal Wallis H test was used to determine whether there is a difference between the categories of qualitative variables with more than three categories for the quantitative variable. The Chi-square test was used to examine the relationship between two qualitative variables. The statistical significance level was taken as 0.05. Machine learning methods of Logistic Regression, Multilayer Perceptron, and Random Forest were used for data analysis. The data set was evaluated by using the 10-fold Cross-Validation test option. Accuracy, F-measure, Precision, Recall, and ROC Area were used as the evaluation criteria.

## Results

Comparisons of quantitative variables for recession surgery type were analyzed in Table 1, and a significant difference was found between surgical type categories for all variables except post-RW ($p<0.05$). Patients undergoing CAF surgery had the highest mean age, while patients undergoing GUG surgery had the lowest mean age. While the GUG surgery group had the highest pre-RD and post-RD values, the CAF surgery group had the highest pre-RW, pre-WKG, and post-WKG values.

Comparisons of qualitative variables for recession surgery type were analyzed in Table 2, and a significant difference was found between surgical type categories for all variables except gender, post-BTT, and post-frenulum position ($p<0.05$). The majority of surgical procedures were performed on the central teeth, or at least the second premolars. While the majority of GUG procedures were performed on the central teeth, the majority of CAF, CAF+CTG, and CAF+PRF procedures were performed on the canine teeth.

The GUG group had greater RT1 and RT2 recessions (40.0% and 48.9%, respectively), but the CAF and CAF+CTG groups had high RT1 recessions (75.0% and 88.0%, respectively). No RT2 or RT3 recessions occurred in the CAF+PRF group. Smokers were mostly seen in the CAF+PRF group. PI values and BTT thickness increased for all groups following the surgeries. Frenulum position was observed to be mucosal following surgeries in both the CAF+CTG and CAF+PRF groups. Before surgery, Miller 1 and 2 mobility were only observed in the GUG group (Table 2).

Information Gain Attribute Evaluation and Gain Ratio Attribute Evaluation methods were employed because there were too many variables in the data set. By using these methods, the importance of the variables and the values they added to the data set were examined. The variables, which were determined to be insignificant by two methods and considered to be unimportant as clinical information, were excluded from the data set. A total of 15 variables (14 independent variables and 1 dependent variable) remained finally. These variables were gender, age, pre-RD, pre-RW, pre-WKG, post-WKG, pre-BTT, post-BTT, pre-PI, post-PI, pre-frenulum position, post-frenulum position, smoking status, teeth, and recession surgery type. Percentages of variable importance according to dependent variable recession surgery type were given in Fig. 1.

The data set was analyzed using different machine learning techniques, and the performance criteria of the best three methods were given in Table 3. The Random Forest method was observed to be the best performing in both surgery categories and overall based on accuracy and F-measure, which are the most widely used performance criteria in the literature (overall, ACC:0.864, F-measure: 0.859). On a surgery categories basis, accuracy value was found to be 90.0% for GUG, 62.5% for CAF, 71.4% for CAF+CTG, and 97.8% for CAF+PRF.

The number of trees for the Random Forest method was determined to be 100, and the structure of one of these trees, J48, is given in Fig. 2. The tree structure gives information about which type of surgery should be chosen when and under what conditions. For instance, when the tree structure is examined, it is seen that the operation type should be chosen as CAF+CTG. When the pre-frenulum position is mucosal, the pre-PI value is 0, the recession type is RT1, and the pre-BTT type is thin.

According to our findings, the Random Forest method was used to create the software system, and the system screenshots were given in Fig. 3 and Fig. 4. Fig. 5 and Fig. 6 show case photographs taken after GUG surgery and CAF+CTG surgery, respectively.

**Table 2.** Descriptive statistics for qualitative variables according to the types of gingival recession

| Variables | | Surgery Type | | | | p value |
|---|---|---|---|---|---|---|
| | | GUG | CAF | CAF+CTG | CAF+PRF | |
| | | n (%) | n (%) | n (%) | n (%) | |
| **Gender** | Male | 10 (22.2) | 2 (12.5) | 14 (28.0) | 9 (42.9) | 0.174[a] |
| | Female | 35 (77.8) | 14 (87.5) | 36 (72.0) | 12 (57.1) | |
| **Teeth** | Central | 45 (100.0) | 4 (25.0) | 8 (16.0) | 3 (14.3) | <0.001[b] |
| | Lateral | 0 (0.0) | 2 (12.5) | 7 (14.0) | 5 (23.8) | |
| | Canine | 0 (0.0) | 6 (37.5) | 16 (32.0) | 8 (38.1) | |
| | 1st premolar | 0 (0.0) | 3 (18.8) | 13 (26.0) | 4 (19.0) | |
| | 2nd premolar | 0 (0.0) | 1 (6.2) | 6 (12.0) | 1 (4.8) | |
| **Type of recession** | RT1 | 18 (40.0) | 12 (75.0) | 44 (88.0) | 21 (100.0) | <0.001[b] |
| | RT2 | 22 (48.9) | 0 (0.0) | 3 (6.0) | 0 (0.0) | |
| | RT3 | 5 (11.1) | 4 (25.0) | 3 (6.0) | 0 (0.0) | |
| **Smoking status** | Non-Smoker | 30 (66.7) | 15 (93.8) | 41 (82.0) | 7 (33.3) | <0.001[b] |
| | <10 per day | 2 (4.4) | 1 (6.2) | 0 (0.0) | 2 (9.5) | |
| | ≥ 10 per day | 13 (28.9) | 0 (0.0) | 9 (18.0) | 12 (57.2) | |
| **Pre-PI** | 0 | 17 (37.8) | 14 (87.5) | 42 (84.0) | 4 (19.0) | <0.001[b] |
| | 1 | 19 (42.2) | 0 (0.0) | 6 (12.0) | 16 (76.2) | |
| | 2 | 6 (13.3) | 2 (12.5) | 2 (4.0) | 1 (4.8) | |
| | 3 | 3 (6.7) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| **Post-PI** | 0 | 7 (15.6) | 5 (31.2) | 32 (64.0) | 12 (57.1) | <0.001[b] |
| | 1 | 11 (24.4) | 11 (68.8) | 9 (18.0) | 4 (19.0) | |
| | 2 | 9 (20.0) | 0 (0.0) | 4 (8.0) | 5 (23.8) | |
| | 3 | 18 (40.0) | 0 (0.0) | 5 (10.0) | 0 (0.0) | |
| **Pre-BTT** | Thick | 14 (31.1) | 13 (81.2) | 21 (42.0) | 13 (61.9) | 0.002[a] |
| | Thin | 31 (68.9) | 3 (18.8) | 29 (58.0) | 8 (38.1) | |
| **Post-BTT** | Thick | 45 (100.0) | 16 (100.0) | 50 (100.0) | 20 (95.2) | 0.280[b] |
| | Thin | 0 (0.0) | 0 (0.0) | 0 (0.0) | 1 (4.8) | |
| **Pre-frenulum position** | Mucosal | 3 (6.7) | 13 (81.2) | 16 (76.2) | 16 (76.2) | <0.001[b] |
| | Gingival | 38 (84.4) | 3 (18.8) | 5 (23.8) | 5 (23.8) | |
| | Papillary | 4 (8.9) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| **Post-frenulum position** | Mucosal | 44 (97.8) | 13 (81.2) | 44 (88.0) | 19 (90.5) | 0.114[b] |
| | Gingival | 1 (2.2) | 3 (18.8) | 6 (12.0) | 2 (9.5) | |
| **Pre-mobility** | 0 | 27 (62.8) | 14 (100.0) | 50 (100.0) | 19 (100.0) | <0.001[b] |
| | 1 | 12 (27.9) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| | 2 | 4 (9.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| **Post-mobility** | 0 | 28 (65.1) | 14 (100.0) | 50 (100.0) | 19 (100.0) | <0.001[b] |
| | 1 | 15 (34.9) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |

Abbreviations: GUG, Gingival unit graft; CAF, Coronally advanced flap; CAF+CTG, Coronally advanced flap + connective tissue graft; CAF+PRF, Coronally advanced flap + platelet rich fibrin; Pre-PI, Preoperative plaque index; Post-PI, Postoperative plaque index; Pre-BTT, Preoperative buccogingival tissue thickness; Post-BTT, Postoperative buccogingival tissue thickness; Pre- frenulum position, Preoperative frenulum position; Post- frenulum position, Postoperative frenulum position; Pre-mobility, Preoperative mobility; Post-mobility, Postoperative mobility. Statistical significant ($p<0.05$). a Chi-squared test, b Fisher exact test.

**Table 3.** Performance Measures for Machine Learning Methods

| Methods | Surgery Type | Performance Measures | | | | |
|---|---|---|---|---|---|---|
| | | Accuracy | F-measure | Precision | Recall | ROC Area |
| **Logistic Regression** | GUG | 0.780 | 0.772 | 0.765 | 0.780 | 0.867 |
| | CAF | 0.625 | 0.645 | 0.667 | 0.625 | 0.881 |
| | CAF+CTG | 0.714 | 0.652 | 0.600 | 0.714 | 0.892 |
| | CAF+PRF | 0.778 | 0.814 | 0.854 | 0.778 | 0.912 |
| | Overall | 0.750 | 0.752 | 0.757 | 0.750 | 0.888 |
| **Multilayer Perceptron** | GUG | 0.800 | 0.800 | 0.800 | 0.800 | 0.898 |
| | CAF | 0.762 | 0.800 | 0.842 | 0.762 | 0.962 |
| | CAF+CTG | 0.838 | 0.833 | 0.829 | 0.838 | 0.895 |
| | CAF+PRF | 0.911 | 0.882 | 0.854 | 0.911 | 0.957 |
| | Overall | 0.811 | 0.809 | 0.809 | 0.811 | 0.925 |
| **Random Forest** | GUG | 0.900 | 0.865 | 0.833 | 0.900 | 0.910 |
| | CAF | 0.625 | 0.741 | 0.909 | 0.625 | 0.966 |
| | CAF+CTG | 0.714 | 0.769 | 0.833 | 0.714 | 0.941 |
| | CAF+PRF | 0.978 | 0.936 | 0.898 | 0.978 | 0.986 |
| | Overall | 0.864 | 0.859 | 0.865 | 0.864 | 0.948 |

Abbreviations: GUG: Gingival unit graft, CAF: Coronally advanced flap, CAF+CTG: Coronally advanced flap + connective tissue graft, CAF+PRF: Coronally advanced flap + platelet rich fibrin.

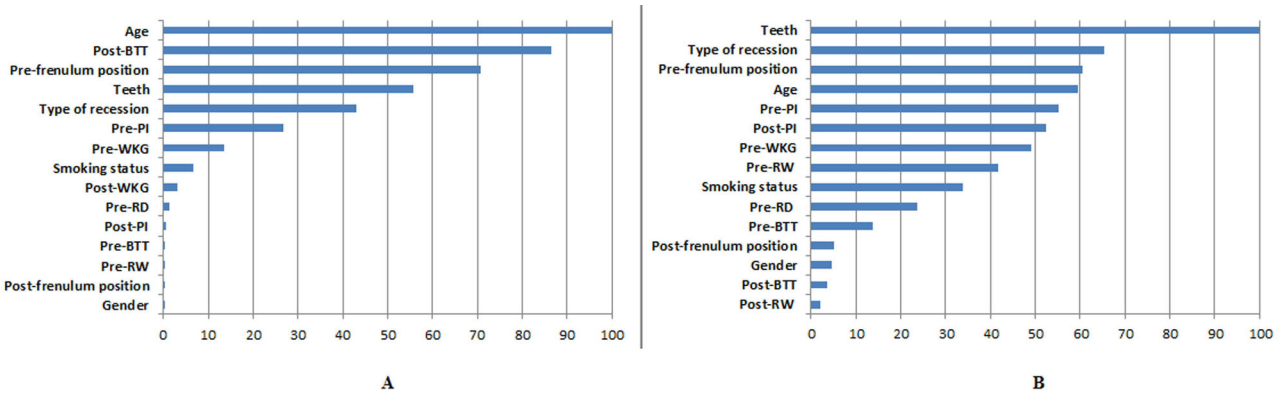


**Figure 1A: Gain Ratio Attribute Eval., Figure 1B: Information Gain Attribute Eval. Abbreviations: Post-BTT, Postoperative buccogingival tissue thickness; Pre-frenulum position, Preoperative frenulum position; Pre-PI, Preoperative plaque index; Pre-WKG, Preoperative width of the keratinized gingiva; Post-WKG, Postoperative width of the keratinized gingiva; Pre-RD, Preoperative recession depth; Post-PI, Postoperative plaque index; Pre-BTT, Preoperative buccogingival tissue thickness; Pre-RW, Preoperative recession width; Post- frenulum position, Postoperative frenulum position.**

**Figure 1.** Variable Importance Test Results for Recession Surgery Type. A: Gain Ratio Attribute Eval., B: Information Gain Attribute Eval

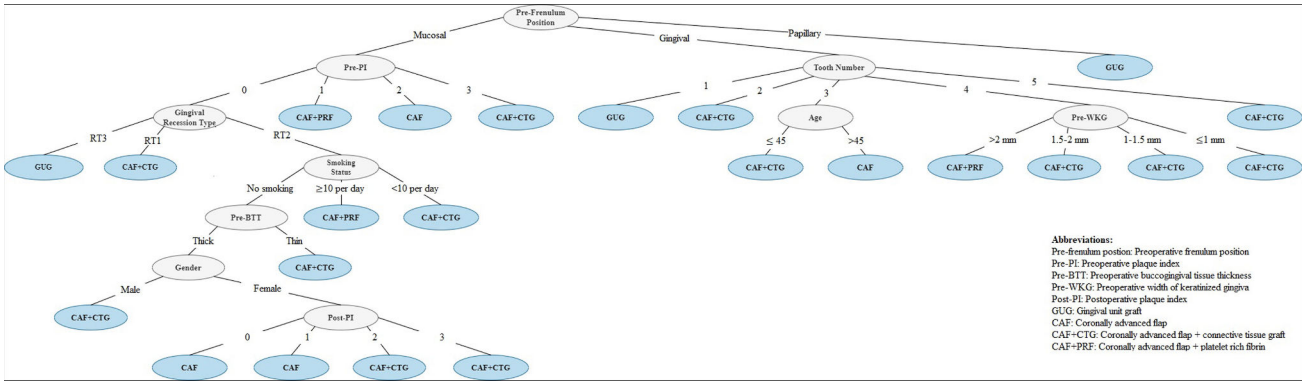


**Figure 2.** Tree Diagram of the Random Forest Method

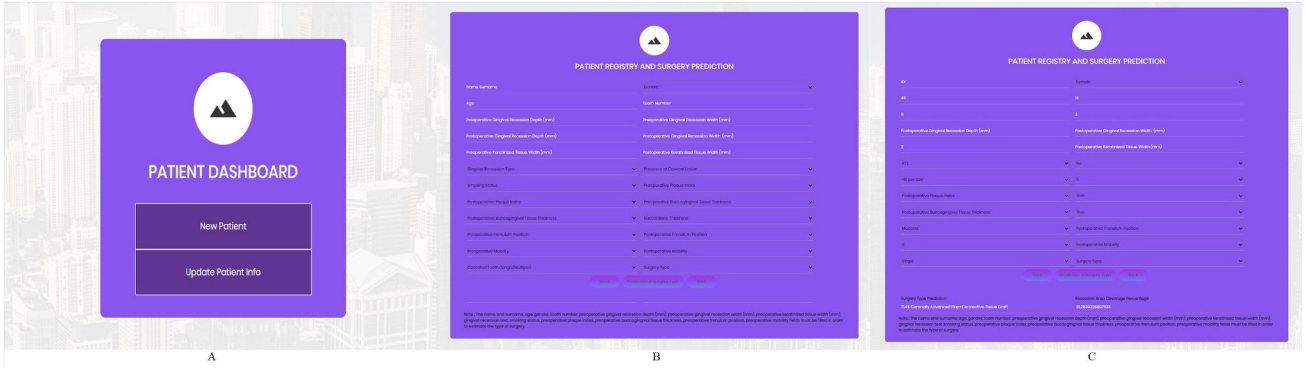


**Figure 3.** Software Outputs for New Patient. A: Patient Dashboard, B: New Patient Entry, C: New Patient Prediction

## Discussion

Gingival recessions have been treated with various strategies over the past 30 years, including FGG, subepithelial or connective tissue grafts, CAF, non-absorbable membranes or absorbable membranes, enamel matrix derivatives, and CAF mixed with platelet-rich gel.[23–30] When estimating the prognosis in cases with gingival recession, clinicians are limited in their ability to select the type of surgery indicated by the existing categories. In this study, the data from four surgery types (GUG, CAF, CAF+CTG, and CAF+PRF) with the highest root closure success rates were incorporated into a computer program that utilized a machine learning approach to predict prognosis. Our study resulted in the development of a software system that can handle a great variety of clinical factors. Although this program allows us to predict surgery prognosis with a high degree of accuracy using the current data, it will also enable machine learning software system to estimate surgery prognosis with an even higher degree of precision when new data becomes available. In our report, we listed the characteristics that influence the kind of surgery, and we instructed a computer program that does statistical calculations and employs machine learning (Decision Trees) to select a prognosis estimation and operation type. In this study, 132 tooth sites with gingival recessions were evaluated using 15 criteria. Our study's machine learning-based computer program utilizes the Decision Trees method's multivariate model, which is accomplished by assessing 15 independent variables simultane-

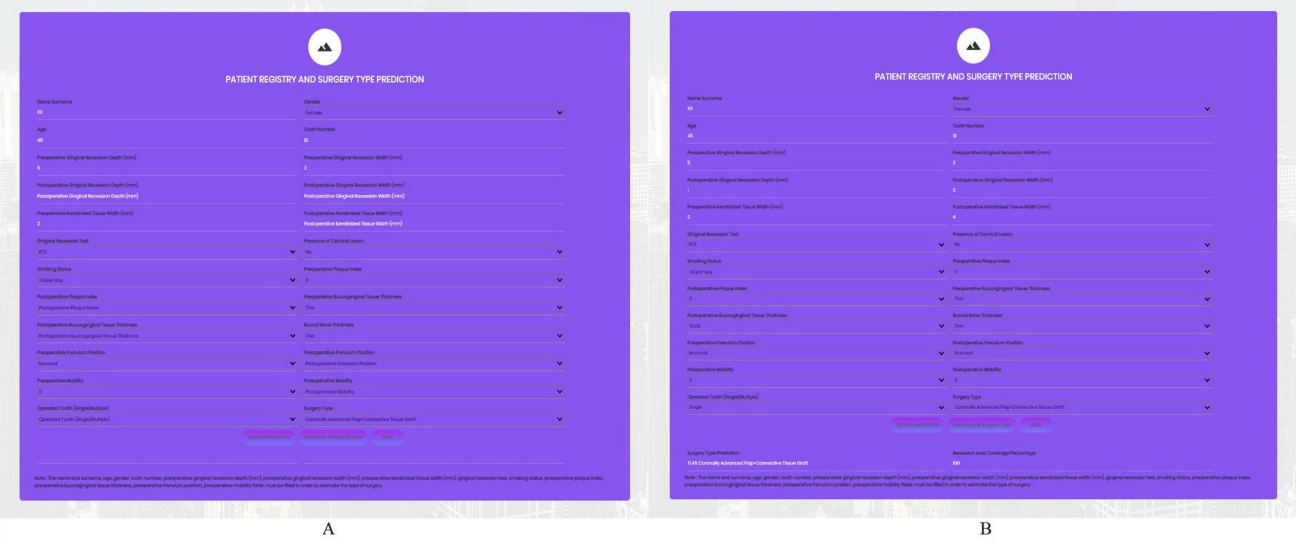


**Figure 4.** Software Outputs for Update Patient. A: Update Patient Entry, B: Update Patient Prediction

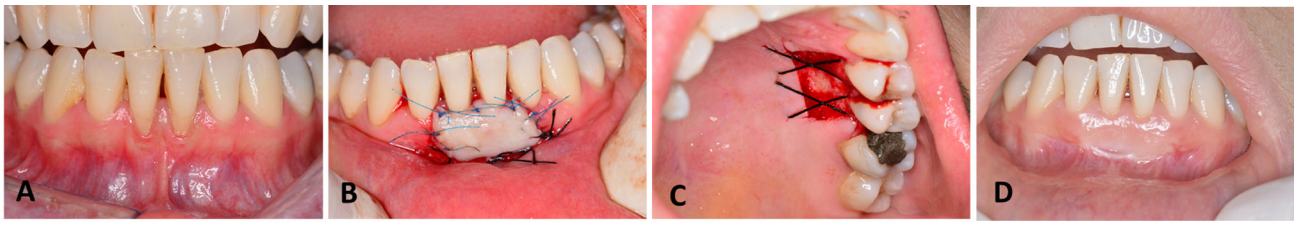


**Figure 5.** Views of the Gingival Unit Graft Surgery. A: Baseline, B: Gingival Unit Graft Suture, C: Donor Site (Palatinal View), D: 6-months Follow-up

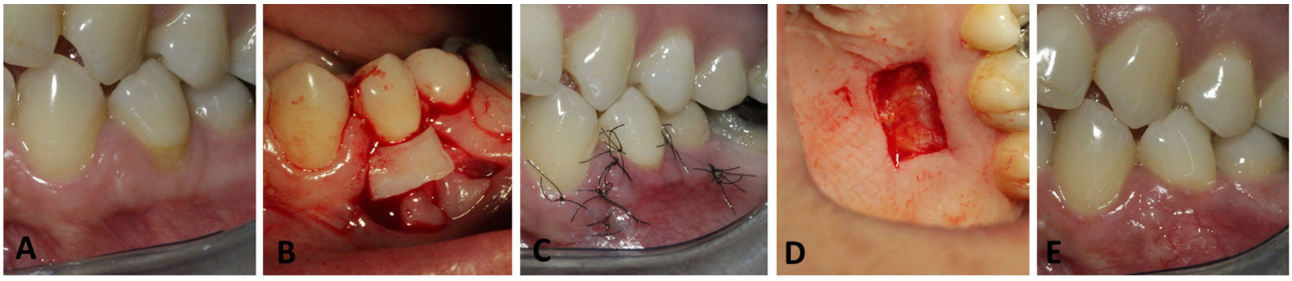


**Figure 6.** Views of the Coronally Advanced Flap+Connective Tissue Graft Surgery. A: Baseline, B: Flap Elevation and Connective Tissue Graft, C: Coronally Advanced Flap Suture, D: Donor Site (Palatinal View), E: 6-months Follow-u

ously. The Decision Trees technique develops a prediction model by integrating these 15 factors. Since just one of these factors would be inadequate for making a prediction, a prediction procedure must be run with all the factors present.

In order to determine the likelihood of developing conditions like diabetes and heart disease, scientists and physician have created a number of risk assessment techniques.[31–33] In 2002, Page et al. published a research in the field of periodontology using a similar calculation approach to ours.[34] They developed a computer-based approach for calculating periodontal disease risk (PRC). In contrast to the software employed in this research, our study utilizes statistical decision trees. Compared to previous statistical approaches, this method (Random Forest) gives a single choice on behalf of the population by integrating the findings of numerous classifiers in identifying the most appropriate treatment option, resulting in more accurate estimations.[35] Persson et al. found that, while assessing periodontal risk, professional physician exhibited greater variability and heterogeneity than PRC software.[36] Their findings showed that utilizing risk ratings to make treatment decisions might lead to treatment errors and that an objective instrument like the PRC could be advantageous. A similar machine-learning-software system was developed, allowing clinicians to anticipate the success rates of treatment techniques to be employed in our study for the treatment of gingival recession. By utilizing data from a variety of dental applications, it is conceivable that the system we developed might be applied to other disciplines. In a study by Covani et al.[37], a software system was used to analyze dominant genes to be associated with periodontitis and Type 2 diabetes mellitus, and Fan et al.[38] used the Decision Trees statistical method to create a model to predict dental prognosis. In health care, decision trees are often used to assist physician in making diagnostic and treatment decisions based on evidence.[39] These tools might also assist public health officials and service providers in selecting evidence-based policies and implementation strategies and in identifying areas where further research is required.[40]

Significant variables have been found to impact the prognosis of root closure surgeries on the location and teeth to be operated on in our study. The contribution of the computer program to the predictability of the tooth to be operated on is crucial. In a study evaluating the parameters influencing the prognosis of root closure

procedures used to treat gingival recession, Aroca et al.[41] discovered that surgeries conducted on the upper jaw were more successful than surgeries performed on the lower jaw. In this study, we found that there were substantial disparities in teeth between the groups. In the future, we will be able to remark on other teeth, and when new data is uploaded into the program by other clinicians, this may alter the variable significance table. The GUG group had the highest increase in WKG after surgery, with a mean of 3.43 mm. The free gingival graft has been successfully used to increase the amount of keratinized tissue in periodontal plastic surgery procedures. Kuru and Yıldırım[25] found a root closure rate of 91.6% for GUG surgery and 87% for free gingival graft surgery. GUG with the gingival margin was included in our analysis since there aren't many studies and data on free gingival graft procedures in the literature. The mean WKG increased by 0.43 mm after surgery in the CAF group, 1.72 mm in the CAF+CTG group, and 0.63 mm in the CAF+PRF group. In 114 gingival recessions, Kuis et al.[42] compared CAF+CTG surgery to CAF surgery. They found a 2.4±0.6 mm average increase in keratinized tissue with CAF+CTG surgery. When the widths of keratinized tissue are assessed prior to surgery in our study, it has been shown that GUG surgery is preferred when the keratinized tissue is less than 2 mm thick. Literature considers free gingival graft surgery to be the gold standard for increasing the quantity of keratinized tissue.[10,43,44]

There were substantial differences in smoking between the groups. In the CAF+PRF group, 57.2% of patients were smokers, whereas the CAF group has no smokers. In a study comparing smokers and nonsmokers, the success rate of CTG root surface closure was 83.3% in smokers and 58% in nonsmokers.[45] In our study, the CAF+CTG group exhibited the highest percentage of root surface closure. Following this are the GUG, CAF+PRF, and CAF groups. In the CAF+PRF group, smoking appeared to have a negative effect on root closure. The low proportion of root closure in the non-smoker CAF group is not just attributable to smoking but may also be due to a number of other variables. While there was a substantial variation in smoking status across the surgical groups in our investigation, these differences contributed considerably to the accuracy of the computer program's prediction.

In our investigation, PI ratings before and after surgery were considerably different. Numerous studies have indicated that the higher the root closure success rates following gingival recession treatments, the lower the PI scores.[46,47] This relevance will assist computer programs in predicting results.

BTT can have an effect on gingival recession. Ercan et al.[48] reported a substantial positive link between gingival phenotype and buccal alveolar bone thickness. In our study, there was a statistically significant difference in BTT between the groups prior to surgery. BTT data were inputted into a computer program to be able to make predictions. Certain forms of maxillary frenulum have an influence on periodontal health, according to Mirko et al..[49] In our study, the location of the frenulum before surgery was substantially different between groups. In 97.8% of the postoperative GUG group, the frenulum was detected in the mucosal position. However, following surgery, the proportion of the frenulum in the mucosal position increased in the CAF+CTG and CAF+PRF groups. It is believed that these disparities have a substantial influence on the capacity of software to predict and function.

Bernimoulin et al. (1977) evaluated tooth mobility during flap surgery.[50] They discovered no correlation between gingival recession and tooth mobility. Where Kerry et al.[51] showed a reduction in tooth mobility one month following non-surgical therapy, but an increase six months after flap surgery. In our study, only the GUG group had Miller 1 and 2 mobility before surgery, and after surgery they had either Miller 1 or no mobility. The system allows for the addition of mobility data, enabling the user to make long-term projections.

On the basis of the most generally used performance criteria in the literature, accuracy and F-measure, random forest was determined to have the best category and overall performance (overall, ACC: 0.864, F-measure: 0.859). GUG accuracy is 90%, CAF accuracy is 62.5 percent, CAF+CTG accuracy is 71%, and CAF+PRF accuracy is 97.8 percent on a categorical basis. The random forest method was used to create the system, according to our findings. If the big data sets remain in their existing condition, the above-mentioned percentage will be utilized to estimate the prediction rates for the future operations, and the system will determine what percentage and kind of surgery the newly added data set may imply. Each new data set, in addition to post-operative measurement data, will be added; by increasing these rates over the present levels, the program will have a greater possibility of predicting. In medicine, risk calculators for illnesses such as heart disease and diabetes have been created.[31–33] Although it is anticipated that entering data on surgical results conducted by different physician may impair standardization, it was determined that this cannot be a limitation because the system will run primarily on data added over time by different surgeons. Gingival recession is one of the most challenging situations in periodontology for physician to address. The forms of surgery recommended by the present classifications can be used to predict prognosis, with some restrictions. With the aid of the system developed in this study, surgical operation prognosis may be predicted with a high level of precision.

## Conclusion

The machine-learning-based-software system, created based on the Random Forest machine learning method, in the study can predict the recession surgery type and success of surgical procedures used to treat gingival recession. The software developed as a part of this study was converted to a web-based application. Using machine learning, the software may generate prognostic predictions for each physician based on data sets produced from data entered by doctors on the website. The accuracy of the prognosis improves as more information is included. Scientists will be able to contribute to the development of a global database on gingival recession using the provided software.

## Ethical Approval

This study was reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Ankara University (Decision No: 36290600/96/2017). Informed consent was obtained from all participants.

## Acknowledgements

Not applicable.

## Financial Support

No funding was received for this study.

## Author Contributions

Study Design : B.K. , E.U. , M.T.
Performed Surgical Procedures : B.K.
Performed Statistical Analysis : B.B.
Recorded Clinical Data : B.K.
Interpreted the Results : B.B. , C.O. , E.U.
Developed the Machine Learning : B.B.
Wrote the Manuscript : All Authors
Revising It Critically and Final Approval : B.K. , C.O. , E.U.
Final Review and Editing : All Authors

## Conflict of Interest

The authors declare that they have no conflicts of interest.

## Authors' ORCID(s)

B.K. 0000-0002-4664-0455
B.B. 0000-0002-5662-8193
C.O. 0000-0002-8995-6361
E.U. 0000-0002-7843-6088
M.T. 0000-0002-0545-8454

## References

1. Cortellini P, Bissada NF. Mucogingival conditions in the natural dentition: Narrative review, case definitions, and diagnostic considerations. J Periodontol. 2018;89 Suppl 1:S204–s213. doi:10.1002/jper.16-0671.
2. Guttiganur N, Aspalli S, Sanikop MV, Desai A, Gaddale R, Devanoorkar A. Classification systems for gingival recession and suggestion of a new classification system. Indian J Dent Res. 2018;29(2):233–237. doi:10.4103/ijdr.IJDR_207_17.
3. Kim DM, Neiva R. Periodontal soft tissue non-root coverage procedures: a systematic review from the AAP Regeneration Workshop. J Periodontol. 2015;86(2 Suppl):S56–572. doi:10.1902/jop.2015.130684.
4. Cairo F, Pagliaro U, Nieri M. Treatment of gingival recession with coronally advanced flap procedures: a systematic review. J Clin Periodontol. 2008;35(8 Suppl):136–162. doi:10.1111/j.1600-051X.2008.01267.x.
5. Chambrone L, Tatakis DN. Periodontal soft tissue root coverage procedures: a systematic review from the AAP Regeneration Workshop. J Periodontol. 2015;86(2 Suppl):S8–51. doi:10.1902/jop.2015.130674.
6. Kassab MM, Cohen RE. The etiology and prevalence of gingival recession. J Am Dent Assoc. 2003;134(2):220–225. doi:10.14219/jada.archive.2003.0137.
7. Cairo F, Nieri M, Cincinelli S, Mervelt J, Pagliaro U. The interproximal clinical attachment level to classify gingival recessions and predict root coverage outcomes: an explorative and reliability study. J Clin Periodontol. 2011;38(7):661–666. doi:10.1111/j.1600-051X.2011.01732.x.
8. Holbrook T, Ochsenbein C. Complete coverage of the denuded root surface with a one-stage gingival graft. Int J Periodontics Restorative Dent. 1983;3(3):8–27.
9. Miller J P D. Root coverage grafting for regeneration and aesthetics. Periodontol 2000. 1993;1:118–127. doi:10.1111/j.1600-0757.1993.tb00213.x.
10. Agudio G, Nieri M, Rotundo R, Cortellini P, Pini Prato G. Free gingival grafts to increase keratinized tissue: a retrospective long-term evaluation (10 to 25 years) of outcomes. J Periodontol. 2008;79(4):587–594. doi:10.1902/jop.2008.070414.
11. Albandar JM, Kingman A. Gingival recession, gingival bleeding, and dental calculus in adults 30 years of age and older in the United States, 1988-1994. J Periodontol. 1999;70(1):30–43. doi:10.1902/jop.1999.70.1.30.
12. Kan JY, Morimoto T, Rungcharassaeng K, Roe P, Smith DH. Gingival biotype assessment in the esthetic zone: visual versus direct measurement. Int J Periodontics Restorative Dent. 2010;30(3):237–243.
13. Mlinek A, Smukler H, Buchner A. The use of free gingival grafts for the coverage of denuded roots. J Periodontol. 1973;44(4):248–254. doi:10.1902/jop.1973.44.4.248.
14. Wennström JL, Zucchelli G. Increased gingival dimensions. A significant factor for successful outcome of root coverage procedures? A 2-year prospective clinical study. J Clin Periodontol. 1996;23(8):770–777. doi:10.1111/j.1600-051x.1996.tb00608.x.
15. Zucchelli G, Testori T, De Sanctis M. Clinical and anatomical factors limiting treatment outcomes of gingival recession: a new method to predetermine the line of root coverage. J Periodontol. 2006;77(4):714–721. doi:10.1902/jop.2006.050038.
16. Han J, Kamber M, Pei J. Concepts and Techniques. Morgan Kaufmann; 2011.
17. Francis NK, Luther A, Salib E, Allanby L, Messenger D, Allison AS, et al. The use of artificial neural networks to predict delayed discharge and readmission in enhanced recovery following laparoscopic colorectal cancer surgery. Tech Coloproctol. 2015;19(7):419–428. doi:10.1007/s10151-015-1319-0.
18. Tanaka T, Voigt MD. Decision tree analysis to stratify risk of de novo non-melanoma skin cancer following liver transplantation. J Cancer Res Clin Oncol. 2018;144(3):607–615. doi:10.1007/s00432-018-2589-5.
19. Kantardzic M. Data mining: concepts, models, methods, and algorithms. John Wiley & Sons; 2011.
20. Silness J, Loe H. Periodontal Disease In Pregnancy. II. Correlation Between Oral Hygiene And Periodontal Condtion. Acta Odontol Scand. 1964;22:121–135. doi:10.3109/00016356408993968.
21. Malpartida-Carrillo V, Tinedo-Lopez PL, Guerrero ME, Amaya-Pajares SP, Özcan M, Rösing CK. Periodontal phenotype: A review of historical and current classifications evaluating different methods and characteristics. J Esthet Restor Dent. 2021;33(3):432–445. doi:10.1111/jerd.12661.
22. Miller SC. Successful Treatment of Periodontal Disease. The Military Surgeon (United States). 1951;108(3):191–193.
23. Aroca S, Keglevich T, Barbieri B, Gera I, Etienne D. Clinical evaluation of a modified coronally advanced flap alone or in combination with a platelet-rich fibrin membrane for the treatment of adjacent multiple gingival recessions: a 6-month study. J Periodontol. 2009;80(2):244–252. doi:10.1902/jop.2009.080253.
24. Bittencourt S, Del Peloso Ribeiro E, Sallum EA, Sallum AW, Nociti J F H, Casati MZ. Comparative 6-month clinical study of a semilunar coronally positioned flap and subepithelial connective tissue graft for the treatment of gingival recession. J Periodontol. 2006;77(2):174–181. doi:10.1902/jop.2006.050114.
25. Kuru B, Yıldırım S. Treatment of localized gingival recessions using gingival unit grafts: a randomized controlled clinical trial. J Periodontol. 2013;84(1):41–50. doi:10.1902/jop.2012.110685.
26. Paolantonio M, di Murro C, Cattabriga A, Cattabriga M. Subpedicle connective tissue graft versus free gingival graft in the coverage of exposed root surfaces. A 5-year clinical study. J Clin Periodontol. 1997;24(1):51–56. doi:10.1111/j.1600-051x.1997.tb01184.x.
27. Paolantonio M, Femminella B, Coppolino E, Sammartino G, D'Arcangelo C, Perfetti G, et al. Autogenous periosteal barrier membranes and bone grafts in the treatment of periodontal intrabony defects of single-rooted teeth: a 12-month reentry randomized controlled clinical trial. J Periodontol. 2010;81(11):1587–1595. doi:10.1902/jop.2010.100094.
28. Pini-Prato GP, Cairo F, Nieri M, Franceschi D, Rotundo R, Cortellini P. Coronally advanced flap versus connective tissue graft in the treatment of multiple gingival recessions: a split-mouth study with a 5-year follow-up. J Clin Periodontol. 2010;37(7):644–650. doi:10.1111/j.1600-051X.2010.01559.x.
29. Pini Prato GP, Baldi C, Nieri M, Franseschi D, Cortellini P, Clauser C, et al. Coronally advanced flap: the post-surgical position of the gingival margin is an important factor for achieving complete root coverage. J Periodontol. 2005;76(5):713–722. doi:10.1902/jop.2005.76.5.713.
30. Pini Prato G, Pagliaro U, Baldi C, Nieri M, Saletta D, Cairo F, et al. Coronally advanced flap procedure for root coverage. Flap with tension versus flap without tension: a randomized controlled clinical study. J Periodontol. 2000;71(2):188–201. doi:10.1902/jop.2000.71.2.188.

31. Gregori D, Petrinco M, Bo S, Rosato R, Pagano E, Berchialla P, et al. Using data mining techniques in monitoring diabetes care. The simpler the better? J Med Syst. 2011;35(2):277–281. doi:10.1007/s10916-009-9363-9.
32. Karaolis MA, Moutiris JA, Hadjipanayi D, Pattichis CS. Assessment of the risk factors of coronary heart events based on data mining with decision trees. IEEE Trans Inf Technol Biomed. 2010;14(3):559–566. doi:10.1109/titb.2009.2038906.
33. Liu H, Xie G, Mei J, Shen W, Sun W, Li X. An efficacy driven approach for medication recommendation in type 2 diabetes treatment using data mining techniques. Stud Health Technol Inform. 2013;192:1071. doi:10.3233/978-1-61499-289-9-1071.
34. Page RC, Krall EA, Martin J, Mancl L, Garcia RI. Validity and accuracy of a risk calculator in predicting periodontal disease. J Am Dent Assoc. 2002;133(5):569–576. doi:10.14219/jada.archive.2002.0232.
35. Page RC, Martin J, Krall EA, Mancl L, Garcia R. Longitudinal validation of a risk calculator for periodontal disease. J Clin Periodontol. 2003;30(9):819–827. doi:10.1034/j.1600-051x.2003.00370.x.
36. Persson GR, Mancl LA, Martin J, Page RC. Assessing periodontal disease risk: a comparison of clinicians' assessment versus a computerized tool. J Am Dent Assoc. 2003;134(5):575–582. doi:10.14219/jada.archive.2003.0224.
37. Covani U, Marconcini S, Derchi G, Barone A, Giacomelli L. Relationship between human periodontitis and type 2 diabetes at a genomic level: a data-mining study. J Periodontol. 2009;80(8):1265–1273. doi:10.1902/jop.2009.080671.
38. Fan J, Nunn ME, Su X. Multivariate Exponential Survival Trees And Their Application to Tooth Prognosis. Comput Stat Data Anal. 2009;53(4):1110–1121. doi:10.1016/j.csda.2008.10.019.
39. Podgorelec V, Kokol P, Stiglic B, Rozman I. Decision trees: an overview and their use in medicine. J Med Syst. 2002;26(5):445–463. doi:10.1023/a:1016409317640.
40. Wolfenden L, Williams CM, Kingsland M, Yoong SL, Nathan N, Sutherland R, et al. Improving the impact of public health service delivery and research: a decision tree to aid evidence-based public health practice and research. Aust N Z J Public Health. 2020;44(5):331–332. doi:10.1111/1753-6405.13023.
41. Aroca S, Barbieri A, Clementini M, Renouard F, de Sanctis M. Treatment of class III multiple gingival recessions: Prognostic factors for achieving a complete root coverage. J Clin Periodontol. 2018;45(7):861–868. doi:10.1111/jcpe.12923.
42. Kuis D, Sciran I, Lajnert V, Snjaric D, Prpic J, Pezelj-Ribaric S, et al. Coronally advanced flap alone or with connective tissue graft in the treatment of single gingival recession defects: a long-term randomized clinical trial. J Periodontol. 2013;84(11):1576–1585. doi:10.1902/jop.2013.120451.
43. Borghetti A, Gardella JP. Thick gingival autograft for the coverage of gingival recession: a clinical evaluation. Int J Periodontics Restorative Dent. 1990;10(3):216–229.
44. Remya V, Kishore Kumar K, Sudharsan S, Arun KV. Free gingival graft in the treatment of class III gingival recession. Indian J Dent Res. 2008;19(3):247–252. doi:10.4103/0970-9290.42959.
45. Souza SL, Macedo GO, Tunes RS, Silveira e Souza AM, Novaes J A B, Grisi MF, et al. Subepithelial connective tissue graft for root coverage in smokers and non-smokers: a clinical and histologic controlled study in humans. J Periodontol. 2008;79(6):1014–1021. doi:10.1902/jop.2008.070479.
46. Huang LH, Neiva RE, Wang HL. Factors affecting the outcomes of coronally advanced flap root coverage procedure. J Periodontol. 2005;76(10):1729–1734. doi:10.1902/jop.2005.76.10.1729.
47. Müller HP, Eger T, Schorb A. Gingival dimensions after root coverage with free connective tissue grafts. J Clin Periodontol. 1998;25(5):424–430. doi:10.1111/j.1600-051x.1998.tb02466.x.
48. Ercan E, Bilgin E, Koprucu S, Kayipmaz S. Evaluation of the relationship between gingival phenotype and alveolar bone morphology. Mucosa. 2019;2(1):6–13.
49. Mirko P, Miroslav S, Lubor M. Significance of the labial frenum attachment in periodontal disease in man. Part I. Classification and epidemiology of the labial frenum attachment. J Periodontol. 1974;45(12):891–894. doi:10.1902/jop.1974.45.12.891.
50. Bernimoulin J, Curilović Z. Gingival recession and tooth mobility. J Clin Periodontol. 1977;4(2):107–114. doi:10.1111/j.1600-051x.1977.tb01890.x.
51. Kerry GJ, Morrison EC, Ramfjord SP, Hill RW, Caffesse RG, Nissle RR, et al. Effect of periodontal treatment on tooth mobility. J Periodontol. 1982;53(10):635–638. doi:10.1902/jop.1982.53.10.635.

European Annals of Dental Sciences
Official Publication of Ankara University, Faculty of Dentistry

*EADS*, 2025, 52 (1), 10–16

e-ISSN : 2757-6744
Article Received/Accepted : November, 4 2024 / March, 18 2025
doi : 10.52037/eads.2025.0002

ORIGINAL RESEARCH ARTICLE

# Evaluation of the Competency of Large Language Models GPT-4o and Claude 3.5 Sonnet in Endodontic Emergencies

Merve Sarı [1ROR], * and Pelin Tüfenkçi [1ROR]

[1]Department of Endodontics, Faculty of Dentistry, Hatay Mustafa Kemal University, Hatay, Türkiye

*Corresponding Author; mervess94.ms@gmail.com

## Abstract

**Purpose:** This study aimed to evaluate the accuracy and comprehensiveness of the responses generated by GPT-4o and Claude-3.5 Sonnet to the most frequently asked questions about endodontic emergencies.
**Materials and Methods:** The most frequently asked questions about nine different topics (inferior alveolar nerve block, sodium hypochlorite accidents, aspiration of dental materials, separated instruments, perforation, transportation, $Ca(OH)_2$ extrusion, root filling, and flare-up) in endodontics were generated by GPT 3.5. Each question was asked to both GPT-4o and Claude 3.5 Sonnet. Two authors independently scored the responses. Accuracy and comprehensiveness were assessed for each question using Likert scales. The data were statistically analyzed using the Mann–Whitney U test and the Kruskal–Wallis test. The significance level was set at 0.05.
**Results:** Responses generated by both GPT-4o and Claude 3.5 Sonnet to a total of 81 open-ended questions were evaluated. The two models yielded similar results in terms of accuracy and comprehensiveness ($p > 0.05$). The topics of root filling, perforation, and flare-up have the lowest accuracy scores, and root filling and separated instruments have the lowest comprehensiveness scores for GPT-4o ($p < 0.05$). The accuracy of Claude 3.5's responses did not show significant differences between the topics ($p > 0.05$); however, separated instruments had the lowest comprehensiveness scores ($p < 0.05$).
**Conclusions:** The accuracy and comprehensiveness scores of GPT-4 and Claude 3.5 Sonnet are statistically similar. Despite the high levels of accuracy and comprehensiveness shown by GPT-4o and Claude 3.5 Sonnet, they do not yet have the effect of replacing the operator in endodontic procedures.

**Keywords**: Artificial intelligence; Claude 3.5; Endodontic emergencies; GPT-4o

## Introduction

Artificial intelligence (AI) can build systems to perform tasks that require human intelligence, such as language understanding, reasoning, learning, and problem solving. In a short period of time, its potential applications in various fields, including dentistry, have been investigated and are the subject of numerous articles.[1] The applications of AI in endodontics have also been investigated, and studies have reported varying levels of effectiveness in detecting radiographic features such as root/canal morphology,[2] periapical lesions,[3] minor apical foramen,[4] and vertical root fractures.[5]

Natural language processing (NLP) is a subfield of AI that aims to enable computers to understand and interpret human language in a way that is both meaningful and useful. Large language models (LLMs) are neural network models trained on vast amounts of text data that demonstrate high performance in NLP-related tasks.[6,7] GPT-3 is the first large-scale language model developed by OpenAI, followed by GPT-3.5, GPT-4, GPT-4 Turbo, and an improved version, GPT-4o, released on May 13, 2024.[8] Claude-3.5 Sonnet, developed by Anthropic and released on June 20, 2024, is a large language model that competes with OpenAI's GPT-4o. According to Anthropic's model description, it was trained on data up to April 2024.[9] However, the effectiveness of LLMs in the field of endodontics has been evaluated in a few studies, and to the best of our knowledge, GPT-4o and Claude-3.5 Sonnet have not yet been studied.

Endodontic emergencies can be challenging for both the clinician and the patient. Clinicians need to know how various complications may arise, how to manage them predictably when they do occur, and what they need to do to prevent such complications.[10] Understanding how a particular complication may affect treatment prognosis is important, as the same complication can lead to dif-



**How to cite:** Sari M, Tufenkci P. Evaluation of the Competency of Large Language Models GPT-4o and Claude 3.5 Sonnet in Endodontic Emergencies. EADS. 2025;52(1): 10-16

ferent outcomes in different cases. During the treatment process, it is necessary to evaluate the clinical factors that determine the prognosis and to identify appropriate treatment strategies for the patient.[11] In these clinical situations where quick decision-making and stress management are crucial for the success of treatment, an AI-based model that can generate accurate and comprehensive responses can be beneficial for practitioners. Therefore, this study aims to evaluate the accuracy and comprehensiveness of the responses generated by GPT-4o and Claude-3.5 Sonnet to the most frequently asked questions about endodontic emergencies. The null hypothesis of the study is that there will be no difference in the evaluated parameters between the two different LLMs.

## Material and Methods

Ethical approval was not provided for this study as no individual or patient details were included.

The authors identified nine different topics related to endodontic emergencies. The GPT 3.5 program was used to generate the ten most frequently asked questions about each of the nine topics. These topics include inferior alveolar nerve block, sodium hypochlorite accidents, aspiration of dental materials, separated instruments, perforation, transportation, $Ca(OH)_2$ extrusion, root filling, and flare-up. Overlapping and irrelevant questions were removed (e.g., What are the potential reasons for inferior alveolar nerve block failure in endodontics? How can the success rate of inferior alveolar nerve blocks be improved to prevent failure in endodontics?) All the questions are available in Table 1.

Each question was directed to two LLMs (GPT-4o and Claude 3.5 Sonnet). The main application programming interface of each LLM was used (GPT-4o available at: https://chatgpt.com/; Claude 3.5 Sonnet available at: https://claude.ai/). It has been reported that LLMs may provide different responses when the same question is asked again or at different time points.[12] Therefore, all the questions were asked only once. To ensure consistency and standardization, each question was directed to both GPT 4o and Claude 3.5 at the same time, respectively. Additionally, the response times of LLMs were recorded. Between July 8, 2024, and July 16, 2024, a different topic was practiced each day. A new chat was created for each question to prevent any influence from previous responses. The questions were asked by an independent researcher using the same computer throughout the study. All the responses were saved as a Word file (Microsoft, Redmond, Washington, USA).

After the LLMs generated responses, two authors independently scored the responses. Accuracy and comprehensiveness were assessed for each question using Likert scales. The authors were blinded to which bot generated the evaluated response. The questions were randomly evaluated. Randomization was performed using an online software (www.randomizer.org) by an independent researcher who asked the questions.

The Accuracy Likert Scale: 1) Completely incorrect; 2) More incorrect than correct; 3) Approximately equal correct and incorrect; 4) More correct than incorrect; 5) Completely correct

The Comprehensiveness Likert Scale:1) Not adequate; 2) Somewhat adequate; 3) Adequate; 4) Very adequate; 5) Extremely adequate

Recent literature and guidelines covering widely accepted treatment approaches were used as references in the evaluation of the responses. When inconsistencies arose in the evaluations, a third endodontic specialist was consulted to reach a consensus. Consequently, a single scoring chart was prepared for each LLM's responses for statistical analysis.

### Statistical Analysis

IBM SPSS Statistics (SPSS Inc., Chicago, IL, USA; Version 22.0) software was used to analyze the collected data. The data were nonnormally distributed according to the Shapiro–Wilk test. Therefore, nonparametric tests were performed. The accuracy and comprehensiveness scores of LLMs and their response times, were compared using the Mann–Whitney U test.

The accuracy and comprehensiveness scores of each LLM's responses to different topics were evaluated using the Kruskal–Wallis test. The statistical significance level was set at 0.05.

## Results

Responses generated by both GPT-4o and Claude 3.5 Sonnet to a total of 81 open-ended questions on nine different topics related to endodontic emergencies were evaluated in terms of accuracy, comprehensiveness, and response generation time. The two models yielded similar results in terms of correct information transfer and comprehensiveness ($p > 0.05$), and high scores were obtained. The time required to generate responses was shorter for Claude 3.5 Sonnet than for GPT-4o. ($p < 0.05$) (Table 2). In the intragroup evaluation of the LLMs' responses, a statistically significant difference was observed in the accuracy and comprehensiveness scores for GPT-4o ($p < 0.05$). The accuracy of responses to the topic of root filling was statistically lower than that for the topics of inferior alveolar nerve block, sodium hypochlorite accidents, aspiration, and transportation. The accuracy of responses to the topic of perforation was statistically lower than that for the topics of inferior alveolar nerve block and transportation. The accuracy of responses to the topic of flare-up was statistically lower than that of the topic of transportation ($p < 0.05$). The comprehensiveness of the responses given to the root filling and separated instruments topics is statistically lower than that given to the transportation topic ($p < 0.05$) (Table 3). The accuracy of the responses given by Claude 3.5 Sonnet did not show a statistically significant difference between topics ($p > 0.05$). The comprehensiveness of the responses given to the separated instruments topic is statistically lower than that given to the transportation and flare-up topics ($p < 0.05$) (Table 4).

## Discussion

Whether LLMs can be used as auxiliary tools for establishing diagnosis[13] and treatment protocols[14] or for education[15] in healthcare applications has been the subject of many recent studies. However, incorrect or inadequate answers[15] and the citing of nonexistent or erroneous sources[16] are concerning. Ramezanzade et al.[17] reported that although the reported accuracy metrics of AI-based models for the detection of radiographic features in endodontic treatments seem promising, most of the articles present methodological biases. Currently, there is a consensus that AI has the potential to facilitate healthcare practice and education, but more extensive research is needed to overcome its limitations.[18,19] Therefore, this study aimed to evaluate the accuracy, comprehensiveness, and response generation time of two different LLMs in the subject of endodontic emergencies whose clinical management requires knowledge, attention, and quickness.

In this study, the accuracy and comprehensiveness scores of the responses did not show a significant difference between the two LLMs. In the intragroup evaluation of the LLMs, the accuracy and comprehensiveness of GPT-4o responses showed significant differences between different topics. The topics of root filling, perforation, and flare-up have the lowest accuracy scores. The topics of root filling and separated instruments have the lowest comprehensiveness scores. The accuracy of Claude 3.5's responses did not show significant differences between different topics; however, the

**Table 1.** Questions

| | |
|---|---|
| **1) Inferior alveolar nerve block** | |
| 1 | What are the potential reasons for inferior alveolar nerve block failure in endodontics? |
| 2 | What are the signs and symptoms of inferior alveolar nerve block failure for patients? |
| 3 | How is inferior alveolar nerve block failure managed in endodontics? |
| 4 | Are there any alternative anesthesia techniques that can be used if an inferior alveolar nerve block fails? |
| 5 | How to prevent trismus after inferior alveolar nerve block? |
| 6 | How do you treat trismus after an inferior alveolar nerve block? |
| 7 | How long does facial palsy typically last after an inferior alveolar nerve block? |
| 8 | Are there any long-term consequences of facial palsy after an inferior alveolar nerve block? |
| 9 | What treatment options are available for facial palsy after an inferior alveolar nerve block? |
| 10 | How can I prevent facial palsy after an inferior alveolar nerve block in the future? |
| **2) Sodium hypochlorite accidents** | |
| 1 | What are the potential risks and complications associated with the injection of sodium hypochlorite in endodontics? |
| 2 | Are there specific safety measures that should be followed when using sodium hypochlorite in endodontics? |
| 3 | What causes sodium hypochlorite extrusion during endodontic procedures? |
| 4 | How is sodium hypochlorite extrusion managed in endodontics? |
| 5 | What are the signs and symptoms of sodium hypochlorite extrusion in patients? |
| 6 | How can sodium hypochlorite extrusion be prevented during endodontic procedures? |
| 7 | Are there any alternative irrigation solutions that can be used to minimize the risk of sodium hypochlorite extrusion in endodontics? |
| 8 | Can sodium hypochlorite accidents lead to legal issues for dentists? |
| 9 | What concentration of sodium hypochlorite is considered safe for endodontic use? |
| **3) Aspiration** | |
| 1 | What are the potential risks and complications associated with aspiration during endodontic procedures? |
| 2 | How common is aspiration during endodontic treatments? |
| 3 | What are the signs and symptoms of aspiration for patients in endodontics? |
| 4 | How can aspiration be prevented in endodontics? |
| 5 | What should be done in the event of aspiration occurring during an endodontic procedure? |
| 6 | Can certain patient conditions increase the risk of aspiration during dental procedures? |
| 7 | What are the legal and ethical considerations if a patient aspirates an object during an endodontic procedure? |
| 8 | How can dental professionals ensure they are trained and prepared to handle aspiration incidents during endodontic procedures? |
| **4) Separated instruments** | |
| 1 | What causes instrument separation during root canal treatment? |
| 2 | How can instrument separation be prevented during endodontic procedures? |
| 3 | What are the potential consequences of instrument separation in root canal treatment? |
| 4 | How is instrument separation managed or treated when it occurs during endodontic treatment? |
| 5 | Are certain instruments more prone to separation than others during endodontic procedures? |
| 6 | How common is instrument separation in endodontics? |
| 7 | What are the consequences of leaving a separated instrument in the root canal? |
| 8 | What are the different techniques for retrieving separated instruments from the root canal? |
| 9 | How long does it take to retrieve a separated instrument from the root canal? |
| **5) Perforation** | |
| 1 | What is a perforation in endodontics? |
| 2 | What are the potential causes of perforation during endodontic procedures? |
| 3 | Can a perforated tooth be saved? |
| 4 | What are the potential consequences of perforation on the success of endodontic treatment? |
| 5 | How is perforation diagnosed and confirmed during an endodontic procedure? |
| 6 | What are the treatment options for managing perforation in endodontics? |
| 7 | What are the best practices for preventing perforation during endodontic treatments? |
| 8 | Are there any specific tools or materials that can help repair perforations in endodontics? |
| 9 | What are the challenges associated with treating perforations in different areas of the tooth? |
| **6) Transportation** | |
| 1 | What is root canal transportation and how does it occur during endodontic procedures? |
| 2 | What is the most important reason for canal transportation in endodontics? |
| 3 | What are the signs and symptoms that may indicate canal transportation has occurred? |
| 4 | What are the treatment options for managing and correcting canal transportation during endodontic procedures? |
| 5 | How can dental professionals improve their techniques and skills to reduce the likelihood of canal transportation? |
| 6 | What are the potential long-term consequences of untreated canal transportation in endodontic cases? |
| 7 | What are the key steps that should be followed to manage apical transportation in endodontics? |
| 8 | What is the success rate of endodontic treatment of vital and nonvital teeth with apical transportation? |
| **7) $Ca(OH)_2$ extrusion** | |
| 1 | What is calcium hydroxide and why is it used in endodontics? |
| 2 | What are the potential consequences of calcium hydroxide extrusion in endodontics? |
| 3 | How common is calcium hydroxide extrusion during root canal treatments? |
| 4 | What are the signs and symptoms of calcium hydroxide extrusion for patients? |
| 5 | How is calcium hydroxide extrusion diagnosed and managed by dental professionals? |
| 6 | Are there any preventive measures that can be taken to minimize the risk of calcium hydroxide extrusion? |
| 7 | What are the challenges associated with removing extruded calcium hydroxide from the periapical region? |
| 8 | How can dental professionals improve their techniques and skills to reduce the likelihood of calcium hydroxide extrusion in endodontic procedures? |
| 9 | What are the legal and ethical considerations if calcium hydroxide extrusion occurs? |

| | |
|---|---|
| **8) Root filling** | |
| 1 | What is underfilling and overfilling in the context of endodontics? |
| 2 | How can I prevent extrusion of filling material beyond the apex? |
| 3 | What are the best techniques to avoid voids in the obturation? |
| 4 | How do I manage a situation where the root filling material has been overextended? |
| 5 | How can I ensure complete obturation in curved canals? |
| 6 | How can I minimize the risk of root fracture during lateral condensation? |
| 7 | What are the pros and cons of different obturation techniques in endodontics? |
| 8 | How do I address inadequate apical seal after obturation? |
| 9 | What should I do if I notice air bubbles in the obturation on the post-operative radiograph? |
| 10 | How can I ensure proper adaptation of the master cone to reduce the risk of overfilling or underfilling? |
| **9) Flare-up** | |
| 1 | What is an endodontic flare-up and what are the common signs and symptoms? |
| 2 | What are the potential causes of endodontic flare-ups during or after treatment? |
| 3 | How common are endodontic flare-ups in endodontic procedures? |
| 4 | What are the risk factors that may contribute to a higher likelihood of experiencing a flare-up in endodontics? |
| 5 | How can endodontic flare-ups be prevented in patients undergoing root canal treatment? |
| 6 | How is an endodontic flare-up managed and treated by dental professionals? |
| 7 | Are there any specific pain management strategies that can help relieve discomfort associated with endodontic flare-ups? |
| 8 | How can dental professionals communicate with patients about the possibility of a flare-up and ensure they are prepared for any potential complications post-treatment? |
| 9 | Is an endodontic flare-up a sign of treatment failure? |

**Table 2.** Accuracy, comprehensiveness, and response time, generated with the GPT-4o and Claude 3.5 Sonnet models.

| | GPT-4o | Claude 3.5 Sonnet | Z | 95% CI | P value |
|---|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | | | |
| **Accuracy** | 4.64 ± 0.53 | 4.61±0.6 | -.115 | .89-.90 | 0.908* |
| **Comprehensiveness** | 3.9 ± 0.7 | 3.95±0.81 | -.596 | .56-.57 | 0.551* |
| **Response time** | 25.08 ± 11.22 | 11.01±3.77 | -8.748 | 0 | P<0.001* |

The data represented as Mean±SD. CI: Confidence Interval, SD: standard deviation, *Mann-Whitney U test. $p < 0.05$ indicates statistical significance.

**Table 3.** Accuracy and comprehensiveness scores for GPT-4o generated answers to questions on key topics in endodontics.

| | | Accuracy | Comprehensiveness |
|---|---|---|---|
| **Inferior alveolar nerve block** | Median (min-max) | $5\ (4–5)^{CD}$ | $4\ (3–5)^{AB}$ |
| | Mean±SD | 4.9 ± 0.32 | 4.2 ± 0.63 |
| **Sodium hypochlorite accidents** | Median (min-max) | $5\ (4–5)^{BCD}$ | $4\ (4–5)^{AB}$ |
| | Mean±SD | 4.78 ± 0.44 | 4.22 ± 0.44 |
| **Aspiration** | Median (min-max) | $5\ (4–5)^{BCD}$ | $4\ (4–5)^{AB}$ |
| | Mean±SD | 4.88 ± 0.35 | 4.38 ± 0.52 |
| **Separated instruments** | Median (min-max) | $5\ (4–5)^{ABCD}$ | $3\ (3–4)^{A}$ |
| | Mean±SD | 4.67 ± 0.5 | 3.44 ± 0.53 |
| **Perforation** | Median (min-max) | $4\ (4–5)^{AB}$ | $4\ (2–4)^{AB}$ |
| | Mean±SD | 4.44 ± 0.53 | 3.67 ± 0.71 |
| **Transportation** | Median (min-max) | $5\ (5–5)^{D}$ | $4.5\ (4–5)^{B}$ |
| | Mean±SD | 5 ± 0 | 4.5 ± 0.54 |
| **$Ca(OH)_2$ extrusion** | Median (min-max) | $5\ (4–5)^{ABCD}$ | $4\ (3–5)^{AB}$ |
| | Mean±SD | 4.56 ± 0.53 | 3.89 ± 0.6 |
| **Root filling** | Median (min-max) | $4\ (3–5)^{A}$ | $3\ (3–4)^{A}$ |
| | Mean±SD | 4.2 ± 0.63 | 3.4 ± 0.52 |
| **Flare-up** | Median (min-max) | $5\ (3–5)^{ABC}$ | $4\ (2–5)^{AB}$ |
| | Mean±SD | 4.44 ± 0.73 | 3.56 ± 0.88 |
| | P value | 0.023* | <0.001* |

The data represented as Median (min-max) and Mean±SD. SD: standard deviation. *Kruskal Wallis test. $p < 0.05$ indicates statistical significance. Different superscript capital letters indicate statistically significant differences in the same column.

**Table 4.** Accuracy and comprehensiveness scores for Claude 3.5 Sonnet generated answers to questions on key topics in endodontics.

| | | Accuracy | Comprehensiveness |
|---|---|---|---|
| **Inferior alveolar nerve block** | Median (min-max) | 5 (4–5) | 4 (3–5) $^{AB}$ |
| | Mean±SD | 4.78 ± 0.44 | 4.3 ± 0.68 |
| **Sodium hypochlorite accidents** | Median (min-max) | 5 (3–5) | 4 (4–5) $^{AB}$ |
| | Mean±SD | 4.56 ± 0.73 | 4.11 ± 0.33 |
| **Aspiration** | Median (min-max) | 5 (4–5) | 4 (3–5)$^{AB}$ |
| | Mean±SD | 4.88 ± 0.35 | 4.13 ± 0.64 |
| **Separated instruments** | Median (min-max) | 5 (4–5) | 3 (2–4) $^{A}$ |
| | Mean±SD | 4.56 ± 0.53 | 3 ± 0.87 |
| **Perforation** | Median (min-max) | 4 (4–5) | 4 (3–4) $^{AB}$ |
| | Mean±SD | 4.44 ± 0.53 | 3.56 ± 0.53 |
| **Transportation** | Median (min-max) | 5 (3–5) | 5 (3–5) $^{B}$ |
| | Mean±SD | 4.75 ± 0.71 | 4.5 ± 0.76 |
| **$Ca(OH)_2$ extrusion** | Median (min-max) | 4 (4–5) | 4 (3–5) $^{AB}$ |
| | Mean±SD | 4.33 ± 0.5 | 4.11 ± 0.6 |
| **Root filling** | Median (min-max) | 5 (2–5) | 3.5 (2–5) $^{AB}$ |
| | Mean±SD | 4.4 ± 0.97 | 3.5 ± 0.85 |
| **Flare-up** | Median (min-max) | 5 (4–5) | 5 (3–5) $^{B}$ |
| | Mean±SD | 4.89 ± 0.33 | 4.44 ± 0.73 |
| | P value | 0.171* | <0.001* |

The data represented as Median (min-max) and Mean±SD. SD: standard deviation. *Kruskal Wallis test. $p < 0.05$ indicates statistical significance. Different superscript capital letters indicate statistically significant differences in the same column.

topic of separated instruments had the lowest comprehensiveness scores. Separated instruments, root fillings, and flare-ups are topics where clinical scenarios can show high variability, which may be a reason for receiving less accurate and inadequate responses. This indicates the limitations of LLMs in risk assessment and treatment planning for certain situations. It should be noted that despite the high accuracy scores for both LLMs, they can provide irrelevant responses and commit crucial errors (Table 5).

Research on LLMs is not yet widespread in the endodontic literature. Suarez et al. [20] reported that 57.33% of GPT-4 responses to clinical endodontic questions were correct. In that study, questions were asked in a dichotomous format (only yes or no) to objectively measure the accuracy of the answers. Similarly, Ozden et al. [21] received 51% and 64% correct answers from GPT-3.5 and Google Bard, respectively, to dichotomous questions asked in the field of dental traumatology. LLMs are not specifically trained for healthcare applications. They use data from publicly available research articles, books, texts, and sources containing health information on the internet, [22] which may explain the different levels of effectiveness shown by the systems. Another disadvantage of LLMs is their current inability to filter out the latest developments effectively. Health sciences have a dynamic nature, and when LLMs fail to keep up with the most recent clinical guidelines, they can provide misleading guidance. [23] For example, GPT-4o reported in Question 2.7 that hydrogen peroxide could be used as an alternative to sodium hypochlorite (Table 5). Hydrogen peroxide has no place in current endodontic irrigation protocols and has not been routinely recommended for a long period of time.

Although there does not seem to be a significant difference in scores between the two LLMs, Claude 3.5 shows a more consistent performance across different topics and has a significantly shorter response generation time. There are no studies evaluating the effectiveness of these two LLMs in health sciences with which we can directly compare our results. However, a study evaluating vulnerability detection with three different prompts for GPT-4o and Claude 3.5 Sonnet reported that Claude 3.5 Sonnet outperformed GPT-4o. Similar to our study, Claude 3.5 Sonnet consistently showed high performance across all prompt types, while GPT-4o's effectiveness is reported to be variable. [24] In LiveBench, a platform for evaluating and comparing the performance of LLMs, Claude 3.5 Sonnet was rated as the best-performing model. [9] Differences in LLM responses can be attributed to the models' architectural design parameters, datasets used for training, optimization techniques and algorithms, response generation strategies (fine-tuning), and response evaluation techniques. [25] However, in this study, the two LLMs were compared on a text–based task. A study evaluating the phonological skills of LLMs reported that no single model consistently outperformed others in all tested tasks. [26] This indicates that in the future, performance in the required field should be considered when selecting LLMs.

In this study, the questions most frequently asked about endodontic emergencies were created using GPT-3.5. GPT-3.5 was thought to be more inclusive due to its free access, but questions created by students, specialty students, and general or specialist dentists could have been different and more detailed. Although the questions were not interfered with to limit the models' responses, and the given responses were evaluated for accuracy and comprehensiveness for two different models, another limitation of this study is that the consistency of the responses at different time points was not evaluated. Additionally, the accuracy and comprehensiveness of the responses were scored by only two endodontics specialists (with 5 and 15 years of experience); evaluation by a broader team could have been more valid. Although there are not yet sufficient articles on the use of AI technologies in endodontics, there is a widespread expectation that LLMs will benefit quickly and effectively. Considering the increasing use and ease of access to these models, it is important to continue studies on scientifically proven datasets with consensus to prevent potential factual errors, the spread of misinformation, and legal problems in medical applications, and to understand how to best utilize AI.

## Conclusion

Despite the level of accuracy and comprehensiveness shown in this study, neither GPT-4o nor Claude 3.5 Sonnet yet has the effect of replacing the operator in endodontic procedures; clinicians should be aware of the limitations of LLMs and use them judiciously. However, integrating these technologies into the practice of endodontics and using human intelligence and AI in collaboration will certainly be beneficial, but it is clear that numerous studies are needed to use them as reliable sources.

**Table 5.** Inaccurate/irrelevant answers

| | |
|---|---|
| **2.1. (GPT-4o)** | Ineffective Irrigation: If not used correctly, sodium hypochlorite may not effectively irrigate the entire root canal system, potentially leaving behind bacteria or necrotic tissue. |
| | Interaction with Other Materials: Sodium hypochlorite can react with other substances used in endodontics, such as chlorhexidine, forming a precipitate that can clog the root canal system or interfere with sealing. |
| | Effect on Dentin: Prolonged exposure to sodium hypochlorite can weaken the dentin, potentially leading to fractures. |
| **2.1. (Claude 3.5 Sonnet)** | Chlorine gas formation: If sodium hypochlorite is mixed with certain other chemicals, it can produce toxic chlorine gas. |
| **2.7. (GPT-4o)** | Hydrogen Peroxide ($H_2O_2$): Hydrogen peroxide has been used as an endodontic irrigant for its effervescent effect, which helps in dislodging debris and providing some antimicrobial action. It is often used in conjunction with other irrigants. |
| **4.5. (Claude 3.5 Sonnet)** | Smaller diameter files: Instruments with smaller diameters (e.g., #10, #15) are more susceptible to separation due to their reduced mass and flexibility. |
| **4.6. (GPT-4o)** | Rotary nickel-titanium (NiTi) instruments are more prone to separation than stainless steel hand files due to their flexibility and tendency to undergo cyclic fatigue. |
| **5.2. (GPT-4o)** | Over-instrumentation: Extending the instruments or filling materials beyond the confines of the root canal system can cause perforation at the apex or in the furcation area. |
| **6.2. (Claude 3.5 Sonnet)** | Avoiding canal transportation is crucial because:<br>1. It helps maintain the structural integrity of the tooth root. |
| | 2. It reduces the risk of weakening the root structure or creating perforations. |
| | 3. It allows for more predictable and efficient cleaning and shaping of the canal. |
| | 4. It facilitates better obturation (filling) of the canal system. |
| | 5. It minimizes the risk of leaving untreated areas of the canal, which could harbor bacteria and lead to treatment failure. |
| **7.3. (Claude 3.5 Sonnet)** | Detection methods: The reported frequency can depend on the method of detection. Extrusion visible on radiographs is less common than microscopic extrusion that might only be detectable in histological studies. |
| **7.5. (Claude 3.5 Sonnet)** | Diagnosis: Pulp vitality tests: To assess the status of the pulp and surrounding tissues |
| **8.1. (GPT-4o)** | Underfilling: Definition: Underfilling occurs when the root canal filling does not extend to the entire length of the prepared root canal. The filling material falls short of the root apex (the tip of the root). |
| **8.2. (GPT-4o)** | Selection of Filling Material: Sealers: Choose biocompatible sealers that have good flow properties but do not tend to extrude beyond the apex easily. |
| | Filling Technique: Vertical Condensation: This technique, such as warm vertical condensation or the continuous wave technique, can help achieve a dense fill without overextension. |
| **8.2. (Claude 3.5 Sonnet)** | Appropriate irrigation techniques:<br>- Use side-vented needles<br>- Keep the needle 1-2 mm short of working length<br>- Apply gentle pressure during irrigation |
| | Employ warm vertical compaction: This technique allows for better control of filling material. |
| **8.4. (Claude 3.5 Sonnet)** | When dealing with overextended filling material in dentistry, here are some steps to manage the situation:<br>1. Remove excess: Carefully remove the overextended material using appropriate dental instruments like finishing burs, polishing discs, or interproximal strips. |
| | 2. Reshape and contour: Adjust the filling to match the natural tooth shape and ensure proper occlusion. |
| | 3. Check contacts: Verify that interproximal contacts are correct and not too tight or loose. |
| | 4. Polish: Smooth the adjusted areas to prevent plaque accumulation and ensure patient comfort. |
| | 5. Evaluate occlusion: Check the bite to ensure the filling doesn't interfere with normal function. |
| **8.6. (GPT-4o)** | Moisture Control: Ensure the canal is dry before lateral condensation to prevent the weakening of dentinal walls. |
| | Employ warm vertical compaction: This technique allows for better control of filling material. |
| **8.10. (Claude 3.5 Sonnet)** | Use of sealers: Apply a thin layer of sealer to improve adhesion and fill small gaps. Avoid excess sealer, which can lead to overfilling. |

## Ethical Approval

Ethical approval was not required for this study.


## Acknowledgements

Not applicable.

## Financial Support

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.


## Author Contributions

Conceptualization : All Authors
Methodology : All Authors
Investigation : All Authors
Formal Analysis : M.S.
Writing – Original Draft : M.S.
Writing – Review and Editing : All Authors

## Conflict of Interest

The authors deny any conflicts of interest related to this study.


## Authors' ORCID(s)

M.S. 0000-0002-9432-3809
P.T. 0000-0001-9881-5395

## References


1. Li ZQ, Wang XF, Liu JP. Publication Trends and Hot Spots of ChatGPT's Application in the Medicine. J Med Syst. 2024;48(1):52. doi:10.1007/s10916-024-02074-y.
2. Jeon SJ, Yun JP, Yeom HG, Shin WS, Lee JH, Jeong SH, et al. Deep-learning for predicting C-shaped canals in mandibular second molars on panoramic radiographs. Dentomaxillofac Radiol. 2021;50(5):20200513. doi:10.1259/dmfr.20200513.
3. Brignardello-Petersen R. Artificial intelligence system seems to be able to detect a high proportion of periapical lesions in cone-beam computed tomographic images. J Am Dent Assoc. 2020;151(9):e83. doi:10.1016/j.adaj.2020.04.006.
4. Saghiri MA, Garcia-Godoy F, Gutmann JL, Lotfi M, Asgar K. The reliability of artificial neural network in locating minor apical foramen: a cadaver study. J Endod. 2012;38(8):1130–4. doi:10.1016/j.joen.2012.05.004.
5. Fukuda M, Inamoto K, Shibata N, Ariji Y, Yanashita Y, Kutsuna S, et al. Evaluation of an artificial intelligence system for detecting vertical root fracture on panoramic radiography. Oral Radiol. 2020;36(4):337–343. doi:10.1007/s11282-019-00409-x.
6. Ghanem YK, Rouhi AD, Al-Houssan A, Saleh Z, Moccia MC, Joshi H, et al. Dr. Google to Dr. ChatGPT: assessing the content and quality of artificial intelligence-generated medical information on appendicitis. Surg Endosc. 2024;38(5):2887–2893. doi:10.1007/s00464-024-10739-5.
7. Kanthavel R, Anathajothi K, Balamurugan S, Ganesh RK. Artificial Intelligent Techniques for Wireless Communication and Networking. John Wiley & Sons; 2022.
8. OpenAI. Hello GPT-4o [Web Page]; 2024. Available from: https://openai.com/index/hello-gpt-4o/.
9. LiveBench [Web Page]; 2024. Available from: :https://livebench.ai/.
10. Nouroloyouni A, Nazi Y, Mikaieli Xiavi H, Noorolouny S, Kuzekanani M, Plotino G, et al. Cone-Beam Computed Tomography Assessment of Prevalence of Procedural Errors in Maxillary Posterior Teeth. Biomed Res Int. 2023;2023:4439890. doi:10.1155/2023/4439890.
11. Johnsen I, Bårdsen A, Haug SR. Impact of Case Difficulty, Endodontic Mishaps, and Instrumentation Method on Endodontic Treatment Outcome and Quality of Life: A Four-Year Follow-up Study. J Endod. 2023;49(4):382–389. doi:10.1016/j.joen.2023.01.005.
12. Vaishya R, Misra A, Vaish A. ChatGPT: Is this version good for healthcare and research? Diabetes Metab Syndr. 2023;17(4):102744. doi:10.1016/j.dsx.2023.102744.
13. Hirosawa T, Harada Y, Mizuta K, Sakamoto T, Tokumasu K, Shimizu T. Evaluating ChatGPT-4's Accuracy in Identifying Final Diagnoses Within Differential Diagnoses Compared With Those of Physicians: Experimental Study for Diagnostic Cases. JMIR Form Res. 2024;8:e59267. doi:10.2196/59267.
14. Howard A, Hope W, Gerada A. ChatGPT and antimicrobial advice: the end of the consulting infection doctor? Lancet Infect Dis. 2023;23(4):405–406. doi:10.1016/s1473-3099(23)00113-5.
15. Sallam M. ChatGPT Utility in Healthcare Education, Research, and Practice: Systematic Review on the Promising Perspectives and Valid Concerns. Healthcare (Basel). 2023;11(6). doi:10.3390/healthcare11060887.
16. Manohar N, Prasad SS. Use of ChatGPT in Academic Publishing: A Rare Case of Seronegative Systemic Lupus Erythematosus in a Patient With HIV Infection. Cureus. 2023;15(2):e34616. doi:10.7759/cureus.34616.
17. Ramezanzade S, Laurentiu T, Bakhshandah A, Ibragimov B, Kvist T, Bjørndal L. The efficiency of artificial intelligence methods for finding radiographic features in different endodontic treatments - a systematic review. Acta Odontol Scand. 2023;81(6):422–435. doi:10.1080/00016357.2022.2158929.
18. Benary M, Wang XD, Schmidt M, Soll D, Hilfenhaus G, Nassir M, et al. Leveraging Large Language Models for Decision Support in Personalized Oncology. JAMA Netw Open. 2023;6(11):e2343689. doi:10.1001/jamanetworkopen.2023.43689.
19. Giannakopoulos K, Kavadella A, Aaqel Salim A, Stamatopoulos V, Kaklamanos EG. Evaluation of the Performance of Generative AI Large Language Models ChatGPT, Google Bard, and Microsoft Bing Chat in Supporting Evidence-Based Dentistry: Comparative Mixed Methods Study. J Med Internet Res. 2023;25:e51580. doi:10.2196/51580.
20. Suárez A, Díaz-Flores García V, Algar J, Gómez Sánchez M, Llorente de Pedro M, Freire Y. Unveiling the ChatGPT phenomenon: Evaluating the consistency and accuracy of endodontic question answers. Int Endod J. 2024;57(1):108–113. doi:10.1111/iej.13985.
21. Ozden I, Gokyar M, Ozden ME, Sazak Ovecoglu H. Assessment of artificial intelligence applications in responding to dental trauma. Dent Traumatol. 2024. doi:10.1111/edt.12965.
22. Lee P, Bubeck S, Petro J. Benefits, Limits, and Risks of GPT-4 as an AI Chatbot for Medicine. N Engl J Med. 2023;388(13):1233–1239. doi:10.1056/NEJMsr2214184.
23. Betzler BK, Chen H, Cheng CY, Lee CS, Ning G, Song SJ, et al. Large language models and their impact in ophthalmology. Lancet Digit Health. 2023;5(12):e917–e924. doi:10.1016/s2589-7500(23)00201-7.
24. Bae J, Kwon S, Myeong SJE. Enhancing Software Code Vulnerability Detection Using GPT-4o and Claude-3.5 Sonnet: A Study on Prompt Engineering Techniques. Electronics. 2024;13(13):2657. doi:10.3390/electronics13132657.
25. Wang L, Ma C, Feng X, Zhang Z, Yang H, Zhang J, et al. A survey on large language model based autonomous agents. Front Comput Sci. 2024;18(6):186345. doi:10.1007/s11704-024-40231-1.
26. Suvarna A, Khandelwal H, Peng N. PhonologyBench: Evaluating Phonological Skills of Large Language Models. ACL. 2024:1–14. doi:10.18653/v1/2024.knowllm-1.1.

European Annals of Dental Sciences
Official Publication of Ankara University, Faculty of Dentistry

*EADS*, 2025, 52 (1), 17–25

e-ISSN : 2757-6744
doi : 10.52037/eads.2025.0003

Article Received/Accepted : September, 8 2024 / December, 1 2024
Ethical Committee No : 36290600/13/2024

ORIGINAL RESEARCH ARTICLE

# The Effect of a Microencapsulated Iron Supplement, Hydrogen Peroxide Superior and Professional Dental Prophylaxis on the Color and Whiteness of Teeth

Kerem Yılmaz [1], *, Fehmi Gönüldaş [2] and Zeynep Bilen [2]

[1]Department of Prosthodontics, Faculty of Dentistry, Antalya Bilim University, Bilimdent Oral and Dental Health Center (ADSUAM), Antalya, Türkiye and [2]Department of Prosthodontics, Faculty of Dentistry, Ankara University, Ankara, Türkiye

*Corresponding Author; drkeremy@hotmail.com

## Abstract

**Purpose:** To investigate the effect of a microencapsulated liposomal nano-iron supplement, a $Fe^{+2}$ supplement, black tea, a bleaching agent with a new composition and professional dental prophylaxis (PDP) on tooth color and whiteness change.
**Materials and Methods:** 84 extracted teeth were immersed in liposomal iron, $Fe^{+2}$ and black tea solutions by special apparatus. Then different applications were applied: (1) no treatment, (2) water polishing, (3) PDP, (4) bleaching with 25% hydrogen peroxide superior (HPS). Measurements were taken at baseline, the 2nd, 4th, and 8th weeks, as well as after the applications. Statistical analysis of color and whiteness changes was performed by ANOVA and Bonferroni tests ($\alpha$=0.05).
**Results:**The effects of time, application, beverage and their interactions on color and whiteness were statistically significant ($p<0.05$). At week 8 and after application, the highest color change was observed in the black tea-HPS pair ($\Delta E_{00}$=3.38, $\Delta E_{00}$=2.21, respectively) ($p<0.001$). At week 8, the highest darkening ($\Delta WI_D$=-4.67) and at after application, the highest whitening ($\Delta WI_D$=3.01) was caused by the black tea-HPS pair ($p<0.001$).
**Conclusions:** Black tea, $Fe^{+2}$ and liposomal iron supplements increased the color change of the teeth towards black over time. Black tea caused the highest darkening of the teeth. The order of magnitude was black tea>$Fe^{+2}$>liposomal iron ($p<0.001$). Hydrogen peroxide superior and PDP provided an effect above the clinical perceptibility threshold selected in this study in terms of color recovery of darkened teeth. The order of magnitude was hydrogen peroxide superior>PDP.

**Keywords**: Color; Hydrogen peroxide superior; Iron supplements; Professional dental prophylaxis; Whiteness

## Introduction

Tooth esthetics and color are crucial for many individuals. However, tooth color may change over time due to internal or external factors. Beverages or iron supplements (ISs) may lead to external discoloration by forming colored regions in the pellicle on the enamel surface.[1]

Iron deficiency (ID) is the most common micronutrient deficiency found worldwide, with at least 20 percent of women experiencing this deficiency during their reproductive life. Approximately 75% of anemias are due to ID. The World Health Organisation (WHO) has targeted a 50% reduction of anemia in women in reproductive years as one of its global nutrition goals for 2025.[2] ID can be overcome by taking ISs. $Fe^{+2}$ and $Fe^{+3}$ salts are often used for this purpose. However, ISs can cause change in tooth color. Due to the fact that iron causes a color change towards black, ISs which have different technologies have been tried to be produced.[3]

The logical way to prevent iron-caused color change in teeth is to prevent direct contact of iron with tooth surface. Encapsulation technology that provides controlled release of the content may help in this regard. Various materials can be used for capsule production. Liposomes are the materials recommended for this purpose. Liposomal phospholipids are microscopic vesicles consisting of a double layer and can be encapsulated to increase the efficacy of drugs.[4] Studies on the effect of iron particles converted into nanoparticles by the micronization process and encapsulated in capsules on the color of teeth are quite insufficient.[5]

Bleaching is one of the most commonly used methods to recover the color of teethchanged by beverages and is usually performed by applying 30-35% hydrogen peroxide (HP) by the dentist in the



**How to cite:** Yilmaz K, Gonuldas F, Bilen Z. The Effect of a Microencapsulated Iron Supplement, Hydrogen Peroxide Superior and Professional Dental Prophylaxis on the Color and Whiteness of Teeth. EADS. 2025;52(1): 17-25

clinic or 10-16% carbamide peroxide (CP) by the patient at home.[6] Hydrogen Peroxide Superior (HPS) gel is a new gel which is being used today. The manufacturer reports that this product, which contains 25% HP, has a unique composition that has the beneficial properties of carbamide peroxide (CP) or polyvinyl pyrrolidone peroxide and thus bleaching can be performed in a short time. It is also claimed that the power of bleaching is higher due to the viscosity controlling poloxamer in the content. A special pen brush has been developed for the use of this product and it is claimed that this is the only product that bleaches using a pen.[7,8] However, no study was found that examined the effect of 25% HPS pen on teeth discolored by beverages or ISs.

Another method for restoring the color of teeth is regularly polishing the teeth by dentists. For this procedure, which is defined as professional dental prophylaxis (PDP), special prophylaxis pastes are used. Various PDP pastes have been introduced to the market in recent years and current research is needed on these new generation pastes having low relative dentin abrasiveness (RDA).[9]

The color values of teeth can be described by L*, a*, b* color space parameters of the International Commission on Illumination (CIE). The CIEDE2000 color difference formula ($\Delta E_{00}$), calculated by using these parameters, is the current recommendation of the CIE.[10] The whiteness index formula ($WI_D$) is a new formula proposed for the study of tooth bleaching and is based on the distance from a nominal white point in the L*, a* ,b* color space, represented as L*=100, a*=0 and b*=0. $\Delta E_{00}$ provides information on the magnitude of the color change, but not on the direction in which the change diverges from the nominal white point. Therefore, in this study, the color change caused by beverages and applications was evaluated by using $\Delta E_{00}$ and $\Delta WI_D$ formulas combined.[11]

For the aforementioned reasons, the aim of this study was to investigate the effect of $Fe^{+2}$ and liposomal iron supplements and black tea on the color and whiteness change of teeth and a fine-grained PDP paste and an HPS bleaching pen on the recovery of color and whiteness in discolored teeth. The null hypotheses were that (1) beverages and (2) applications would not cause changes in tooth color and whiteness.

## Material and Methods

The study protocol including human research specimens was approved by Ethics Committee of the Faculty of Dentistry, Ankara University (Number: 36290600/13/2024, Date: 11.03.2024). A power analysis (G*Power ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Germany) was performed to ensure a sampling size that produced a significant group effect. Using a significance level (alpha) of 0.05, power of 0.80 and a moderate group effect size (partial eta squared) of 0.06, the minimum sampling size was calculated as 5 specimens in each application group and 60 specimens in total. Considering potential sample loss during the research process, the minimum sample size was set at 7and the total sampling size at 84.[12,13]

The 84 teeth were randomly allocated into 3 groups (n=28) according to the beverages in which they would be kept: (1) $Fe^{+2}$ solution (Bestiron Plus; Valens İlaç, Turkey) (IR2), (2) liposomal iron solution (Newvit Iron Syruo; RC Farma, Turkey) (LPI), (3) black tea (Lipton Earl Grey Tea Bag; Unilever, Turkey) (TEA). TEA was set as a positive control for comparison with iron solutions. The pH levels of the beverages were measured using a pH meter (SevenExcellence, Mettler-Toledo; Oregon, USA). Each group was divided into groups of 4 (n=7) according to the applications to be applied after the waiting period in the beverages: (1) Waiting in distilled water without treatment (negative control) (NOT), (2) Polishing with water (positive control) (PWW), (3) Professional dental prophylaxis (PDP), (4) Hydrogen Peroxide Superior (HPS). The materials used in the study are shown in Table 1 and the design of the study is shown in Figure 1.

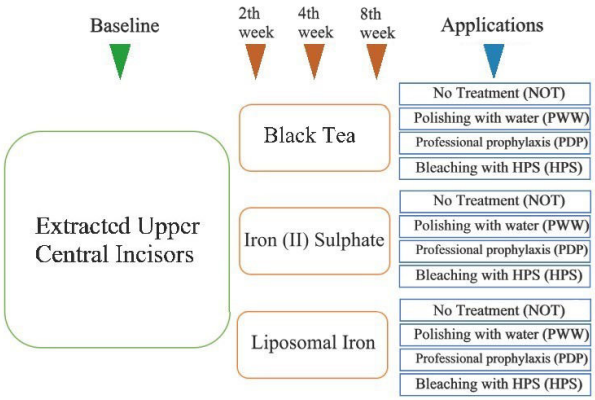


**Figure 1.** The study design

Extracted teeth that had been stored in distilled water at 4°C for a maximum of 1 month were included in the study. Human maxillary anterior incisors, extracted for periodontal reasons and free of hypocalcification and caries, were carefully cleaned of calculus and other debris. A quantitative light source digital camera (Stemi305; ZEISS, Germany) was used to select suitable teeth.

The root of each tooth was cut 2 mm below the enamel-cement border under water cooling. The pulp chambers of the teeth were sealed apically with a flowable resin composite (Aelite Flo; Bisco, Schaumburg, USA) after abrasion and rinsing to prevent the solution from entering through the roots. The teeth were attached to specially prepared retainers. The spindle at the top of the retainer had a feature that pointed to the center of the enamel-cement border of the tooth. The containers had a volume of 5 mL. To provide a close-to-natural color measurement, black colored immersion cups were used.[12] The immersion cup of each specimen was coded with the label of that specimen.

Previous studies have reported that the recommended daily dose for adults with anemia is between 15-20 mg. A dosing period of at least 6 months is recommended to overcome ID and to fully replenish existing stores with iron.[14] The daily dose required for IR2 and LPI is approximately 4-6 mL. Specimens were immersed in the containers for 1 min, 3 times a day, at 8 h intervals[15] (Figure 2). After each immersion, the specimens were washed and dried and placed in an artificial saliva solution (Artificial Saliva Solution; Colin Kimya, Turkey) at 37 °C to simulate the oral environment. This solution has a pH of 6.8 and meets the standard DN 53160-1, which is required for studies examining the effect of dental materials in saliva. The process was continued for 2 months to simulate 6-month iron intake.[16] The specimens in the TEA group were kept in the beverage for 2.5 hours per day. The specimens were washed and dried after each immersion and kept in artificial saliva at 37°C. To prepare the TEA, 3.2 g of tea bags were added to 250 mL of boiled water and allowed to infuse for 10 min. The beverage was replaced daily. The process continued for 2 months. Taking into account that a 24-hour immersion procedure simulates a consumption of approximately 1 month, it can be reported that a 2-month intermittent immersion procedure simulates a 6-month consumption.[17]

After the immersion process was completed, the application process was initiated. The specimens in the NOT group were not treated but were kept in distilled water to prevent the teeth from drying out. Specimens in the PWT group were polished under distilled water at 2500 rpm using a dental contra-angle handpiece (CrossPro; Anthogyr SA, France) with a latex-free rubber brush (Pro-Cup light blue; Kerr, Germany) attached. The PDP procedure is performed up to 4 times a year and takes approximately 20 s to polish one surface of the tooth. Therefore, the application for each specimen in the PDP group lasted for 1.4 min to simulate 1 year.[18] The PDP paste was used in a circular motion with a drop of distilled

**Table 1.** Materials used in the study

| Name | Code | Type | Composition | Manufacturer |
|---|---|---|---|---|
| Bestiron Plus | LPI | Micro-encapsulated iron | 16 mg iron (2.5 mL), deionised water, ferric pyrphosphate | Valens İlaç, İstanbul, Turkey |
| Newvit Iron Syrup | IR2 | +2 valence ferrous bisglycinate | 16 mg $Fe^{+2}$ sulphate (5 mL) | RC Farma, İstanbul, Turkey |
| Lipton Earl Grey Tea Bag | TEA | Black tea | Black tea | Unilever, İstanbul, Turkey |
| Cavex Bite&White In-Office | HPS | Office bleaching gel | 25% hydrogen peroxide superior, thickeners, pH regulators,reversible poloxamer, glycerine | Cavex Holland BV, Haarlem, Netherlands |
| Proxyt Fine | PDP | Fine-grain professional prophylaxis paste | Silica (RDA 7 size particles), water, glycerine, sorbite, xylit, anorganic fillers, natriumfluoride, flavor and pigments | Ivoclar Vivadent, Schaan, Liechtenstein |

**Figure 2.** Immersion of specimens in LPI

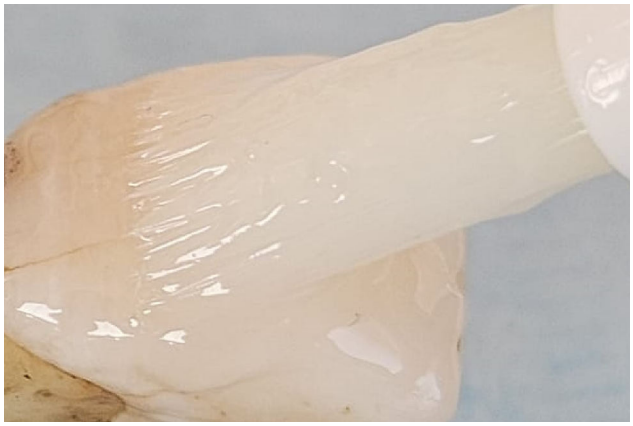

**Figure 3.** Application of the HPS agent

water. In the HPS group, the gel was applied to the middle region of the teeth using the bleaching pen provided by the manufacturer and the entire labial surface was covered with a thickness of approximately 2 mm (Figure 3). The gel was left on the teeth for 45 minutes, the maximum holding time specified by the manufacturer.[19]

Color change measurements were calculated for a total of 4 time points (TP): TP 1: between BAS-2th week; TP 2: between BAS-4th week; TP 3: between BAS-8th week; TP 4: between 8th week and after application. Color measurements were performed using a spectrophotometer (Vita Easyshade V; VITA Zahnfabrik, Germany). Three measurements were taken from the center of the buccal surface of each specimen with the spindle tip as a reference, the average of which was calculated and recorded. The color change was calculated by the following formula including the parameters L*, a*, and b*[20]:

$$\Delta E_{00}=[(\frac{\Delta L'}{K_L S_L})^2+(\frac{\Delta C'}{K_C S_C})^2+(\frac{\Delta H'}{K_H S_H})^2+R_T(\frac{\Delta C'}{K_C S_C})(\frac{\Delta H'}{K_H S_H})]^{1/2}$$

The whiteness index was calculated by the following formula: $WI_D$=0.511L-2.324a-1.100b. Then, whiteness index changes were calculated with the following formula[11]: $\Delta WI_D=WID_{treatment}-WID_{baseline}$. Whiteness change measurements were calculated for a total of 3 TPs: TP 1: between BAS-2th week; TP 3: between BAS-8th week; TP 4: between 8th week and after application.

Statistical analyses of TPs were performed using a statistical software package (IBM SPSS Statistics 29.0.2.0; IBM Corp, Chicago, USA). The effects of time (TIME), beverage (BEV) and application (APP) variables on $\Delta E_{00}$ and $\Delta WI_D$ were analyzed using 3-way ANOVA and Bonferroni tests. The statistical significance level was set at $p<0.05$.

## Results

The ANOVA results of $\Delta E_{00}$ are shown in Table 2. The effect of TIME, APP, BEV, TIME-APP, TIME-BEV, APP-BEV and TIME-APP-BEV on $\Delta E_{00}$ was statistically significant ($p<0.001$).

Bonferroni results for $\Delta E_{00}$ are shown in Table 3. In TP 1, the lowest $\Delta E_{00}$ was in the specimens immersed in LPI in the PWW group ($p=0.031$). In TP 2, the lowest $\Delta E_{00}$ was also in the specimens immersed in LPI in the PWW group ($p<0.001$). In TP 3, the highest $\Delta E_{00}$ was in the specimens immersed in TEA in the PWW group ($p<0.001$) and the lowest was in the specimens immersed in LPI in the PDP group ($p<0.001$). In TP 4, the lowest $\Delta E_{00}$ was in the specimens immersed in LPI and in the NOT group ($p=0.003$), and the highest was in the specimens immersed in TEA and in the HPS group ($p<0.001$).

When analyzing the APP-BEV pair, the highest color change occurred in the following order: HPS>PDP> PWW > NOT for applications and TEA > IR2 > LPI for beverages ($p<0.001$) (Figure 4). When the TIME-BEV pair were examined, the highest color change for BEV was TEA>IR2>LPI at the TP 3 ($p<0.001$) (Figure 5). The $\Delta E_{00}$ value exceeded the 2 level at TP 3 but dropped below this level at TP 4 ($p<0.001$). Analyzing the TIME-APP pair, the order of magnitude of $\Delta E_{00}$ provided by the APPs was HPS>PDP>PWW>NOT ($p<0.001$). HPS provided a color change above 1.5, while PWW and NOT provided a color change below 1.0 ($p<0.001$) (Figure 6).

The ANOVA results of $\Delta WI_D$ are shown in Table 4. The effect of TIME, APP, BEV, TIME-APP, TIME-BEV, APP-BEV and TIME-APP-BEV on $\Delta WI_D$ was statistically significant ($p<0.001$).

Bonferroni results for $\Delta WI_D$ are shown in Table 5. In TP 1, the highest $\Delta WI_D$ was in specimens immersed in LPI in the PWW group

**Table 2.** Results of 3-way ANOVA of $\Delta E_{00}$

| Source | Type III Sum of Squares | df | Mean Square | | p-value | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 362.135[a] | 47 | 7.705 | 593.780 | <0.001 | 0.990 |
| Intercept | 563.688 | 1 | 563.688 | 43440.147 | <0.001 | 0.993 |
| TIME | 300.708 | 3 | 100.236 | 7724.606 | <0.001 | 0.988 |
| APP | 7.239 | 3 | 2.413 | 185.945 | <0.001 | 0.660 |
| BEV | 21.781 | 2 | 10.890 | 839.259 | <0.001 | 0.854 |
| TIME-APP | 18.215 | 9 | 2.024 | 155.973 | <0.001 | 0.830 |
| TIME-BEV | 9.722 | 6 | 1.620 | 124.874 | <0.001 | 0.722 |
| APP-BEV | 0.288 | 6 | 0.048 | 3.700 | 0.001 | 0.072 |
| TIME-APP-BEV | 4.182 | 18 | 0.232 | 17.905 | <0.001 | 0.528 |
| Error | 3.737 | 288 | 0.013 | | | |
| Total | 929.560 | 336 | | | | |
| Corrected Total | 365,872 | 335 | | | | |

[a] R Squared = 0.990 (Adjusted R Squared = 0.988)

**Table 3.** Bonferroni results of $\Delta E_{00}$

| $\Delta E_{00}$ | | TEA | IR2 | LPI | Total |
|---|---|---|---|---|---|
| TP 1 | NOT | 0,17 (0,07) | 0,11 (0,06) | 0,21 (0,06) | 0,16 (0,07) |
| | PWW | 0,24 (0,09)$^{A}$ | 0,20 (0,05)$^{B}$ | 0,09 (0,06)$^{A}$ | 0,17 (0,09) |
| | PDP | 0,22 (0,07) | 0,17(0.07) | 0.11 (0.09) | 0.17 (0.09) |
| | HPS | 0.15 (0.05) | 0.11 (0.06) | 0.10(0.05) | 0.12 (0.06) |
| | Total | 0.20 (0.81) | 0.15 (0.07) | 0.12 (0.85) | 0.15 (0.08) |
| TP 2 | NOT | 1.50 (0.08)$^{A,a}$ | 1.38 (0.06)$^{A,a}$ | 0.58 (0.15)$^{B,a}$ | 1.15 (0.42)$^{a}$ |
| | PWW | 1.50 (0.12)$^{A,b}$ | 1.32 (0.09)$^{A,ab}$ | 0.75 (0.12)$^{B,b}$ | 0.12 (0.29)$^{a}$ |
| | PDP | 1.50 (0.08)$^{A,a}$ | 1.20 (0.08)$^{B,b}$ | 1.08 (0.13)$^{B,c}$ | 1.26 (0.20)$^{b}$ |
| | HPS | 1.38 (0.06)$^{A,ab}$ | 1.17 (0.34)$^{B,b}$ | 1.21 (0.06)$^{B,c}$ | 1.25 (0.21)$^{b}$ |
| | Total | 1.42 (0.12)$^{A}$ | 1.27 (0.19)$^{B}$ | 0.91 (0.28)$^{C}$ | 1.2 (0.30) |
| TP 3 | NOT | 3.42 (0.11)$^{A,ab}$ | 2.78 (0.10)$^{B,ab}$ | 2.05 (0.09)$^{C,a}$ | 2.75 (0.58) |
| | PWW | 3.50 (0.14)$^{A,a}$ | 2.65 (0.09)$^{B,a}$ | 2.31 (0.03)$^{C,b}$ | 2.82 (0.51) |
| | PDP | 3.30 (0.16)$^{A,b}$ | 2.84 (0.18)$^{B,b}$ | 2.17 (0.07)$^{C,ab}$ | 2.77 (0.49) |
| | HPS | 3.38 (0.10)$^{A,ab}$ | 2.75 (0.09)$^{B,ab}$ | 2.20 (0.10)$^{C,ab}$ | 2.20 (0.10) |
| | Total | 3.40 (0.14)$^{A}$ | 2.76 (0.13)$^{B}$ | 2.18 (0.12)$^{C}$ | 2.78 (0.50) |
| TP 4 | NOT | 0.38 (0.14)$^{A,a}$ | 0.40 (0.08)$^{A,a}$ | 0.18 (0.06)$^{B,a}$ | 0.18 (0.06)$^{B,a}$ |
| | PWW | 0.88 (0.19)$^{A,b}$ | 0.78 (0.15)$^{A,b}$ | 0.41 (0.09)$^{B,b}$ | 0.41 (0.09)$^{B,b}$ |
| | PDP | 1.92 (0.09)$^{A,c}$ | 1.57 (0.11)$^{B,c}$ | 0.95 (0.07)$^{C,c}$ | 0.95 (0.07)$^{C,c}$ |
| | HPS | 2.21 (0.06)$^{A,d}$ | 1.61 (0.10)$^{B,c}$ | 1.10 (0.11)$^{C,c}$ | 1.10 (0.11)$^{C,d}$ |
| | Total | 1.35 (0.77)$^{A}$ | 1.09 (0.53)$^{B}$ | 0.66 (0.39)$^{C}$ | 1.03 (0.64) |
| Total | NOT | 1.37 (1.31)$^{A,a}$ | 1.17 (1.06)$^{B,a}$ | 0.76 (0.78)$^{C,a}$ | 1.10 (1.09)$^{a}$ |
| | PWW | 1.48 (1.25)$^{A,b}$ | 1.24 (0.93)$^{B,b}$ | 0.89 (0.87)$^{C,b}$ | 1.20 (1.04)$^{b}$ |
| | PDP | 1.73 (1.12)$^{A,c}$ | 1.44 (0.97)$^{B,b}$ | 1.08 (0.75)$^{C,c}$ | 1.42 (0.98)$^{c}$ |
| | HPS | 1.78 (1.12)$^{A,c}$ | 1.41 (0.98)$^{B,c}$ | 1.15 (0.76)$^{C,c}$ | 1.45 (1.02)$^{c}$ |
| | Total | 1.59 (1.22)$^{A}$ | 1.31 (0.98)$^{B}$ | 0.97 (0.79)$^{C}$ | 1.29 (1.04) |

Different letters in upper case in row and lower case in column indicate statistically significant difference ($p<0.05$).

**Table 4.** Results of 3-way ANOVA of $\Delta WI_D$

| Source | Type III Sum of Squares | df | Mean Square | F | p-value | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 1154.962[a] | 35 | 32.999 | 304.283 | <0.001 | 0.980 |
| Intercept | 179.765 | 1 | 179.765 | 1657.616 | <0.001 | 0.885 |
| TIME | 1012.586 | 2 | 506.293 | 4668.528 | <0.001 | 0.977 |
| APP | 16.872 | 3 | 5.624 | 51.858 | <0.001 | 0.419 |
| BEV | 8.126 | 2 | 4.063 | 37.463 | <0.001 | 0.258 |
| TIME-APP | 35.480 | 6 | 5.913 | 54.527 | <0.001 | 0.602 |
| TIME-BEV | 73.090 | 4 | 18.272 | 168.490 | <0.001 | 0.757 |
| APP-BEV | 1.989 | 6 | 0.331 | 3.056 | 0.007 | 0.078 |
| TIME-APP-BEV | 6.820 | 12 | 0.568 | 5.241 | <0.001 | 0.225 |
| Error | 23.425 | 216 | 0.108 | | | |
| Total | 1358.153 | 252 | | | | |
| Corrected Total | 1178.387 | 251 | | | | |

[a] R Squared = 0.980 (Adjusted R Squared = 0.977)

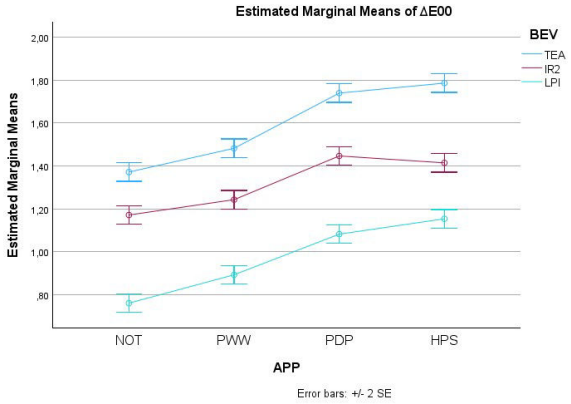


**Figure 4.** $\Delta E_{00}$ results for APP-BEV pair

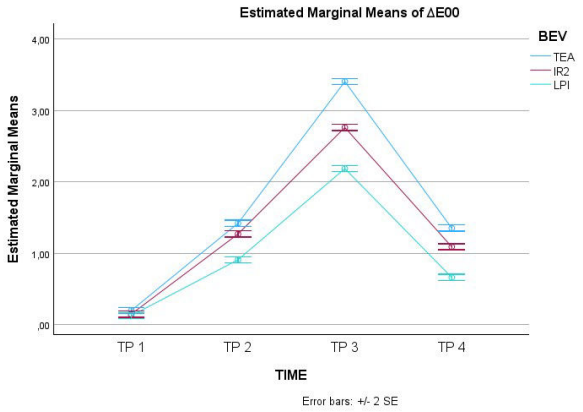


**Figure 5.** $\Delta E_{00}$ results for TIME-BEV pair

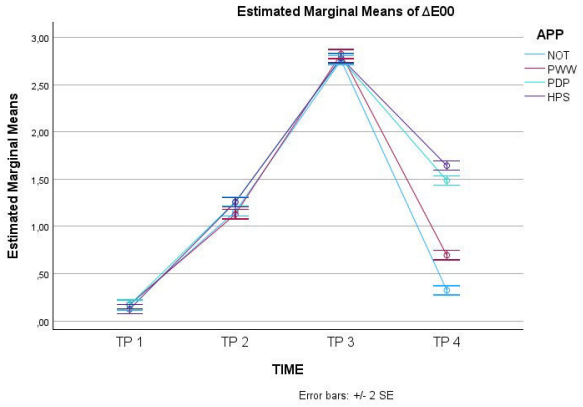


**Figure 6.** $\Delta E_{00}$ results for TIME-APP pair

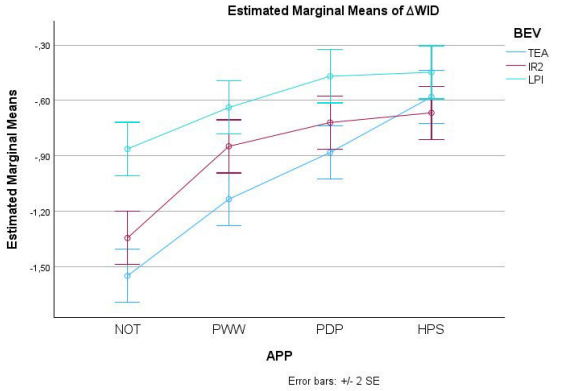


**Figure 7.** $\Delta WI_D$ results for APP-BEV pair

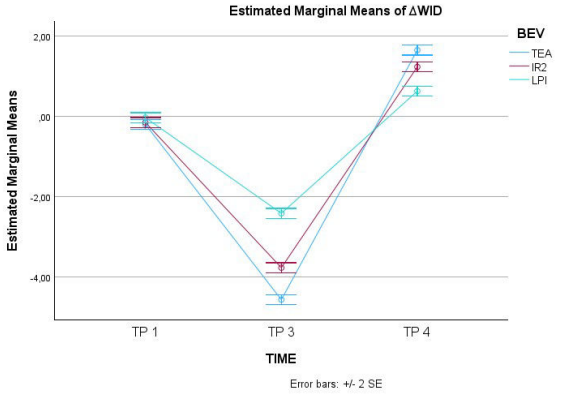


**Figure 8.** $\Delta WI_D$ results for TIME-BEV pair

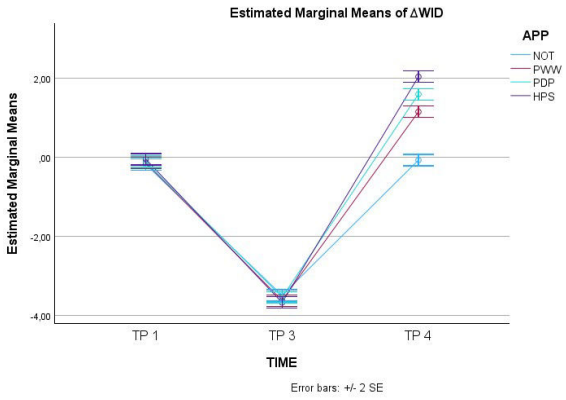


**Figure 9.** $\Delta WI_D$ results for TIME-APP pair

(p>0.05). The values were negative in the other specimens and the highest negative value was in the specimens immersed in TEA in the PWW group (p>0.05). In TP 3, the highest negative value was in the specimens immersed in TEA in the PWW group and the nearest to positive value was in the specimens immersed in LPI in the PDP group (p<0.001). In TP 4, the lowest value was in specimens immersed in TEA in the NOT group (p>0.05) and the highest value was in specimens immersed in TEA in the HPS group (p<0.001).

When the APP-BEV pair was analyzed, the magnitude of the increase from negative to positive values after APP was LPI>TEA>IR2 (p<0.001) (Figure 7). When the TIME-BEV pair was analyzed, $\Delta WI_D$ in the specimens immersed in TEA decreased to the lowest negative value at TP 3 and increased to the highest positive value at TP 4 in the opposite direction (p<0.001) (Figure 8). The order of magnitude at TP 4 was TEA>IRO2>LPI (p<0.001). When the TIME-APP pair was analyzed, $\Delta WI_D$ decreased to below -2.0 at TP 3 and increased again at TP 4 (p<0.001) (Figure 9). With NOT, the $\Delta WI_D$ was as high as 0.0, while with HPS the $\Delta WI_D$ was as high as 2.0 (p<0.001).

## Discussion

The International Organization for Standardization (ISO) recommended the use of 50:50 perceptibility and acceptability thresholds (PT and AT) for the interpretation of color results. In this study, PT/AT was 0.8/1.8 for $\Delta E_{00}$ and 0.72/2.60 for $\Delta WI_D$.[11] According

**Table 5.** Bonferroni results of $\Delta WI_D$

| $\Delta WI_D$ | | TEA | IR2 | LPI | Total |
|---|---|---|---|---|---|
| TP 1 | NOT | -0.25 (0.97) | -0.18 (0.69) | -0.11 (0.69) | -0.11 (0.69) |
| | PWW | -0.27 (0.75) | -0.20 (0.05) | 0.04 (0.06) | 0.04 (0.06) |
| | PDP | -0.17 (0.75) | -0.10 (0.12) | -0.08 (0.10) | -0.08 (0.10) |
| | HPS | -0,08 (0.06) | -0.11 (0.10) | -0.04 (0.09) | -0.04 (0.09) |
| | Total | -0.19 (0,10) | -0.15 (0.10) | -0.02 (0.11) | -0.12 (0.12) |
| TP 3 | NOT | $-4.27\ (1.67)^{A}$ | $-3.75\ (0.15)^{B}$ | $-2.44\ (0.09)^{C}$ | $-2.44\ (0.09)^{C}$ |
| | PWW | $-4.70\ (0.20)^{A}$ | $-3.75\ (0.09)^{B}$ | $-3.78\ (0.08)^{C}$ | $-3.78\ (0.08)^{C}$ |
| | PDP | $-4.60\ (0.08)^{A}$ | $-3.78\ (0.14)^{B}$ | $-2.22\ (0.87)^{C}$ | $-2.22\ (0.87)^{C}$ |
| | HPS | $-4.67\ (0.07)^{A}$ | $-3.75\ (0.09)^{B}$ | $-2.58\ (0.10)^{C}$ | $-2.58\ (0.10)^{C}$ |
| | Total | $-4.56\ (0.81)^{A}$ | $-3.76\ (0.11)^{B}$ | $-2.41\ (0.43)^{C}$ | -3.57 (1.03) |
| TP 4 | NOT | $-0.11\ (0.10)^{a}$ | $-0.08\ (0.06)^{a}$ | $-0.02\ (0.09)^{a}$ | $-0.02\ (0.09)^{a}$ |
| | PWW | $1.57\ (0.09)^{A,b}$ | $1.41\ (0.10)^{A,b}$ | $0.44\ (0.05)^{B,b}$ | $0.44\ (0.05)^{B,b}$ |
| | PDP | $2.12\ (0.09)^{A,c}$ | $1.72\ (0.11)^{A,b}$ | $0.90\ (0.08)^{B,c}$ | $0.90\ (0.08)^{B,c}$ |
| | HPS | $3.01\ (0.08)^{A,d}$ | $1.87\ (0.09)^{B,b}$ | $1.20\ (0.08)^{C,c}$ | $1.20\ (0.08)^{C,d}$ |
| | Total | $1.65\ (1.16)^{A}$ | $1.23\ (0.79)^{B}$ | $0.62\ (0.47)^{C}$ | 1.17 (0.94) |
| Total | NOT | $-1.15\ (2.17)^{A}$ | $-1.34\ (1.75)^{A}$ | $-0.86\ (1.14)^{B}$ | $-1.25\ (1.74)^{a}$ |
| | PWW | $-1.13\ (2.70)^{A}$ | $-0.84\ (2.21)^{B}$ | $-0.63\ (1.28)^{B}$ | $-0.87\ (2.12)^{b}$ |
| | PDP | $-0.88\ (2.86)^{A}$ | $-0.71\ (2.35)^{A}$ | $-0.46\ (1.41)^{B}$ | $-0.68\ (2.26)^{b}$ |
| | HPS | -0.58 (3.23) | -0.66 (2.39) | -0.44 (1.62) | $-0.56\ (2.46)^{c}$ |
| | Total | $-1.03\ (2.74)^{A}$ | $-0.89\ (2.16)^{B}$ | $-0.60\ (1.36)^{C}$ | -0.84 (2.16) |

Different letters in upper case in row and lower case in column indicate statistically significant difference ($p<0.05$).

to the findings, the first null hypothesis that beverages would not cause color and whiteness changes in teeth was rejected. In TP 1, $\Delta E_{00}$ did not exceed the PT for any APP-BEV pair. In TP 2, $\Delta E_{00}$ was between the PT and AT for all pairs except NOT-LPI and PWW-LPI. In TP 3, $\Delta E_{00}$ exceeded AT for all time pairs. In TP 4, the AT was exceeded for PDP-TEA and HPS-TEA pairs, but not for NOT-TEA, NOT-IR 2, NOT-LPI, PWW-IR2, and PWW-LPI pairs. For PWW-TEA, PDP-IR2, PDP-LPI, HPS-IR2, and HPS-LPI pairs, $\Delta E_{00}$ was between PT and AT.

When the results were examined regardless of time point, the highest color change was for the TEA-HPS pair ($\Delta E_{00}$=1.78) and the lowest for the LPI-NOT pair ($\Delta E_{00}$=0.76). When the results were examined regardless of time point and application, the highest color change was for TEA ($\Delta E_{00}$=1.59) and the lowest for LPI ($\Delta E_{00}$=0.97). When the results were examined regardless of beverage, the highest color change was for the TP3-PWW pair ($\Delta E_{00}$=2.82) and the lowest for the TP1-HPS and TP2-PWW pair ($\Delta E_{00}$=0.12). When the results were examined regardless of application and beverage, the highest color change was for TP3 ($\Delta E_{00}$=2.78) and the lowest for TP1 ($\Delta E_{00}$=0.15).

Spectrophotometers are the most commonly used devices for color measurement today. These devices are highly accurate and can be used for the long-term without sensitivity to object metamerism.[21] For these reasons, the Vita Easyshade V was used in this study. However, to eliminate limiting environmental conditions and to ensure standardization between multiple measurements, the tooth specimens were placed in custom-made holders.

The majority of studies investigating the effect of beverages on the color of teeth have been for beverages such as tea, coffee and wine.[22] There are limited studies on the effect of ISs on tooth color. However, iron is one of the essential elements required by the human body and ID is the most common micronutrient deficiency affecting the world population. Food supplements taken to remedy ID can lead to deeply penetrating, permanent color changes in teeth.[3]

Two types of ISs were used in this study. The first was a $Fe^{+2}$ sulfate supplement reported to contain no additional colorant.[23] Nowadays, new ISs have been developed in which iron particles reduced to nanoparticles are encapsulated in liposomal microcapsules.[4] It is claimed that these supplements do not change the color of teeth to a clinically perceptible magnitude.[5] However, the number of studies for LPI supplements was very limited; therefore, this study included an LPI supplement reported to contain no additional colorants as a second IS.[24]

Since the mechanism by which iron causes tooth color change has not yet been fully explained, and since the hypothesis that iron binds to the pellicle was still the most widely accepted theory,[13] the teeth were immersed in artificial saliva for the time intervals between immersion in iron solutions, and were not polished, even though they were rinsed when removed from the dishes.

Some previous studies[4,25,26] have produced results for ISs that are consistent with this study. In a study[4] in which LPI caused a considerable magnitude of color change than IR2, it was reported that the consumption time and acidity of the beverage caused color change. In this study, LPI and IR2 were kept in 5 mL containers for equal periods of time. It can be reported that citric acid increases the magnitude of the color change.This acid may lead to the chelation of calcium, an increase in the solubility of hydroxyapatite and thus, surface degradation.[27] However, acidity alone cannot explain why LPI produces less color change than IR2. In conventional iron supplements, the amount of iron circulating freely in the mouth is higher than in LPIs.[13] The prevention of direct contact of LPI particles to the tooth by microencapsulation technology and the presence of particles smaller than 100 nm in size reduces the possibility of tooth color change. In conventional ISs, free circulating particles bind to compounds such as tannins, leading to the formation of larger coloring compounds.

In this study, even though IR2 caused less color change than TEA, the magnitude of the color change was higher than that of AT, as in a previous study.[26] TEA has low polarity yellow pigments and tannins that bond more strongly to the tooth than IR2 and LPI. Furthermore, in a study,[28] with results consistent with this study, it was reported that the polyphenols of TEA reacted with the cationic salivary membrane to form thick layers of coloring particles.

The $\Delta E_{00}$ formula, which is widely used today, gives the magnitude of the color change, but not its direction. The $\Delta WI_D$ formula, which is currently used to calculate the direction in which the color changes away from the nominal point L*=100, a*=0, b*=0, has emerged as a new formula suggested by the CIE.[11] In this study, it was found that the $\Delta WI_D$ findings were compatible with the $\Delta E_{00}$ findings. According to the findings, the second null hypothesis that the applications would not lead to color and whiteness changes in teeth was rejected. In TP 1, $\Delta WI_D$ did not exceed the PTfor any APP-BEV pair. In TP 3, $\Delta WI_D$ for NOT-LPI, PDP-LPI, and HPS-LPI was between the PT and AT with a negative value. For the other pairs, it exceeded the AT threshold with negative value. In TP 4, for

the other pairs except for the HPS-TEA pair, values between PT and AT with positive values were detected, and for the HPS-TEA pair, values above the AT with positive values were detected.

When the results were examined regardless of time point, the highest whiteness change was for the IR2-NOT pair ($\Delta WI_D$=-1.34) and the lowest for the LPI-HPS pair ($\Delta WI_D$=-0.44). When the results were examined regardless of time point and application, the highest whiteness change was for TEA ($\Delta WI_D$=-1.03) and the lowest for LPI ($\Delta WI_D$=-0.60). When the results were examined regardless of beverage, the highest whiteness change was for TP3-PWW ($\Delta WI_D$=-3.78) and the lowest for TP1-HPS pair ($\Delta WI_D$=-0.04) and TP1-PWW pair ($\Delta WI_D$=0.04). When the results were examined regardless of application and beverage, the highest whiteness change was for TP3 ($\Delta WI_D$=-3.57) and the lowest for TP1 ($\Delta WI_D$=-0.12).

PDP is a polishing procedure used by most dentists to remove color change and plaque deposits after prosthodontic application. Nowadays, new generation PDP pastes with low dentin abrasiveness have been developed and their effects on dental materials should be investigated.[9] However, no study was found on the recovery of the color of teeth discolored by ISs using PDP or alternative polishing/bleaching methods.

In a study using multivitamins,[29] it was reported that the pH level decreased due to the oral environment, resulting in deterioration of the tooth surface and facilitating the adhesion of yellow coloring pigments to the tooth surface. The pH levels of the beverages used for this study were not specified by the manufacturer; therefore, pH levels were measured using a pH meter and the values obtained were 5.5 for TEA, 2.92 for IR2 and 4.6 for LPI. The results showed that the recovery of color by PDP was naturally higher in teeth that discolored more with beverages (TEA>IR2>LPI). Few studies[8,11] were found on the effect of new PDP pastes on color and whiteness change, and the findings of this study were consistent with the mentioned studies. Further research on the new generation of pastes which has a lower RDA than conventional pastes, is necessary for an in-depth study of the subject.

HP, the active component of bleaching agents, is a strong oxidizing agent that generates reactive oxygen species and HP anions. The reactive molecules attack the long-chain dark colored molecules and break them down into smaller, less colored molecules that diffuse to the outside of the tooth. In this study, a new HP component called HPS was used. A limited number of studies[30,31] have previously been carried out on the 6% formulation of HPS and, in agreement with the findings of the present study, this agent was found to be effective for color change. The fact that 25% HPS produced a color and whiteness change between PT and AT for IR2 and LPI, higher than AT for TEA, may be due to its composition, which is different from conventional bleaching agents. In conventional bleaching agents, HP or polyvinyl pyrrolidone peroxide is used. HPS has a new composition that combines the properties of these two agents. Since it is a material with high viscosity, it can stay on the tooth surface for a longer time without flowing, and this is provided by the poloxamer contained in the content. Due to the high temperature and saliva, a reaction begins (water breaks down into oxygen and radicals). Following this, energy is released. The process releases a new energy that repeats the whole process. Thus, a rapid, large bleaching effect occurs.[7,30]

In a previous study,[31] which showed results consistent with this study, it was shown that the color deteriorated by TEA could be recovered by HP. Since TEA has polar colorants, it is easy for HP to react with TEA pigments deposited on the teeth. In addition, bleaching does not only oxidize coloring pigments; it may also affect the inner layers of enamel and dentin.[32] Previous studies[33,34] on the effect of bleaching agents on teeth discolored by beverages have reported that the magnitude of the effect of these agents depends on the application method, agent concentration, and application time. Future research involving ISs is critically needed, as the available evidence is only on commonly consumed beverages such as tea, coffee and wine.

It is expected that the color of teeth with a nice appearance should be preserved its color as much as possible over time. Therefore, it is recommended to consume as little as possible of beverages that have the potential to cause discoloration. However, ISs are important supplements that should be taken in case of ID. Liposomal ISs can cause less color change than conventional $Fe^{+2}$ supplements because of their technology, which reduces contact with the teeth. Therefore, it could be reported as a good alternative for the protection of the appearance of teeth. On the other hand, the findings from this study showed that the HPS with new technology and the fine-grained PDP paste were effective in recovering the discoloration of the teeth. Therefore, HPS and PDP could be the preferred methods for recovering the color of teeth discolored by black tea or ISs.

A limitation of this study is that only two types of IS were used. The relationship betweenpH and the polishing method may also affect the result. In addition, it is not possible to exactly replicate the intraoral condition in a laboratory environment. Therefore, more research is needed on the effect of ISs, new generation PDP paste and new bleaching agents on the color and whiteness of teeth.

## Conclusion

The results obtained within the limitations of this study are as follows:

(1) Tooth discoloration after 2 months exceeded the AT, regardless of the beverage in which they were immersed. The whiteness change exceeded the AT for all beverages except liposomal iron supplementation. The order of color and whiteness change was TEA>IR2>LPI2.

(2) PDP and HPS caused a color change in the specimens in TEA that exceeded AT. The change in whiteness exceeding AT in magnitude was only due to HPS. Regardless of the applications, the order of color and whiteness change in the beverage groups was TEA>IR2>LPI, and regardless of the beverages, the order of color and whiteness change in the application groups was HPS>PDP>PWW>NOT.

## Ethical Approval

This study was reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Ankara University (Decision No: 36290600/13/2024). Informed consent was obtained from all participants.

## Acknowledgements

We would like to thank, Pharmacist Gülşah Akbülbül Yılmaz for her efforts.

## Financial Support

The authors do not have any financial interest in the companies whose materials are included in this article.

## Author Contributions

Creation of the Methodology : K.Y.
Preparation of Specimens, Performing the Tests : K.Y.
Project Administration : F.G.
Validation, Writing the References : F.G.
Writing the Ethics Report File : Z.B.
Writing the Tables, Visualisation : Z.B.

Writing the Manuscript : K.Y.

## Conflict of Interest

The authors declare no conflicts of interest.

## Authors' ORCID(s)

K.Y. 0000-0002-2974-6696
F.G. 0000-0002-4009-3972
Z.B. 0009-0008-2308-8232

## References

1. Pani SC, Alenazi FM, Alotain AM, Alanazi HD, Alasmari AS. Extrinsic tooth staining potential of high dose and sustained release iron syrups on primary teeth. BMC Oral Health. 2015;15:90. doi:10.1186/s12903-015-0072-0.
2. Percy L, Mansour D, Fraser I. Iron deficiency and iron deficiency anaemia in women. Best Pract Res Clin Obstet Gynaecol. 2017;40:55–67. doi:10.1016/j.bpobgyn.2016.09.007.
3. Mesonjesi I. Are extrinsic black stains of teeth iron-saturated bovine lactoferrin and a sign of iron deficient anemia or iron overload? Med Hypotheses. 2012;79(2):219–21. doi:10.1016/j.mehy.2012.04.044.
4. Abbasi M, Mazhari F, Jaafari MR, Afshari E, Bagheri H, Parisay I. Color change of primary teeth following exposure to an experimentally synthesized liposomal nano-encapsulated ferrous sulfate drop versus the commercially available iron drops. Pediatr Dent J. 2021;31(3):256–267. doi:https://doi.org/10.1016/j.pdj.2021.07.003.
5. Kaya E. The effect of surface sealants on discoloration of primary teeth related to iron syrups. Yeditepe J Dent. 2021;17(3):171–176. doi:10.5505/yeditepe.2021.64426.
6. Tinastepe N, Malkondu O, Iscan I, Kazazoglu E. Effect of home and over the contour bleaching on stainability of CAD/CAM esthetic restorative materials. J Esthet Restor Dent. 2021;33(2):303–313. doi:10.1111/jerd.12604.
7. Cavex. What makes "hydrogen peroxide superior" superior? [Web Page]; 2024. Available from: https://www.cavex.nl/hydrogen-peroxide-superior/?lang=en.
8. Kanat-Ertürk B. Color Stability of CAD/CAM Ceramics Prepared with Different Surface Finishing Procedures. J Prosthodont. 2020;29(2):166–172. doi:10.1111/jopr.13019.
9. Tejada-Casado M, Ghinea R, Perez MM, Lübbe H, Pop-Ciutrila IS, Ruiz-López J, et al. Reflectance and color prediction of dental material monolithic samples with varying thickness. Dent Mater. 2022;38(4):622–631. doi:10.1016/j.dental.2021.12.140.
10. Babaier R, Alhotan A, Haider J, Silikas N, Watts DC. Effects of two dentifrices on the surface properties and staining susceptibility of polymer-based materials. J Prosthodont. 2024. doi:10.1111/jopr.13927.
11. Peña RC, Ramos AC, Dos Santos Nunes Reis JM, Dovigo LN, Salomon JGO, Del Mar Pérez M, et al. Effect of polishing and bleaching on color, whiteness, and translucency of CAD/CAM monolithic materials. J Esthet Restor Dent. 2025;37(2):440–455. doi:10.1111/jerd.13288.
12. Choi J, Kim HE. In vitro evaluation of the tooth bleaching efficacy and safety of high-concentration hydrogen peroxide with cold atmospheric plasma. Photodiagnosis Photodyn Ther. 2024;47:104101. doi:10.1016/j.pdpdt.2024.104101.
13. Farawati FAL, Hsu SM, O'Neill E, Neal D, Clark A, Esquivel-Upshaw J. Effect of carbamide peroxide bleaching on enamel characteristics and susceptibility to further discoloration. J Prosthet Dent. 2019;121(2):340–346. doi:10.1016/j.prosdent.2018.03.006.
14. Elstrott B, Khan L, Olson S, Raghunathan V, DeLoughery T, Shatzel JJ. The role of iron repletion in adult iron deficiency anemia and other diseases. Eur J Haematol. 2020;104(3):153–161. doi:10.1111/ejh.13345.
15. Tüzüner T, Turgut S, Baygin O, Yilmaz N, Tuna EB, Ozen B. Effects of Different Pediatric Drugs on the Color Stability of Various Restorative Materials Applicable in Pediatric Dentistry. Biomed Res Int. 2017;2017:9684193. doi:10.1155/2017/9684193.
16. Amaechi BT, Higham SM, Edgar WM. Factors influencing the development of dental erosion in vitro: enamel type, temperature and exposure time. J Oral Rehabil. 1999;26(8):624–630. doi:10.1046/j.1365-2842.1999.00433.x.
17. Korać S, Ajanović M, Džanković A, Konjhodžić A, Hasić-Branković L, Gavranović-Glamoč A, et al. Color Stability of Dental Composites after Immersion in Beverages and Performed Whitening Procedures. Acta Stomatol Croat. 2022;56(1):22–32. doi:10.15644/asc56/1/3.
18. Miyashita-Kobayashi A, Haruyama A, Nakamura K, Wu CY, Kuroiwa A, Yoshinari N, et al. Changes in Gloss Alteration, Surface Roughness, and Color of Direct Dental Restorative Materials after Professional Dental Prophylaxis. J Funct Biomater. 2023;15(1):8. doi:10.3390/jfb15010008.
19. Cavex. Cavex Bite&White In-Office, Instructions for use [Web Page]; 2023. Available from: https://www.cavex.nl/producten/whitening-and-oral-care-en/whitening-en/cavex-bitewhite-in-office-systeem/?lang=en.
20. Sampaio CS, Belfus J, Avila A, Cordero C, Freitte M, Ferrari V, et al. Effect of different fabrication steps on color and translucency of a CAD-CAM feldspathic ceramic. J Esthet Restor Dent. 2021;33(7):1038–1044. doi:10.1111/jerd.12789.
21. Posavec I, Prpić V, Zlatarić DK. Influence of Light Conditions and Light Sources on Clinical Measurement of Natural Teeth Color using VITA Easyshade Advance 4,0(®) Spectrophotometer. Pilot Study. Acta Stomatol Croat. 2016;50(4):337–347. doi:10.15644/asc50/4/7.
22. Koçak EF, Ekren O, Johnston WM, Uçar Y. Analysis of color differences in stained contemporary esthetic dental materials. J Prosthet Dent. 2021;126(3):438–445. doi:10.1016/j.prosdent.2020.08.006.
23. Farma R. Newvit Iron Drops: Instructions for use [Web Page]; 2024. Available from: https://www.rcfarma.com/en/urunler/newvit-iron-drops-2x50-ml/.
24. Valens. Bestiron Plus: Instructions for use [Web Page]; 2024. Available from: https://www.instagram.com/valensilac/p/C9hekbWA-xy/?img_index=1.
25. Lokhande RS, Nagarathna PJ, Deoghare A, Chhatani N, Busi S, Malladi S. Effect of Different Iron Supplements on Color Stability of Nanocomposite Restorative Materials. Int J Clin Pediatr Dent. 2024;17(3):274–278. doi:10.5005/jp-journals-10005-2790.
26. Nazemisalman B, Mohseni M, Darvish S, Farsadeghi M, Luchian I. Effects of Iron Salts on Demineralization and Discoloration of Primary Incisor Enamel Subjected to Artificial Cariogenic Challenge versus Saline Immersion. Healthcare (Basel). 2023;11(4):569. doi:10.3390/healthcare11040569.
27. Dos Santos DM, da Silva EVF, Watanabe D, Bitencourt SB, Guiotti AM, Goiato MC. Effect of different acidic solutions on the optical behavior of lithium disilicate ceramics. J Prosthet Dent. 2017;118(3):430–436. doi:10.1016/j.prosdent.2016.10.023.
28. Chen YH, Yang S, Hong DW, Attin T, Yu H. Short-term effects of stain-causing beverages on tooth bleaching: A randomized controlled clinical trial. J Dent. 2020;95:103318. doi:10.1016/j.jdent.2020.103318.
29. Doğu Kaya B, Yılmaz Atalı P, Özmen S, Öztürk S, Tarçın B. Effect of an Effervescent Multivitamin on Color and Surface

Roughness of Micro-Hybrid Dental Resin Composites. Materials (Basel). 2024;17(5):1040. doi:10.3390/ma17051040.
30. Carneiro TS, Favoreto MW, Mena-Serrano A, Wendlinger M, Forville H, Reis A, et al. In vitro evaluation of the effect of different bleaching varnishes: Hydrogen peroxide penetration into the pulp chamber and color change. J Esthet Restor Dent. 2024;36(2):402–409. doi:10.1111/jerd.13133.
31. Panahandeh N, Mohammadkhani S, Sedighi S, Nejadkarimi S, Ghasemi A. Comparative Effects of Three Bleaching Techniques on Tooth Discoloration Caused by Tea. Front Dent. 2023;20:25. doi:10.18502/fid.v20i25.13343.
32. Tartari T, Bachmann L, Maliza AG, Andrade FB, Duarte MA, Bramante CM. Tissue dissolution and modifications in dentin composition by different sodium hypochlorite concentrations. J Appl Oral Sci. 2016;24(3):291–298. doi:10.1590/1678-775720150524.
33. Bazzi JZ, Bindo MJ, Rached RN, Mazur RF, Vieira S, de Souza EM. The effect of at-home bleaching and toothbrushing on removal of coffee and cigarette smoke stains and color stability of enamel. J Am Dent Assoc. 2012;143(5):e1–7. doi:10.14219/jada.archive.2012.0188.
34. Rodrigues FT, Serro AP, Polido M, Ramalho A, Figueiredo-Pina CG. Effect of bleaching teeth with hydrogen peroxide on the morphology, hydrophilicity, and mechanical and tribological properties of the enamel. Wear. 2017;374-375:21–28. doi:https://doi.org/10.1016/j.wear.2016.11.001.

European Annals of Dental Sciences
Official Publication of Ankara University, Faculty of Dentistry

*EADS*, 2025, 52 (1), 26–33

e-ISSN : 2757-6744
Article Received/Accepted : September, 4 2024 / February, 27 2025
doi : 10.52037/eads.2025.0004

ORIGINAL RESEARCH ARTICLE

# Evaluating Clarity and Quality of Sinus Augmentation Information Online

Yaren Doğan [1] and Yiğit Şirin [2], *

[1]Department of Oral and Maxillofacial Surgery, Institute of Graduate Studies in Health Sciences, Istanbul University, Istanbul, Türkiye and [2]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Istanbul University, Istanbul, Türkiye

*Corresponding Author; ysirin@istanbul.edu.tr

## Abstract

**Purpose:** This study evaluates the transparency, information quality, and readability of English-language websites concerning maxillary sinus augmentation, aiming to distinguish between clinical and blog-type websites. The findings underscore the importance of improving online health information to support informed decision-making and enhance health literacy.
**Materials and Methods:** In August 2024, an internet search was conducted using Google Chrome along with Google, Bing, Yahoo, and Yandex search engines, employing specific keywords related to maxillary sinus augmentation. Websites were independently evaluated by two observers using established tools, including the JAMA benchmarks, DISCERN, QUEST, and EQIP, to assess transparency, information quality, and adherence to evidence-based practices. Readability was assessed using the Flesch–Kincaid tests, Gunning-Fog Index, SMOG, Coleman-Liau Index, and Automated Readability Index. Statistical comparisons were performed using non-parametric tests.
**Results:** Among the 137 websites analyzed, 21.89% to 24.08% achieved scores above the 75th percentile for transparency and information quality, as evaluated by JAMA, DISCERN, QUEST, and EQIP tools. Blog-like websites scored significantly higher than clinical websites across all assessment tools ($p<0.05$), indicating better transparency and content quality. However, blog-like sites also required a higher educational level for comprehension compared to clinical websites ($p<0.05$), which may limit accessibility for some readers.
**Conclusions:** Individuals searching for information on sinus augmentation surgery have roughly a one-in-four or one-in-five chance of finding websites that adhere to acceptable standards of content quality and transparency. While blog-type websites provide superior content quality and transparency, they often require higher literacy levels, potentially excluding a portion of the population. These findings call for the development of standardized guidelines to ensure that online health information is both high-quality and accessible, ultimately improving patient education, health literacy, and decision-making.

**Keywords**: Attitude to health; Health information systems; Information seeking behavior; Internet-based intervention; Sinus floor augmentation

## Introduction

The maxillary sinus, one of four pairs of paranasal sinuses, is located in the maxilla near the nasal bones and orbits. As the largest and pyramid-shaped sinus, its apex points toward the zygomatic process, and its base is part of the lateral nasal wall.[1] It is lined with a thin mucous membrane and contains air, contributing to skull weight reduction and voice tone modulation. Sinus floor augmentation aims to increase bone volume in the posterior maxilla, primarily for dental implant placement.[2] This procedure typically involves lifting the sinus membrane to insert bone graft material. Techniques vary, including the lateral window approach, creating an opening in the sinus wall, and the osteotome technique, which taps the sinus floor through the alveolar ridge.[3] While effective, the procedure carries risks such as sinus membrane perforation, infection, bleeding, or postoperative sinusitis, affecting graft and implant success. Thus, meticulous planning and execution are essential to mitigate these risks.[4] Effective patient communication regarding the procedure, potential complications, and postoperative care is paramount. This process involves outlining benefits and risks, setting realistic expectations, and providing comprehensive pre- and post-operative instructions to foster informed consent and enhance patient satisfaction and trust.[5,6]

The shift from traditional professional-patient interactions to

relying on internet searches for health information represents a significant change in how individuals access health knowledge. The technological evolution has led many to seek medical data online. The internet might be a crucial health information resource. However, this shift can also lead to incorrect diagnoses, inappropriate self-treatments, and increased anxiety.[5] As of August 2024, there were 5.35 billion internet users worldwide, which corresponds to 66.2% of the global population (https://www.statista.com). Based on Eurostat data, on average, 55% of Europeans between the ages of 16 and 74 looked up health-related information on the internet in 2022. Specifically, more than 70% of individuals in Finland, the Netherlands, Denmark, and Norway engaged in seeking health information online in 2023 (https://ec.europa.eu/eurostat). In 2017, 74.4% of the US population turned to the internet first for health information.[7] In certain Asian countries, the tendency to seek health information online is even more pronounced, ranging from 79% to 86%.[8,9]

Readability and transparency are essential components of effective health communication. The reliability of online health information depends on its transparency about authorship, sourcing, conflict of interest disclosures, and its adherence to evidence-based content.[10] The readability of health websites has a crucial role in ensuring that information is accessible and comprehensible to the public.[11] High readability ensures that medical information is accessible to a wide audience, enabling patients to understand complex procedures and make informed decisions. These factors significantly influence the effectiveness and trustworthiness of online health resources, highlighting the importance of evaluating websites to prevent misinformation and empower patients in making informed health decisions.[12]

While sinus floor augmentation is a well-established procedure[13], the quality of online information available to patients remains inconsistent. Previous research has highlighted gaps in the availability, transparency, and readability of online health information, particularly in areas such as post-operative care, risks, and complications for other dental and surgical procedures.[14] Studies focusing on orthognathic surgery and dental implants have shown that many websites fail to meet quality standards, lack clear authorship or citations, and present information at a readability level unsuitable for the general public.[15,16] Similarly, there is a lack of comprehensive evaluation of websites related specifically to sinus augmentation. This study aims to comprehensively assess the transparency, information quality, and readability of English-language websites on this subject. It also seeks to identify discrepancies between clinical and blog-type websites and their impact on patient education and decision-making. The null hypothesis is that there is no significant difference between the two website categories concerning transparency, information quality, and readability.

## Material and Methods

### Website search and selection process

An internet search was conducted in August 2024 by using the latest version of Google Chrome (version 120.0.6099.217), which has a market share of 62.85% as of 2023. Google (www.google.com), Bing (www.bing.com), Yahoo (www.yahoo.com), and Yandex (www.yandex.com) search engines were included in the analysis. The keywords "maxillary augmentation," "sinus lift surgery," "maxillary sinus augmentation," "sinus augmentation," and "sinus floor augmentation" were employed. To ensure a comprehensive search, the virtual private network settings were altered during the process. The search protocol included all web pages displayed by the search engines. Websites were excluded from consideration if they were inaccessible, not pertinent to the search, presented in a language other than English, solely contained video content, or were dedicated to scientific publications such as academic journals or textbooks. Additionally, mobile browsing data was excluded from the research.

### Evaluation protocols and website categorization

Two observers independently evaluated the first 20 websites, and their level of agreement was assessed using the intraclass correlation coefficient. Given that these values were acceptably high (0.86 to 0.94), the remaining websites were assessed based on the consensus between both observers. Depending on their characteristics, they were classified into two broad categories: clinical websites and blog-like information websites. Clinical ones were defined as those associated with healthcare providers, clinics, or hospitals. These sites were characterized by professional domain names, and their content primarily focused on promoting clinical services or treatments. Blog-like websites were defined as those created by individuals, patient advocates, or non-clinical organizations with the primary goal of sharing experiences, personal insights, or general information. These sites were characterized by a narrative or informal tone in their writing, often focusing on opinion sharing.

### Transparency and information quality evaluation

The Journal of the American Medical Association (JAMA) benchmarks focus on authorship identification, attribution, disclosure, and currency. For each of these four criteria, a website can be scored with a 0 (information absent) or a 1 (information present). These questionnaire items can be treated as categorical variables, or their sums can be considered a scalar variable, ranging from 0 to 4.[17] The DISCERN tool comprises 16 items divided into two main subdomains. The sum of the first 8 items indicates the reliability of the information (DISCERN-REL), including the clarity of its aims and the accuracy of its sources. The sum of the next 7 items is used to assess the depth and balance of information provided on treatment choices (DISCERN-INFO). Each question is rated on a scale from 1 to 5, leading to a possible score range between 16 and 80, with higher scores denoting more reliable and useful content.[18] The Quality Evaluation Scoring Tool (QUEST) assesses the adherence to seven quality domains, with points assigned according to the degree of compliance with best practices. The score range is from 0 to 28, with higher scores indicating better quality.[19] The Ensuring Quality Information for Patients (EQIP) tool focuses on their relevance, readability, and reliability. This tool uses a scoring system where each item or criterion is rated on a scale, often from 1 to 4 or 1 to 5; total scores range from 0 to 100, with higher scores indicating better quality.[20]

### Interpretation of the assessment tools

In this study, a quantitative methodology is employed to analyze the performance of the JAMA, DISCERN, QUEST, and EQIP tools, focusing on their 75th percentile. The scores at or above this percentile were categorized as "above average." Since no universal cut-off standards have been defined, this approach utilizes the upper quartile to highlight high-performing entities. Similar methods have been applied in prior studies to categorize and interpret the quality of health information available online.[21] This approach provides an objective framework for identifying websites that meet or exceed acceptable quality standards.

### Readability evaluation

The readability of the websites was assessed using multiple established instruments: the Flesch–Kincaid Reading Ease, Flesch–Kincaid Grade Level, Gunning-Fog Index, Simple Measure

of Gobbledygook, and the Automated Readability Index. These tools evaluate readability based on sentence structure, word complexity, and syllable count, providing estimates of the educational level required to comprehend the content. These calculations were conducted using the online WebFX Readability Test Tool (www.webfx.com/tools/read-able/).

The Flesch–Kincaid readability tests, comprising the Flesch Reading-Ease and the Flesch–Kincaid Grade Level, are designed to gauge the difficulty of understanding English passages.[22] The formula for the Flesch-Kincaid Reading Ease is as follows: 206.835-1.015×(words/sentences)-84.6×(syllables/words). Scores range from 0 to 100, with higher scores denoting easier readability. The Flesch-Kincaid Grade Level, which indicates the U.S. school grade level necessary for comprehension, offers an additional metric. The formula for calculating the Flesch-Kincaid Grade Level is given as 0.39×(words/sentences) +11.8×(syllables/words)-15.59. The Gunning Fog Index estimates the number of years of formal education required to understand a text upon first reading. To calculate the Gunning Fog Index, the number of words and syllables in a text passage of at least 100 words is counted. The total number of words is divided by the number of sentences to determine the Average Sentence Length (ASL). Then, the number of words that have three or more syllables, excluding proper nouns, compounds made of simple words, hyphenated words, and two-syllable verbs that become three with '-es' or '-ed,' is counted. This number, divided by the total word count, yields the Percentage of Hard Words (PHW). To finalize the calculation, ASL is added to PHW, and the sum is multiplied by 0.4. Simple Measure of Gobbledygook (SMOG) is best suited for texts of 30 sentences or more. The length of 10 sentences at the beginning, middle, and end of the text, totaling 30 sentences, is counted. Every word with three or more syllables is counted. The square root of this number is then taken and rounded to the nearest 10, and three is added to this figure. It measures the number of years of education that an average person needs to understand a text. The Coleman-Liau Index is a readability metric that emphasizes character count and benefits from computerized assessments to evaluate characters with greater ease and accuracy. This formula facilitates the automated calculation of writing samples, expressed as 5.89×(characters/words)-0.3×(sentences/words)-15.8. This index provides a score indicative of the U.S. school grade level required for understanding the text.[23] The Automated Readability Index (ARI) is a tool specifically designed to assess the readability of text, measuring its comprehension ease. ARI offers an estimate of the U.S. grade level needed for understanding a particular piece of text. The formula for the Automated Readability Index is defined as 4.71×(characters/words) +0.5×(words/sentences)-21.43. The ARI score thus obtained acts as an indicator of the age at which a reader is expected to understand the text.[24,25]

### Statistical analysis

IBM SPSS v20.0 software (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY, USA), was used for statistical analysis. Mean and standard deviation, median, and frequency were used for descriptive statistics. The normality of the continuous variables was checked with Shapiro-Wilk test and graphic methods. The Mann-Whitney U test was employed for non-parametric data comparisons. The strength and significance of bivariate correlations were evaluated with the Spearman correlation coefficient. The significant correlation strengths were interpreted as follows: up to 0.19 as very weak, 0.20 to 0.39 as weak, 0.40 to 0.59 as moderate, 0.60 to 0.79 as strong and higher than 0.80 as very strong.[26] The confidence interval was set to 95%, and $p<0.05$ was considered significant.

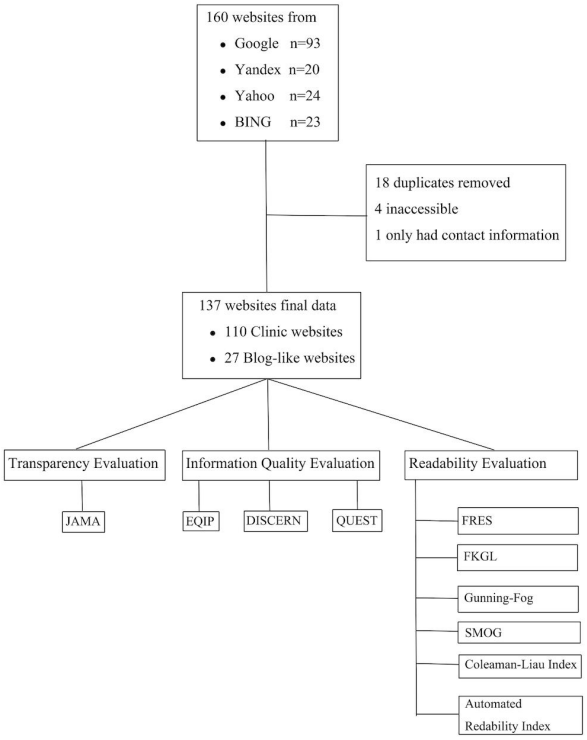


**Figure 1.** Study flowchart demonstrating the website selection, categorization and evaluation protocols (JAMA: Journal of American Medical Association, EQIP: Ensuring Quality Information for Patients, QUEST: Quality Evaluation Scoring Tool, FRES: Flesch Reading Ease Score, FKGL: Flesch-Kincaid Grade Level, SMOG: Simple Measure of Gobbledygook).

## Results

160 pages were found to be eligible for inclusion criteria. 93 results were found in Google, 20 in Yandex, 24 in Yahoo, and 23 in Bing search engines. 4 of them could not be opened, and 1 of them had only a contact number. After removing overlapping titles, 137 websites were used for the study. Out of the 137 (N=137) websites, 110 were categorized as clinical (n=110) and 27 as blog sites (n=27) (Figure 1).

The analysis revealed that blog-like websites consistently outperformed clinical websites in transparency and content quality, as measured by JAMA, DISCERN, QUEST, and EQIP tools, with statistically significant differences across all instruments ($p<0.001$). For example, the average DISCERN score for blog sites was 47.51 ± 12.58, significantly higher than the 31.84 ± 8.07 for clinical sites, indicating superior reliability and depth of information in blogs. Similarly, the QUEST scores for blog-like sites (14.00 ± 6.07) far exceeded those for clinical websites (5.38 ± 3.29). In addition, based on the DISCERN tool, 18.51% of the blog sites and 60% of the clinic websites did not mention any risks of treatments (Figure 2) (Table 1).

Per JAMA, 24.08% of scales were rated as above average, surpassing the 75th percentile. DISCERN, EQIP, and QUEST followed with 23.35%, 22.62%, and 21.89% of scales classified as above average, respectively.

In terms of readability, the content of clinical websites was found to be more accessible, with lower Gunning-Fog Index and SMOG scores indicating an educational level closer to the recommended 8th-grade standard. However, blog-like websites, while offering higher quality content, required a slightly higher educational level for comprehension ($p<0.001$). These findings highlight the trade-off between content quality and readability across the two types of websites (Figure 3) (Table 1).

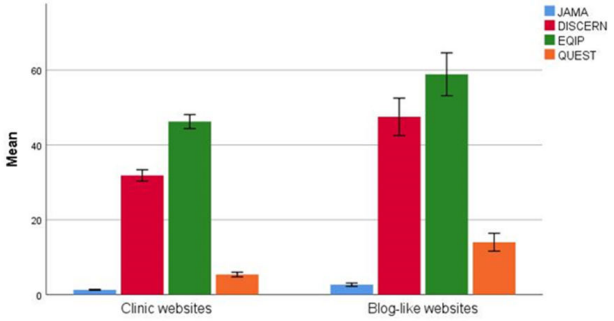


**Figure 2.** Bar graphic representation of the transparency and content quality assessment instruments stratified by the website types (JAMA: Journal of American Medical Association, EQIP: Ensuring Quality Information for Patients, QUEST: Quality Evaluation Scoring Tool).

**Table 1**

| Assessment instrument | Clinic websites | Blog-like websites | Total scores |
|---|---|---|---|
| JAMA Benchmarks | 1.28±0.69A | 2.67±1.07a | 1.55±0.95 |
| DISCERN total | 31.84±8.07A | 47.51±12.58a | 34.93±11.02 |
| DISCERN reliability | 17.60±4.26A | 26.70±6.46a | 19.39±5.98 |
| DISCERN treatment | 11.95±3.91A | 17.88±6.68a | 13.12±5.14 |
| EQUIP | 46.24±9.84A | 58.88±14.48a | 48.73±11.96 |
| QUEST | 5.38±3.29A | 14.00±6.07a | 7.08±5.25 |
| FRES | 55.36±13.46 | 54.63±7.54 | 55.22±12.50 |
| FKGL | 7.71±2.07 | 7.99±1.20 | 7.76±1.93 |
| Gunning-Fog Index | 8.13±2.25A | 9.65±1.77a | 8.43±2.24 |
| SMOG Index | 6.79±1.25A | 7.46±1.11a | 6.92±1.25 |
| Coleman-Liau Index | 13.53±2.76 | 13.30±1.39 | 13.49±2.54 |
| Automated Readability Index | 6.53±2.54 | 6.57±1.44 | 6.54±2.36 |

Mean and standard deviations of the transparency, content quality and readability assessment instruments stratified by the type of websites. Values followed by an uppercase letter indicate significant differences from its lowercase counterpart written in the same row (JAMA: Journal of American Medical Association, EQIP: Ensuring Quality Information for Patients, QUEST: Quality Evaluation Scoring Tool, FRES: Flesch Reading Ease Score, FKGL: Flesch-Kincaid Grade Level, SMOG: Simple Measure of Gobbledygook).

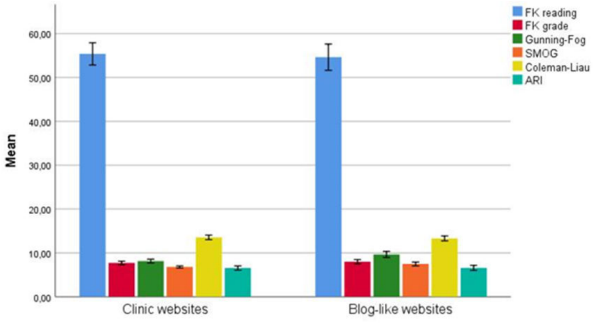


**Figure 3.** Bar graphic representation of the readability assessment instruments stratified by the website types (FK: Flesch-Kincaid, SMOG: Simple Measure of Gobbledygook, ARI: Automated Readability Index).

There were moderate to strong positive correlations among JAMA, DISCERN, QUEST, and EQIP scores (rho: 0.43 to 0.71, p<0.001 for each pairwise comparison). The same tools were also found to be positively but weakly correlated with Gunning-Fog readability index scores (rho: 0.16 to 0.20, p<0.05 for each pairwise comparison) (Table 2).

## Discussion

Sinus floor augmentation is a well-established and elective surgical procedure based on strong clinical evidence.[13,27] However, laypersons informed about the potential for undergoing such surgery typically seek extensive information on its risks and benefits, often turning to internet resources.[28,29] This study focuses on this particular issue.

The scientific method allowed for verification of the integrity of material published online. The JAMA benchmark criteria serve as an effective tool for evaluating the transparency and reliability of online information.[17] DISCERN facilitates the evaluation of the reliability and quality of patient education materials, especially those concerning treatment options.[18] The QUEST aims to assess the quality of online health information for both researchers and clinicians.[19] EQIP has been developed for use by patient information managers and healthcare professionals, and it requires at least some knowledge of the topics.[20] These assessment tools were used together to offer a more comprehensive view of information transparency and content quality. The total scores of these scales were found to be positively correlated. On the other hand, apart from Weil et al.[21], who had presented an arbitrary categorization of DISCERN scores, there is a lack of normative data-based threshold standards for these assessment tools. The present study, therefore, implemented its own 75th percentile range-based categorization. According to this criterion, individuals searching online for information on sinus lifting have a 20% to 25% chance of encountering relatively transparent information sources. However, this may be an overestimate, as our data includes 137 relevant results, and 97% of people typically only visit the first 10 websites listed by search engines.[30]

Despite the importance of quality control measures, this study found that online resources on sinus augmentation failed to meet acceptable transparency and information quality standards. This finding aligns with previous reports indicating that digital health information, particularly in dentistry and oral surgery, is inconsistent in accuracy, readability, and reliability.[14,16] Studies on other dental procedures, such as orthodontic treatments and peri-implantitis, report similar deficiencies, highlighting the broader challenges faced in online patient education.[31–33] Although the present study is the first related to sinus augmentation websites, content analysis is a common research area in oral and maxillofacial surgery. Meade and Dreyer[34], using DISCERN, have found that the quality of online information on ectopic and impacted maxillary canines was insufficient in terms of content and readability. Similarly, a recent study by Yoo et al.[16] assessed YouTube videos on sinus elevation procedures and found that most did not meet educational quality standards. These findings suggest that a significant number of online resources across dental and maxillofacial surgery topics fail to provide accurate, patient-friendly information. Engelmann et al.[35] and Lee et al.[36] criticized the lack of information related to post-operative care and complications on websites about orthognathic surgery. Websites on dental implants share similar drawbacks. Leira et al.[37], using the same instruments as this study, revealed that the websites regarding peri-implantitis did not meet the information quality standards. More recently, Rehman et al.[38] pointed out that only 6.8% of 118 dental practice websites in the United Kingdom covered all implant-related complications. These studies also indicated that most websites do not list the author, source, or publication date. The findings of the present study were consistent with this trend, as the overall quality of information and transparency was found to be below acceptable standards with

**Table 2**

| | | JAMA | DISCERN | EQIP | QUEST | GUNNING-FOG |
|---|---|---|---|---|---|---|
| **JAMA** | rho | 1 | 0,605** | 0,525** | 0,717** | 0,197* |
| | p | | <0.001 | <0.001 | <0.001 | 0,021 |
| **DISCERN** | rho | 0,605** | 1 | 0,874** | 0,591** | 0,207* |
| | p | <0.001 | | <0.001 | <0.001 | 0,015 |
| **EQIP** | rho | 0,525** | 0,874** | 1,000 | 0,513** | 0,185* |
| | p | <0.001 | <0.001 | | <0.001 | 0,030 |
| **QUEST** | rho | 0,717** | 0,591** | 0,513** | 1 | 0,166* |
| | p | <0.001 | <0.001 | <0.001 | | 0,050 |
| **GUNNING-FOG** | rho | 0,197* | 0,207* | 0,185* | 0,166* | 1 |
| | p | 0,021 | 0,015 | 0,030 | 0,050 | |

Presentation of the significant correlations and their Spearman correlation (rho) coefficients among study variables. The correlation strengths were interpreted as follows: up to 0.19 as very weak, 0.20 to 0.39 as weak, 0.40 to 0.59 as moderate, 0.60 to 0.79 as strong and higher than 0.80 as very strong (**Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level. JAMA: Journal of American Medical Association, EQIP: Ensuring Quality Information for Patients, QUEST: Quality Evaluation Scoring Tool).

respect to each assessment tool. This may be due to editorial policies that favor anonymity, ensure impartiality, and minimize the influence of individual authors' reputations or credentials. Naming authors or changing dates could lead to legal and credibility issues. In addition, continuously updating websites makes it difficult to document exact update dates. To avoid seeming outdated, some sites claim frequent content reviews without specifying dates.

Misinformation in medical content can have serious psychological effects, including increased patient anxiety, distrust in healthcare providers, and misinformed decision-making.[39,40] Patients who encounter conflicting or unreliable health information online may either avoid necessary treatments due to fear or seek unnecessary procedures based on misleading claims.[5,8] In terms of sinus augmentation, exaggerated claims about success rates, underreporting of potential complications, or misinformation about post-operative recovery can directly influence patient perceptions and treatment choices. The need for credible, accessible, and standardized online medical resources is therefore critical for ensuring informed patient decisions and reducing unnecessary fear.

Another important consideration is the variation in online health information quality and accessibility across different regions. High-income countries generally provide more comprehensive and transparent health information. However, resources in lower-income regions are often incomplete, outdated, or poorly structured.[41] The problem can be even more pronounced in multilingual countries or regions with lower literacy levels. Non-English medical content tends to be less detailed and lacks the quality controls found in English-language sources.[42] Addressing these problems through international collaboration and language-specific readability guidelines could significantly improve global patient education.

The present study categorized websites into clinical and blog-like informational sites. The analysis revealed that blog-like websites outperformed clinical ones based on criteria from the JAMA, DISCERN, EQIP, and QUEST instruments. The superior performance of blog sites in transparency may be attributed to their primary focus on disseminating information rather than promoting clinical services. Blog sites often prioritize content aimed at engaging and educating readers, incorporating clear authorship attributions, detailed disclosure statements, frequent updates, and discussions on risks and complications. In contrast, clinical websites may focus more on their services and treatments, often presenting information in a more generalized or marketing-oriented format. They could also be intending to provide detailed information during face-to-face interactions with patients. It is hypothesized that these sites often employ similar software templates and may be motivated by financial expectations. These factors could explain the sparse information on risks, complications, and alternative treatments. Additionally, clinical sites may avoid detailed disclosures, such as listing authors or publication dates, to maintain a uniform authoritative voice or mitigate liability concerns. These distinctions likely contribute to the observed differences in transparency between the two website types.

Our analysis indicated that the textual content of websites was suitable for an 8th-grade reading level or below. This finding aligns with the guidelines of the American Medical Association and the National Institutes of Health, which recommend that patient materials be readable at levels between the sixth and eighth grades.[43] However, although the blog-like information websites scored higher on the JAMA, DISCERN, QUEST, and EQIP instruments, the level of education required to comprehend them, as indicated by the SMOG and Gunning Fog indexes, was higher than the clinical ones, suggesting a 9th-grade level. Put simply, as the quality of content improves, so does the level of education needed to understand it. Schwarzbach et al.[44] found a positive correlation between the QUEST score and the FKGL score of 27 sites and a negative correlation with the FRES score. Similar to our findings, other studies have indicated that certain readability tests may exhibit significant differences among them even when there is no significant correlation between quality assessment tools and readability metrics.[45,46] The number and diversity of the websites included in this study might have contributed to this finding. This perspective also underscores the need for improved readability standards in the development of online health resources. Ensuring readability levels appropriate for a broader audience could make high-quality content accessible to a wider range of users, particularly those with lower health literacy.[10] Establishing standardized readability guidelines could facilitate the creation of more reliable online health information, ultimately improving patient decision-making and health outcomes.

Although a significant volume of studies exists in current literature, their impact on daily practice remains minimal. This underscores the necessity for standardized methodologies. First, clinical websites could incorporate features such as named authors, citations of reliable sources, and regular content updates to enhance trust and credibility. Second, the use of informed consent forms could serve as a potential initial step. Mandating the inclusion of these forms on clinical websites, in formats that are easily visible and accessible, could prompt patients to seek more detailed information. This, in turn, may encourage providers to present more comprehensive details regarding risks and complications. On the other hand, the findings of this study must be considered within the context of algorithmic influences that shape the presentation of information on search engines. Blog sites, often optimized for user engagement and search engine ranking, may outperform clinical websites in visibility and perceived transparency. Conversely, clinical websites, which may not prioritize search engine optimization, could be underrepresented despite offering credible content. These algorithmic dynamics highlight to optimize the search engine's visibility while maintaining high standards of transparency and quality. Moreover, regulators could implement accreditation systems

or quality seals for health websites that meet predefined criteria. Encouraging collaboration between healthcare providers, patient advocacy groups, and technology companies could enable the creation of evidence-based online health resources. Future regulations can mitigate misinformation, promote informed decision-making, and ultimately improve patient outcomes.

Technological advancements may be used to improve the quality of online health information.[47] While currently considered a threat to information authenticity, artificial intelligence (AI) also holds significant potential for improving its accessibility, readability, and accuracy. It can simplify complex medical terminology[48] as well, making it understandable for individuals with lower health literacy. AI can be used to address the lack of real-time content updates, which was a key issue identified in this study. Furthermore, AI-powered content analysis and fact-checking algorithms can ensure that online materials meet established quality benchmarks such as JAMA, DISCERN, QUEST, and EQIP.[49] Additionally, AI can help credible clinical websites rank higher in search results by enhancing search engine optimization strategies.[50] As such technologies continue to evolve, their integration into online health content development could standardize educational resources.

This study has several inherent limitations. The selection process of websites may not fully capture how patients typically find these resources, as variations in search terms, geographic location, and the presence of ad blockers can significantly affect the results. The exclusion of mobile browsing data may impact the generalizability of our findings, since browsing behaviors and website presentations often vary between desktop and mobile platforms. Furthermore, the search engine personalization, influenced by factors such as user history, location, and browsing behavior, may have impacted the search results obtained in this study. Although efforts were made to minimize this effect by using a virtual private network and clearing browser cache before each search, complete elimination of personalization bias cannot be guaranteed. Another limitation lies in the study's reliance on quantitative measures for assessing information quality and readability, potentially neglecting the qualitative aspects of user experience and understanding. Furthermore, the classification into clinical and blog-type websites, while useful, might oversimplify the diverse landscape of online health information, ignoring other valuable sources such as patient forums or professional organizations. Lastly, our analysis was constrained to English-language websites, possibly omitting high-quality information available in other languages, which could be particularly relevant in multilingual regions or among non-English speaking populations seeking sinus augmentation information.

## Conclusion

Individuals searching for information on sinus augmentation surgery have roughly a one-in-four or one-in-five chance of finding websites that adhere to acceptable standards of content quality and transparency. While blog-type websites provide superior content quality and transparency compared to their clinical counterparts, they often require higher literacy levels, potentially excluding a portion of the population. These findings call for the development of standardized guidelines to ensure that online health information is both high-quality and accessible, ultimately improving patient education, health literacy, and decision-making.

## Ethical Approval

Ethical approval was not required for this study.

## Acknowledgements

Not applicable.

## Financial Support

The author(s) received no financial support for the research, authorship, and/or publication of this article.

## Author Contributions

Conceptualization : All Authors
Methodology : All Authors
Investigation : All Authors
Data Curation : All Authors
Writing Original Draft : All Authors
Review & Editing : All Authors

## Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Authors' ORCID(s)

Y.D. 0009-0006-8155-4305
Y.S. 0000-0003-4488-0938

## References

1. Stern A, Green J. Sinus lift procedures: an overview of current techniques. Dent Clin North Am. 2012;56(1):219–33, x. doi:10.1016/j.cden.2011.09.003.
2. Bagis N, Yıldız H, Barbaros R. Maxillary Sinus Lifting. International Journal of Experimental Dental Science. 2018;7:91–97. doi:10.5005/jp-journals-10029-1181.
3. Tiwana PS, Kushner GM, Haug RH. Maxillary sinus augmentation. Dent Clin North Am. 2006;50(3):409–424, vii. doi:10.1016/j.cden.2006.03.004.
4. Molina A, Sanz-Sanchez I, Sanz-Martin I, Ortiz-Vigon A, Sanz M. Complications in sinus lifting procedures: Classification and management. Periodontol 2000. 2022;88(1):103–115. doi:10.1111/prd.12414.
5. Battineni G, Baldoni S, Chintalapudi N, Sagaro GG, Pallotta G, Nittari G, et al. Factors affecting the quality and reliability of online health information. Digit Health. 2020;6:2055207620948996. doi:10.1177/2055207620948996.
6. Sharkiya SH. Quality communication can improve patient-centred health outcomes among older patients: a rapid review. BMC Health Serv Res. 2023;23(1):886. doi:10.1186/s12913-023-09869-8.
7. Finney Rutten LJ, Blake KD, Greenberg-Worisek AJ, Allen SV, Moser RP, Hesse BW. Online Health Information Seeking Among US Adults: Measuring Progress Toward a Healthy People 2020 Objective. Public Health Rep. 2019;134(6):617–625. doi:10.1177/0033354919874074.
8. Jia X, Pang Y, Liu LS. Online Health Information Seeking Behavior: A Systematic Review. Healthcare (Basel). 2021;9(12). doi:10.3390/healthcare9121740.
9. Wang X, Cohen R. Health Information Technology Use Among Adults: United States, July-December 2022. NCHS. 2023;482:8. doi:10.15620/cdc:133700.
10. Okuhara T, Furukawa E, Okada H, Kiuchi T. Readability

of online and offline written health information: a protocol of a systematic review of systematic reviews. BMJ Open. 2024;14(12):e079756. doi:10.1136/bmjopen-2023-079756.
11. Eysenbach G, Powell J, Kuss O, Sa ER. Empirical studies assessing the quality of health information for consumers on the world wide web: a systematic review. JAMA. 2002;287(20):2691–2700. doi:10.1001/jama.287.20.2691.
12. Daraz L, Morrow AS, Ponce OJ, Beuschel B, Farah MH, Katabi A, et al. Can Patients Trust Online Health Information? A Meta-narrative Systematic Review Addressing the Quality of Health Information on the Internet. J Gen Intern Med. 2019;34(9):1884–1891. doi:10.1007/s11606-019-05109-0.
13. Decker AM, Stuhr S, Testori T, Wang HL. Clinical and radiographic changes following transcrestal sinus augmentation: A scoping review of the last 25 years. Clin Implant Dent Relat Res. 2024;26(6):1338–1353. doi:10.1111/cid.13389.
14. Alpaydin MT, Alpaydin T, Koklu M, Buyuk SK. Quality assessment of available Internet information on early orthodontic treatment. BMC Oral Health. 2024;24(1):351. doi:10.1186/s12903-024-04019-w.
15. Qurban HA, Alturki S K N, Alharbi NM, Alerwi AH, Alharbi RJ, Alassaf MS. Assessment of Arabic Web-Based Knowledge About Root Canal Treatment: An Infodemiologic Study. Cureus. 2024;16(5):e59794. doi:10.7759/cureus.59794.
16. Yoo SR, Yoo JH, Kim BS, Kim BC. Assessment of the Quality of Sinus Elevation with Lateral Window Approach Procedure Videos on YouTube: A Content-quality Analysis. J Craniofac Surg. 2024;35(4):1138–1142. doi:10.1097/SCS.0000000000010169.
17. Silberg WM, Lundberg GD, Musacchio RA. Assessing, controlling, and assuring the quality of medical information on the Internet: Caveant lector et viewor—Let the reader and viewer beware. JAMA. 1997;277(15):1244–1245.
18. Charnock D, Shepperd S, Needham G, Gann R. DISCERN: an instrument for judging the quality of written consumer health information on treatment choices. J Epidemiol Community Health. 1999;53(2):105–111. doi:10.1136/jech.53.2.105.
19. Robillard JM, Jun JH, Lai JA, Feng TL. The QUEST for quality online health information: validation of a short quantitative tool. BMC Med Inform Decis Mak. 2018;18(1):87. doi:10.1186/s12911-018-0668-9.
20. Moult B, Franck LS, Brady H. Ensuring quality information for patients: development and preliminary validation of a new instrument to improve the quality of written health care information. Health Expect. 2004;7(2):165–75. doi:10.1111/j.1369-7625.2004.00273.x.
21. Weil AG, Bojanowski MW, Jamart J, Gustin T, Leveque M. Evaluation of the quality of information on the Internet available to patients undergoing cervical spine surgery. World Neurosurg. 2014;82(1-2):e31–39. doi:10.1016/j.wneu.2012.11.003.
22. Flesch R. A new readability yardstick. J Appl Psychol. 1948;32(3):221–233. doi:10.1037/h0057532.
23. Coleman M, Liau TL. A computer readability formula designed for machine scoring. Journal of Applied Psychology. 1975;60(2):283–284. doi:10.1037/h0076540.
24. Kher A, Johnson S, Griffith R. Readability Assessment of Online Patient Education Material on Congestive Heart Failure. Adv Prev Med. 2017;2017:9780317. doi:10.1155/2017/9780317.
25. van Ballegooie C, Hoang P. Assessment of the Readability of Online Patient Education Material from Major Geriatric Associations. J Am Geriatr Soc. 2021;69(4):1051–1056. doi:10.1111/jgs.16960.
26. Cohen J. Set Correlation and Contingency Tables. Applied Psychological Measurement. 1988;12(4):425–434. doi:10.1177/014662168801200410.
27. Raja SV. Management of the posterior maxilla with sinus lift: review of techniques. J Oral Maxillofac Surg. 2009;67(8):1730–1734. doi:10.1016/j.joms.2009.03.042.
28. Chu JT, Wang MP, Shen C, Viswanath K, Lam TH, Chan SSC. How, When and Why People Seek Health Information Online: Qualitative Study in Hong Kong. Interact J Med Res. 2017;6(2):e24. doi:10.2196/ijmr.7000.
29. Wang J, Sun X, Lv H, Du L, Wang L, Zhou Y. Endoscope-Assisted Maxillary Sinus Floor Elevation with Platelet-Rich Fibrin Grafting and Simultaneous Implant Placement: A Prospective Clinical Trial. Int J Oral Maxillofac Implants. 2021;36(1):137–145. doi:10.11607/jomi.8723.
30. Urman A, Makhortykh M. You are how (and where) you search? Comparative analysis of web search behavior using web tracking data. J Comput Soc Sci. 2023;6(2):1–16. doi:10.1007/s42001-023-00208-9.
31. Ferlias N, Smith K, Straarup A, Travancic L, Kristensen KD, Stoustrup P. Quality assessment of online information on orthodontic Web sites in the United States. Am J Orthod Dentofacial Orthop. 2023;163(6):843–850. doi:10.1016/j.ajodo.2022.09.012.
32. Goller Bulut D, Paksoy T, Ustaoglu G. Is Online Video a Suitable Source to Obtain Sufficient and Useful Information About Peri-Implantitis? J Oral Maxillofac Surg. 2023;81(1):56–64. doi:10.1016/j.joms.2022.10.001.
33. Meade MJ, Jensen S, Ju X, Hunter D, Jamieson L. Assessment of the quality and accuracy of information contained within the websites of marketed orthodontic products: a cross-sectional investigation. Angle Orthod. 2024;94(3):273–279. doi:10.2319/100423-672.1.
34. Meade MJ, Dreyer CW. Ectopic and impacted maxillary canines: A quality evaluation of online information. J Orthod. 2022;49(4):420–425. doi:10.1177/14653125221109281.
35. Engelmann J, Fischer C, Nkenke E. Quality assessment of patient information on orthognathic surgery on the internet. J Craniomaxillofac Surg. 2020;48(7):661–665. doi:10.1016/j.jcms.2020.05.004.
36. Lee KC, Berg ET, Jazayeri HE, Chuang SK, Eisig SB. Online Patient Education Materials for Orthognathic Surgery Fail to Meet Readability and Quality Standards. J Oral Maxillofac Surg. 2019;77(1):180 e1–180 e8. doi:10.1016/j.joms.2018.08.033.
37. Leira Y, Castelo-Baz P, Perez-Sayans M, Blanco J, Lorenzo-Pouso AI. Available patient-centered Internet information on peri-implantitis. Can our patients understand it? Clin Oral Investig. 2019;23(4):1569–1574. doi:10.1007/s00784-018-2583-y.
38. Rehman I, Elmahgoub F, Goodall C. Evaluation of the information provided by UK dental practice websites regarding complications of dental implants. Br Dent J. 2021;230(12):831–834. doi:10.1038/s41415-021-3080-2.
39. Ngo MK, Kee NLY, Jensen ED, Meade MJ. A scoping review of website-based orthognathic surgery information. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology. 2025. doi:https://doi.org/10.1016/j.oooo.2024.12.022.
40. Yuan S, John D, Shambhunath S, Humphris G. A scoping review to explore patient trust in dentistry: the definition, assessment and dental professionals' perception. Br Dent J. 2023. doi:10.1038/s41415-023-5882-x.
41. Johnston JS, Skinner NA, Tokar A, Arabi E, Ndiaye NY, Strehlow MC, et al. Global Use, Adaptation, and Sharing of Massive Open Online Courses for Emergency Health on the OpenWHO Platform: Survey Study. J Med Internet Res. 2025;27:e52591. doi:10.2196/52591.
42. Twersky SE, Jefferson R, Garcia-Ortiz L, Williams E, Pina C. The Impact of Limited English Proficiency on Healthcare Access and Outcomes in the U.S.: A Scoping Review. Healthcare (Basel). 2024;12(3):364. doi:10.3390/healthcare12030364.
43. Association AM, Schwartzberg J. Health Literacy Help Your Patients Understand [Electronic Book]. American Medical Association Press; 2003. Available from: https://books.google.com/books/about/Health_Literacy_Help_Your_Patients_Under.html?hl=&id=qinZMQEACAAJ.
44. Schwarzbach HL, Mady LJ, Kaffenberger TM, Duvvuri U, Jab-

bour N. Quality and Readability Assessment of Websites on Human Papillomavirus and Oropharyngeal Cancer. Laryngoscope. 2021;131(1):87–94. doi:10.1002/lary.28670.
45. Jo JH, Kim JR, Kim MJ, Chung JW, Park JW. Quality and readability of online information on dental treatment for snoring and obstructive sleep apnea. Int J Med Inform. 2020;133:104000. doi:10.1016/j.ijmedinf.2019.104000.
46. Patel U, Cobourne MT. Orthodontic extractions and the Internet: quality of online information available to the public. Am J Orthod Dentofacial Orthop. 2011;139(2):e103–9. doi:10.1016/j.ajodo.2010.07.019.
47. Baqraf YKA, Keikhosrokiani P, Al-Rawashdeh M. Evaluating online health information quality using machine learning and deep learning: A systematic literature review. Digit Health. 2023;9:20552076231212296. doi:10.1177/20552076231212296.
48. Abreu AA, Murimwa GZ, Farah E, Stewart JW, Zhang L, Rodriguez J, et al. Enhancing Readability of Online Patient-Facing Content: The Role of AI Chatbots in Improving Cancer Information Accessibility. J Natl Compr Canc Netw. 2024;22(2 D):e237334. doi:10.6004/jnccn.2023.7334.
49. Golan R, Ripps SJ, Reddy R, Loloi J, Bernstein AP, Connelly ZM, et al. ChatGPT's Ability to Assess Quality and Readability of Online Medical Information: Evidence From a Cross-Sectional Study. Cureus. 2023;15(7):e42214. doi:10.7759/cureus.42214.
50. Ziakis C, Vlachopoulou M. Artificial Intelligence's Revolutionary Role in Search Engine Optimization. In: Strategic Innovative Marketing and Tourism. Springer Nature Switzerland; 2024. p. 391–399.

European Annals of Dental Sciences
Official Publication of Ankara University, Faculty of Dentistry

*EADS*, 2025, 52 (1), 34–40

e-ISSN : 2757-6744
doi : 10.52037/eads.2025.0005

Article Received/Accepted : December, 22 2024 / February, 3 2025

ORIGINAL RESEARCH ARTICLE

# Evaluation of Color Stability in One and Multi-Shade Composite Resin Materials Polymerized with Different Curing Modes

Leyla Kerimova Köse [1], Ruhsan Müdüroğlu Adıgüzel [1,*], Bilge Ersöz [2], Meriç Yavuz Çolak [3] and Kıvanç Yamanel [4]

[1]Department of Restorative Dentistry, Başkent University, Faculty of Dentistry, Ankara, Türkiye and [2]Department of Restorative Dental Treatment, University of Health Sciences, Gulhane Faculty of Dentistry, Ankara, Türkiye and [3]Department of Biostatistics, Başkent University, Faculty of Medicine, Ankara, Türkiye and [4]Private Dental Practice, Ankara, Türkiye

*Corresponding Author; ruhsanm@gmail.com

## Abstract

**Purpose:** This in vitro study aimed to compare the color stability of one-shade (Omnichroma and Vittra APS Unique) and multi-shade (Filtek Z250) composite resin materials after light-curing using standard (ST) and soft-start (SS) curing modes.
**Materials and Methods:** Seventy-eight disc-shaped specimens (n=13 per subgroup) were prepared using Omnichroma, Vittra APS Unique, and Filtek Z250 composite resins. Specimens were light-cured in either Soft Start or Standard mode and immersed in coffee solution at 37°C for 30 days. Color changes ($\Delta E_{00}$) were measured with a spectrophotometer on days 1, 7, and 30, using the CIEDE2000 formula.
**Results:** All materials showed significant and clinically unacceptable color changes ($\Delta E_{00} > 1.8$). The highest staining occurred during the first 7 days. Filtek Z250 exhibited the least staining, while SS curing mode led to greater discoloration compared to ST for Vittra APS Unique and Filtek Z250. Omnichroma's color change was not significantly affected by curing mode over 30 days.
**Conclusions:** Both curing modes failed to maintain clinically acceptable color stability in all tested materials. The type of composite resin and polymerization mode influenced staining, with soft-start curing increasing susceptibility to discoloration in certain materials.

**Keywords**: Color stability; Composite resin; Polymerization mode; One-shade composite; Soft-start polymerization

## Introduction

Composite resin-based materials are frequently preferred by dental practitioners today for the construction of esthetic restorations. Nowadays, dentists are interested in using one-shade restorative materials as they reduce the need for a wide range of composite shades, minimize the wastage of unnecessary shades, and save chairside time for shade selection or combination.[1]

Color stability is a crucial physical property of esthetic restorations. The color stability of resin composites significantly impacts their clinical longevity and performance in the oral cavity[2] and in case of severe staining replacing the restoration could be inevitable.

Polymerization reaction starts when the cross-linking reaction begins, and the carbon-carbon double bonds are converted into carbon-carbon single bonds. The percentage of double bonds converted to single bonds is indicated by the degree of conversion (DC).[3] DC is an important factor for the clinical performance of resin-based composite restorations, as it affects various composite properties including mechanical properties, polymerization shrinkage and stress, biocompatibility, solubility, color stability, degradation, and water sorption.[4,5] DC of light-cured resin-based composites depends on extrinsic and intrinsic factors. Intrinsic factors are associated with the composition of restorative materials (photoinitiator system, monomer type and amount, and filler composition) while the extrinsic factors include variables related to the polymerization process such as the curing mode, the light curing tip positioning, irradiance, light spectrum, and post-cure reactions.[3] Composite resin restorations may show extrinsic staining due to insufficient polymerization, water or food's and beverages' col-



**How to cite:** Kerimova Kose L, Muduroglu Adiguzel R, Ersoz B, Yavuz Colak M, Yamanel K. Evaluation of Color Stability in One- and Multi-Shade Composite Resin Materials Polymerized with Different Curing Modes. EADS. 2025;52(1): 34-40

orants absorption.[6,7] Residual monomers remaining as a result of an insufficient degree of conversion can cause color deterioration therefore polymerization adequacy is critical to achieve color stability.[8] Different curing modes, have appeared to improve polymerization by affecting polymer composition, degree of conversion, and number of cross-links.[9] Previous studies reported that curing mode has an impact on the color stability of the composite resins.[10,11] Thus, choosing of suitable curing mode is important to obtain long-lasting color stability of restorations. Besides the existence of residual unconverted monomers which can increase water sorption of resin matrix might result in absorption and adsorption of colorants of beverages such as coffee into the resin surface[12] and further staining, as well.

In recent years, growing interest in one-shade composites has led to increased research on their color stability. However, there is limited knowledge regarding the long-term impact of polymerization modes on the color stability of these composites in clinical settings. Thus, the aim of this study is to instrumentally compare the color stability of two different one-shade universal composite resin materials (Omnichroma and Vittra APS Unique) with the control group (Filtek Z250), a multi-shade composite resin material, after light-curing in soft start (SS) and standard (ST) curing modes, by using spectrophotometry.

Two null hypotheses were established in the study. The first null hypothesis states that there is no difference between composite resin restorative materials in terms of color stability against staining, regardless of curing modes. The second null hypothesis suggests that the curing mode used for the polymerization, regardless of the composite resin material, does not affect staining.

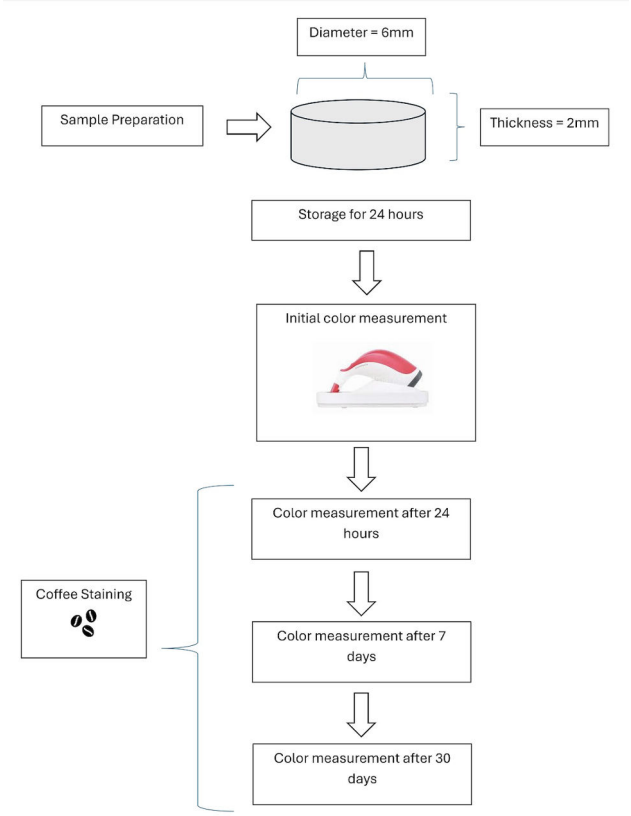


**Figure 1.** Flowchart of the study process

## Material and Methods

### Calculation of Sample Size

The calculation of the sample size required to test the research hypothesis was made with the G*Power 3.1.9 program. The minimum sample size for each tested subgroup was calculated as 11, which will provide 95% test power at a 95% confidence level, with the effect width for "Two-Way Variance Analysis in Repeated Measurements with Repetitions on a Single Factor" being small effect width, f=0.25, and each composite. An equal number of 26 samples were prepared for each material under two different curing modes, accounting for potential dropouts due to sample defects (n=13 for each group).

### Specimen preparation

Two different one-shade composite materials, Omnichroma (Tokuyama Dental, Tokyo, Japan), Vittra APS Unique (FGM, Joinville, SC, Brazil), and A2 shade of Filtek Z250 (Filtek, 3M ESPE, St Paul, MN, USA), a multi-shade universal resin-based composite, were used for this study (Table 1). Seventy-eight discs (thickness=2 mm, and diameter=6 mm) were prepared by placing the material in a Teflon mold with a single increment (Figure 1). Then, the mold was covered with a mylar strip, and the excess material removed by gentle pressure was applied by placing microscopic slides on the top and bottom surfaces of the mold. In the group where ST curing mode was applied, discs were light-cured for 20 seconds at a constant light power of 1000-1200 mW/cm$^2$ using an LED device (B-Cure, Guilin Woodpecker Medical Instrument Co., Ltd., Guilin, China). In the group where SS curing mode was applied, discs were light-cured for 20 seconds at continuously increasing light power of 0-1200 mW/cm$^2$. The light device was rested for 30 seconds after every 10 exposures following the user instructions. The power of the unit was verified using a radiometer (Bluephase Meter II; Ivoclar Vivadent, Amherst, New York) after every third measurement. For polishing the samples, polishing discs with hard, medium, fine and super fine grains ranging from hard to super fine were used (Sof-Lex, 3M/ESPE, St Paul, MN, USA). Polishing operations were limited to 10 seconds for each disc to prevent microcracks formation. Each polishing disc changed in every 3 samples to avoid loss of abrasiveness.

After each polishing step, the sample was checked by washing and drying it with an air syringe to obtain a smoother and uniform surface. Then, the samples were kept in distilled water in a light-proof container at 100% humidity and 37°C for 24 hours before initial color measurement.

### Staining procedure

The initial colors (L*, a* and b* values) of the samples were measured with a spectrophotometer device (Vita Easyshade V; VITA Zahnfabrik, Germany) under D65 lighting conditions.

The samples were placed in multiple well plates, each containing 5 ml of coffee. A coffee solution (Nescafe Classic; Nestle, Bursa, Turkey) was prepared according to the manufacturer's instructions (2 g of coffee per 200 ml of water) and added to the samples at 37 °C. The samples were then incubated at 37 °C for 30 days (FN 500, Nüve, Türkiye) to simulate color changes over time. The coffee solution was replaced with a fresh one every 24 hours. On the $1^{st}$, $7^{th}$, and $30^{th}$ days measurements of L*, a* and b* values of each sample were performed with the same spectrophotometer device in the abovementioned conditions. A schematic view of the study design is shown in Figure 2.

### Statistical Analysis

The CIEDE2000 formula ($\Delta E_{00}$) was used to calculate color changes in composite resins based on L*, a* and b* values of the samples

**Table 1.** Composite materials evaluated in this study

| Material | Manufacturer | Filler type | Filler content wt% vol% | Particle size | Monomer | Shades |
|---|---|---|---|---|---|---|
| Omnichroma | Tokuyama Dental, Tokyo, Japan | Spherical Silica-Zirconia and Composite fillers | 79 68 | 260nm | UDMA, TEGDMA | Universal Shade |
| Vittra APS Unique | FGM, Joinville, SC, Brazil | Charge particles of zirconia and silica | 75 55 | | Mixture of methacrylate monomers | Universal Shade |
| Filtek Z250 | 3M ESPE, St. Paul, MN | Ceramic treated silane (65–90) Silica treated silane (1–10) Zirconium | 84.5 60 | 0.01–3.5 μm | Bis-GMA, UDMA, BisEMA | A2 |

Abbreviations: Bis-EMA, bisphenol A polyethylene glycol diether dimethacrylate; Bis-GMA, bisphenol A diglycidylmethacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate

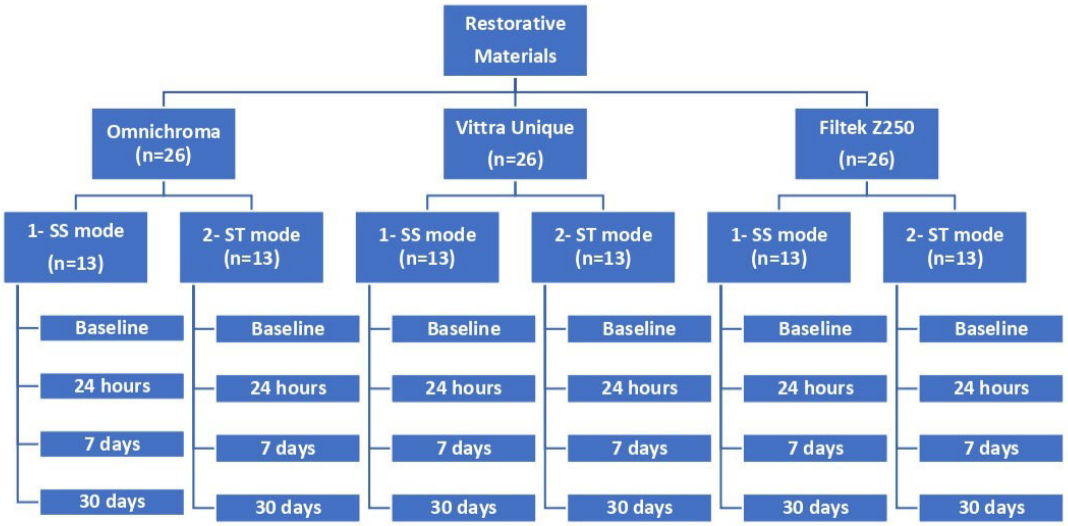


**Figure 2.** Schematic view of the study design

measured in different time intervals by using an Excel spreadsheet implementation of the CIEDE2000 formula. A measured color difference ($\Delta E_{00}$) greater than 1.8 was considered a clinically unacceptable color change. By averaging the three $\Delta E_{00}$ values obtained for each sample, an average $\Delta E_{00}$ value was obtained for each of the samples of the three materials.

Statistical analyses were conducted using SPSS version 25.0 software for Windows (IBM SPSS, Chicago, IL, USA) and Jamovi version 2.4 software. The normality of the distribution of variables was examined with the Shapiro-Wilk test. Descriptive analyses were presented using mean, standard deviation, median, minimum, and maximum values. To investigate significant differences in repeated measures obtained at different times across material groups, a Mixed-Effect Model was used. Differences between groups were determined by Dunn's Bonferroni Test. A $p < 0.05$ was considered statistically significant.

## Results

The independent variables tested in the study were as follows:

- Type of composite resin material (Omnichroma, Vittra APS Unique, and Filtek Z250)
- Type of Polymerization Mode (Soft Start: SS and Standard: ST).
- Different time intervals (Baseline-24 hours, Baseline-7 days, Baseline-30 days, 24 hours-7 days, 24 hours-30 days, 7days-30 days)

**Table 2.** Mixed Effect ANOVA Model Results

| | F | Num df | p |
|---|---|---|---|
| **Material** | 104.75 | 2 | <.001 |
| **Mode** | 117.20 | 1 | <.001 |
| **Time** | 1039.95 | 5 | <.001 |
| **Material ⋆ Mode** | 5.12 | 2 | 0.008 |
| **Material ⋆ Time** | 31.34 | 10 | <.001 |
| **Mode ⋆ Time** | 89.32 | 5 | <.001 |
| **Material ⋆ Mode⋆ Time** | 44.94 | 10 | <.001 |

A mixed-effects ANOVA was conducted to evaluate the impact of composite resin material and polymerization mode on the mean color differences ($\Delta E_{00}$) of specimens over time. The results are summarized in Table 2.

The $\Delta E_{00}$ values ranged from 0.93 to 11.74 after 30 days of exposure to coffee solutions, as shown in Figure 3. Mean color differences ($\Delta E_{00}$), standard deviations, and median values for specimens polymerized using different curing modes and stained with coffee at various time intervals are presented in Table 3 and Figure 3.

The simple main effects analysis of the mixed-effects ANOVA revealed that the composite resin material had a statistically significant effect ($F(2) = 104.75$, $p < 0.001$). All materials were statistically significantly different from each other ($p < 0.001$ for all comparisons). Polymerization mode also showed a statistically significant effect ($F(1) = 117.20$, $p < 0.001$). Additionally, time demonstrated a statistically significant effect ($F(5) = 1039.95$, $p < 0.001$). Across all

**Table 3.** Comparisons of mean color differences ($\Delta E_{00}$), standard deviations for specimens polymerized at different composite resin material and curing modes and stained with coffee at different times

| Composite resin material | Time | Curing Modes SS $\bar{x} \pm s$ | Curing Modes ST $\bar{x} \pm s$ | p mat x mod x time | p material | p mat x mode | p mat x time |
|---|---|---|---|---|---|---|---|
| Omnichroma | Baseline-24 hours | $3,26 \pm 0,40^{a,A}$ | $6,5 \pm 1,09^{a,B}$ | <0.001 | | | |
| | Baseline-7 days coffee | $6,91 \pm 0,32^{c,A}$ | $7,02 \pm 1,06^{c,A}$ | 0.99 | | | |
| | Baseline-30 days coffee | $9,28 \pm 0,96^{d,A}$ | $8,48 \pm 1,47^{d,A}$ | 0.99 | | | |
| | 24 hours-7 days coffee | $3,98 \pm 0,84^{b,A}$ | $0,95 \pm 0,59^{b,B}$ | <0.001 | | | |
| | 24 hours-30 days coffee | $6,24 \pm 1,33^{a,A}$ | $2,24 \pm 0,85^{a,B}$ | <0.001 | | | |
| | 7days-30 days coffee | $2,68 \pm 0,78^{b,A}$ | $1,94 \pm 1,04^{b,A}$ | 0.99 | | | |
| **p Omnichroma x mode** | | **<0.001** | | **p** | | | |
| Vittra APS Unique | Baseline-24 hours | $6,43 \pm 0,57^{a,A}$ | $4,63 \pm 0,45^{a,B}$ | <0.001 | | | |
| | Baseline-7 days coffee | $10,26 \pm 0,75^{c,A}$ | $5,9 \pm 0,59^{c,B}$ | <0.001 | | | |
| | Baseline-30 days coffee | $11,74 \pm 0,85^{d,A}$ | $9,1 \pm 0,84^{d,B}$ | <0.001 | | | |
| | 24 hours-7 days coffee | $4,28 \pm 0,91^{b,A}$ | $1,6 \pm 0,12^{b,B}$ | <0.001 | **<0.001** | **0.008** | **<0.001** |
| | 24 hours-30 days coffee | $5,65 \pm 1,07^{a,A}$ | $4,69 \pm 0,74^{a,A}$ | 0.99 | | | |
| | 7days-30 days coffee | $1,57 \pm 0,10^{b,A}$ | $3,27 \pm 0,84^{b,B}$ | <0.001 | | | |
| **p Vittra APS Unique x mode** | | **<0.001** | | **p** | | | |
| Filtek Z250 | Baseline-24 hours | $3,07 \pm 0,68^{a,A}$ | $2,84 \pm 0,17^{a,A}$ | 0.99 | | | |
| | Baseline-7 days coffee | $5,87 \pm 0,47^{c,A}$ | $3,47 \pm 0,50^{c,B}$ | <0.001 | | | |
| | Baseline-30 days coffee | $7,35 \pm 0,60^{d,A}$ | $5,78 \pm 0,84^{d,B}$ | <0.001 | | | |
| | 24 hours-7 days coffee | $3,17 \pm 0,89^{b,A}$ | $0,93 \pm 0,42^{b,B}$ | <0.001 | | | |
| | 24 hours-30 days coffee | $4,62 \pm 0,84^{a,A}$ | $3,02 \pm 0,81^{a,B}$ | <0.001 | | | |
| | 7days-30 days coffee | $1,55 \pm 0,29^{b,A}$ | $2,51 \pm 1,00^{b,A}$ | 0.99 | | | |
| **p Filtek Z250 x mode** | | **<0.001** | | | | | |
| | **p time<0.001** | **p mode<0.001** | | | | | |
| | | **p mod x zaman <0.001** | | | | | |
| **p mat x mod x time <0.001** | | | | | | | |

Abbreviations: $\bar{x}$: mean; s: Standard deviation. SS: Soft start, ST: Standard. *Different superscript lowercase letters in the same column indicate a statistically significant difference between time intervals within each material and curing mode (p< 0,05). *Different superscript uppercase letters in the same row indicate a statistically significant difference between curing modes within each composite resin material (p< 0,05).

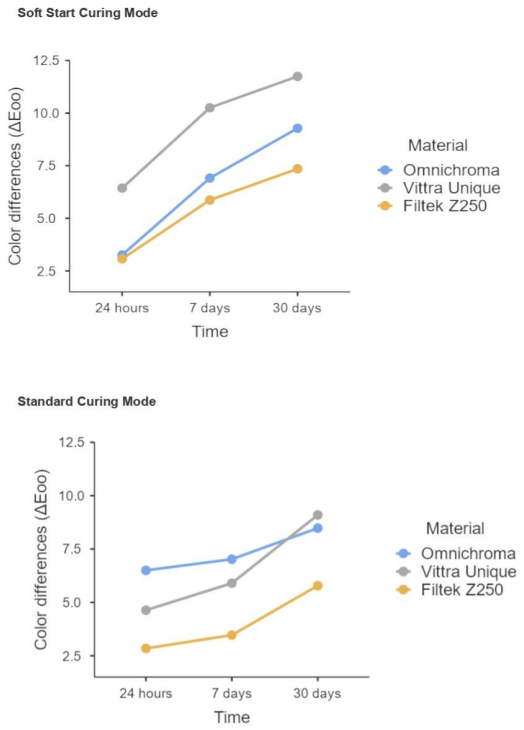


**Figure 3.** Time-dependent color changes of various materials with different polymerization modes

materials and polymerization modes, the most significant staining occurred within the first 24 hours and during the first 7 days.

There was a statistically significant interaction between the effects of composite resin material and polymerization mode ($F(2) = 5.12$, $p = 0.008$). The variability in values across materials differed between polymerization modes. Additionally, there was a statistically significant interaction between the effects of composite resin material and time ($F(10) = 31.34$, $p < 0.001$). All materials exhibited statistically significant increases in color change over time, regardless of the polymerization mode (Table 3 and Figure 3).

There was a statistically significant interaction between the effects of polymerization mode and time ($F(5) = 89.32$, $p < 0.001$). The changes over time differed between polymerization modes, regardless of the material. Additionally, a statistically significant three-way interaction was observed between composite resin material, polymerization mode, and time ($F(10) = 44.94$, $p < 0.001$). For all three materials, polymerization modes demonstrated significant interactions with time ($p < 0.001$ for all comparisons).

For the Omnichroma material, polymerization modes showed significant differences at all time points except for Baseline–7 days, Baseline–30 days, and 7 days–30 days. For the Vittra APS Unique material, significant differences were observed at all time points except for 24 hours–30 days. In the Filtek Z250 material, polymerization modes showed significant differences at all time points except for Baseline–24 hours and 7 days–30 days (Table 3).

Based on the comparisons between Baseline–30 days, Vittra APS Unique samples cured with the SS mode exhibited the highest staining, while Filtek Z250 samples cured with the ST mode exhibited the least staining (Table 4).

After the first 24 hours, the curing mode had no statistically significant effect on staining for Filtek Z250 samples (Table 3).

When comparing measurements between Baseline–30 days, no statistical difference was observed between the curing modes in terms of staining for Omnichroma samples. However, Filtek Z250 and Vittra APS Unique samples exhibited greater staining when cured with the SS mode (Table 4).

For measurements taken between 24 hours–7 days, no statistically significant differences in staining were observed among any

**Table 4.** Mean color differences ($\Delta E_{00}$), standard deviations, and significant differences for each time interval among composite resin material specimens cured using two different modes

| **Light Curing Mode** | **Soft Start** | | | **Standard** | | |
|---|---|---|---|---|---|---|
| **Composite Resin Material** | **Omnichroma** | **Vittra APS Unique** | **Filtek Z250** | **Omnichroma** | **Vittra APS Unique** | **Filtek Z250** |
| | **$\bar{x}$ ± s** | **$\bar{x}$ ± s** | **$\bar{x}$ ± s** | **$\bar{x}$ ± s** | **$\bar{x}$ ± s** | **$\bar{x}$ ± s** |
| **Baseline-24 hours** | 3,26± 0,40$^{A}$ | 6,43± 0,57$^{B}$ | 3,07± 0,68$^{A}$ | 6,5± 1,09$^{A}$ | 4,63± 0,45$^{B}$ | 2,84± 0,17$^{C}$ |
| **Baseline-7 days coffee** | 6,91± 0,32$^{A}$ | 10,26± 0,75$^{B}$ | 5,87± 0,47$^{A}$ | 7,02± 1,06$^{A}$ | 5,9± 0,59$^{A}$ | 3,47± 0,50$^{B}$ |
| **Baseline-30 days coffee** | 9,28± 0,96$^{A}$ | 11,74± 0,85$^{B}$ | 7,35± 0,60$^{C}$ | 8,48± 1,47$^{A}$ | 9,1± 0,84$^{A}$ | 5,78± 0,84$^{B}$ |
| **24 hours-7 days coffee** | 3,98± 0,84$^{A}$ | 4,28± 0,91$^{A}$ | 3,17± 0,89$^{A}$ | 0,95± 0,59$^{A}$ | 1,6± 0,12$^{A}$ | 0,93± 0,42$^{A}$ |
| **24 hours-30 days coffee** | 6,24± 1,33$^{A}$ | 5,65± 1,07$^{AB}$ | 4,62± 0,84$^{B}$ | 2,24± 0,85$^{A}$ | 4,69± 0,74$^{B}$ | 3,02± 0,81$^{A}$ |
| **7days-30 days coffee** | 2,68± 0,78$^{A}$ | 1,57± 0,10$^{A}$ | 1,55± 0,29$^{A}$ | 1,94± 1,04$^{A}$ | 3,27± 0,84$^{B}$ | 2,51± 1,00$^{AB}$ |
| | **p mat x mod x time <0.001** | | | | | |

Abbreviations: $\bar{x}$: mean; s: Standard deviation. SS: Soft start, ST: Standard. *Different superscript letters in the same row indicate a statistically significant difference among composite resin materials within the same curing mode (p< 0,05).

composite resin materials for either curing mode. Similarly, no significant differences were observed for measurements taken between 7–30 days among materials cured with the SS mode (Table 4).

## Discussion

Color stability is a key factor affecting the esthetic outcome of composite restorations providing dentists' and patients' satisfaction. Changes in color over time can be attributed to the material itself as well as the factors associated with dental practitioners such as curing light intensity, ignoring the manufacturer recommendations, or poor isolation revealed during the application procedure. Also, the dietary habits of patients with partially frequent/long-lasting consumption of discoloring beverages might result in surface staining. In this context, the time during which the restorations are exposed to staining beverages should also be considered.

Two null hypotheses were tested in the present study. The first null hypothesis stated that there was no difference between restorative materials in terms of color stability against staining, regardless of curing modes while the second null hypothesis stated that regardless of the restorative material, the curing mode used, does not affect staining. According to the findings of the study, the staining amount resulting from exposure to the colorant varied according to the material and the curing mode affected the staining in all time intervals except the first 24 hours. Therefore, both null hypotheses were rejected.

In the field of dentistry, precise measurement of color differences is critical for assessing dental restorative materials. The CIELAB ($\Delta E_{a_b}$) formula is a commonly employed method that quantifies color using three spatial coordinates: L* (lightness), a* (red-green axis), and b* (yellow-blue axis). This model has been foundational in color difference evaluation. However, the CIEDE2000 ($\Delta E_{00}$) model offers an enhanced approach by incorporating factors such as lightness, chroma, and hue, alongside weighting functions that adjust for perceptual non-uniformities. Crucially, $\Delta E_{00}$ includes an interaction term that accounts for the interplay between chroma and hue differences, which better reflects the shade differences as recognized by the human eye compared to the CIELAB formula. Consequently, the CIEDE2000 formula provides a superior correlation between visually perceived color differences and mathematically calculated values.[13] In light of these advantages, the CIEDE2000 color difference formula was selected for data evaluation in our study.[14,15] Establishing perceptual and receptive thresholds for color differences is crucial for effectively interpreting and assessing clinical outcomes. Specifically, perceptibility thresholds (PT) and acceptability thresholds (AT) for clinical judgment have been defined based on color difference values. For the CIEDE2000 model, PT and AT values are set at 0.8 and 1.8, respectively. In the present study, the color changes observed in materials following staining challenges were not found to be within the acceptable range according to these thresholds.

During an ST light-cure application with an immediate application of full light power intensity, the gel point typically occurs in 1.5-2 seconds. The most crucial period for stress decrease is in the initial seconds after polymerization begins, as this is when the culminant adhesive bond strength is still forming. Consequently, delaying the attainment of the gel point can slow down the development of stress by extending the viscous phase, allowing for greater flow capability and resulting in a decreased definite polymerization stress.[16,17] The SS curing mode is an alternative technique that gradually increases light intensity over the first few seconds before maintaining maximum intensity for the rest of the curing process. Previous studies demonstrated SS light curing technique results in relatively lower polymerization shrinkage stress, but this effect depends on the restorative material type.[16,18–20] However, modifying the light intensity may decrease the degree of cure in relatively deeper cavities[21] leading to the remaining of unreacted monomers. In the present study, the greater color change observed in the SS groups following staining challenges can be attributed to the under-polymerization of the restorative materials. This under-polymerization likely leads to increased water absorption and the solubility of the unreacted monomer, rendering the materials more susceptible to staining. These findings are consistent with previous research indicating that the curing mode can significantly impact the staining susceptibility of restorative materials.[10,11] Furthermore, our study corroborates the findings of Ozan et al. demonstrating that the curing mode did not influence the degree of staining within the first 24 hours.[10] This similarity underscores that despite the different polymerization methods, neither approach could maintain clinically acceptable color stability over time. However, another study demonstrated that polymerization time has no effect on the amount of color change of one-shade or multi-shade composites.[22] The absence of difference in terms of discoloration could be attributed to variations in curing time rather than the curing mode. Interestingly, samples subjected to the energy drink maintain clinically acceptable color stability for 7 days under certain protocols applied in the aforementioned study.

The results of the present study revealed that the color change was material dependent. Therefore, it should be considered that single-shade restorative materials tested in the present study were declared to have innovative and unique content by manufacturers. Omnichroma (Tokuyama Dental, Tokyo, Japan) was introduced as the first one-shade composite resin material claimed to adapt to all tooth shades within the 16 VITA classic colors, from A1 to D4, due to its uniformly sized supra-nano spherical filler (260 nm spherical $SiO_2$-$ZrO_2$) combined with Smart Chromatic Technology.[23] Vittra APS Unique (FGM, Joinville, SC, Brazil), is a one-shade universal composite that mimics the shade of the dental substrate during the polymerization process and provides color imitation thanks to the chromatic reflection properties of the composite. The manufacturer declares that the exclusive APS Technology (Advanced Polymerization System) provides shadow transmission and mirror-

ing esthetics by more transparent photoinitiators. Specifically, the overall color change for Filtek Z250 (3M ESPE, St Paul, MN, USA), was lower compared to Omnichroma (Tokuyama Dental, Tokyo, Japan) and Vittra (FGM, Joinville, SC, Brazil). This superior staining resistance of Filtek Z250 (3M ESPE, St Paul, MN, USA), can be attributed to its formulation, which does not include Triethylene glycol dimethacrylate (TEGDMA). In contrast, both Omnichroma (Tokuyama Dental, Tokyo, Japan) and Vittra (FGM, Joinville, SC, Brazil), contain TEGDMA, a component known to increase water absorption and thus susceptibility to staining. These findings are consistent with other studies that have reported Filtek Z250 (3M ESPE, St Paul, MN, USA), to be more color-stable due to its use of a hydrophobic resin system, which results in lower water sorption rates and consequently better resistance to staining.[24] In contrast, another study evaluated the color stability of different restorative materials and demonstrated a relatively higher tendency for staining of Filtek Z250 (3M ESPE, St Paul, MN, USA).[25] This controversial finding could be attributed to the difference between coloring beverages used in the study and restorative control materials.

The difference in filler size among Filtek Z250 (3M ESPE, St Paul, MN, USA), Omnichroma (Tokuyama Dental, Tokyo, Japan), and Vittra (FGM, Joinville, SC, Brazil) may have influenced their surface smoothness. Materials with nano-sized fillers, such as Omnichroma (Tokuyama Dental, Tokyo, Japan) and Vittra (FGM, Joinville, SC, Brazil), are generally thought to achieve a smoother surface compared to microhybrid restoratives like Filtek Z250 (3M ESPE, St Paul, MN, USA). However, according to the present study, this advantage in surface smoothness did not translate to a decreased tendency for staining of materials with nano-sized fillers. This suggests that despite the enhanced surface smoothness associated with nano-sized fillers, it does not necessarily improve the stain resistance of dental restorative materials.

Previous studies have reported that one-shade resin composites exposed to wine, coffee, and black tea exhibit greater color changes compared to multi-shade resin composites.[22,26–28] Only one accessed study found no difference in terms of color change among one-shade composite resin and multi-shade composite resin materials.[29] Moreover, studies compared evaluated discoloration after thermocycling protocol revealed a higher tendency to color change of one-shade composites.[27,30,31] These findings are concerning because one-shade composites are often used to quickly and effectively achieve esthetic results by matching the tooth shade. However, their tendency to become significantly discolored over time implies that additional interventions may be necessary to maintain the esthetic functions of the material. On the other hand, it is important to note that due to the limited number of brands of one-shade and multi-shade materials used in this study, making a general judgment regarding the performance of one-shade versus multi-shade composites would be premature. The staining of composite resins is influenced by a variety of factors beyond the resin matrix and filler type, including the composition of activators, inhibitors, and initiators. Therefore, further research involving a broader range of materials is required to draw more definitive conclusions about the impact of shade variability on staining.[32]

In studies evaluating the color stability of restorations, the oral environment is typically simulated using various colorants such as coffee, wine, and energy drinks. However, these study designs have limitations and are insufficient to fully replicate real oral conditions. Factors such as brushing frequency, abrasion due to the kinds of toothpaste used, and nutrition involving hard foods cannot be adequately simulated in experimental conditions, yet they can significantly impact the staining of restorations. Ozan et al.[10] reported that while brushing can reduce superficial staining caused by substances like tea and cola, it is not effective in completely removing these stains. Conversely, brushing with abrasive dentifrices can deteriorate the surface smoothness of restorations, potentially leading to increased staining. On the other hand, one-shade composites showed comparable performance to multi-shade composites in terms of color stability after aging in samples that underwent brushing simulation.[31] Therefore, it is important to acknowledge that accurately replicating the dynamic conditions of the oral cavity in study designs is virtually impossible.

## Conclusion

In alignment with earlier studies, our results reinforce the notion that both curing modes failed to achieve the desired color stability in all tested restorative materials, suggesting a need for improved techniques or materials that can better withstand staining challenges.

## Ethical Approval

Ethical approval was not required for this study.

## Acknowledgements

Tokuyama Turkey is gratefully acknowledged for providing the composite resin materials used in this project. The authors do not have any financial interest in the companies whose materials are included in this article.

## Financial Support

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Author Contributions

Concept : L.K.K.
Design : L.K.K. , R.M.A.
Data Collection and/or Processing : B.E.
Analysis and/or Interpretation : M.Y.C.
Literature Research : L.K.K.
Control/Supervision : K.Y.
Writing the Article : L.K.K. , R.M.A.
Critical Review : K.Y. , B.E.

## Conflict of Interest

The authors declare no competing interests.

## Authors' ORCID(s)

L.K.K. 0000-0002-8071-1755
R.M.A. 0000-0001-5926-5378
B.E. 0000-0003-0769-0457
M.Y.C. 0000-0002-0294-6874
K.Y. 0000-0003-4237-1232

## References

1. AlHamdan EM, Bashiri A, Alnashmi F, Al-Saleh S, Al-Shahrani K, Al-Shahrani S, et al. Evaluation of smart chromatic technology for a single-shade dental polymer resin: an in vitro study. Applied Sciences. 2021;11(21):10108. doi:10.3390/app112110108.
2. Shamszadeh S, Sheikh-Al-Eslamian SM, Hasani E, Abrandabadi AN, Panahandeh N. Color Stability of the Bulk-Fill

Composite Resins with Different Thickness in Response to Coffee/Water Immersion. Int J Dent. 2016;2016:7186140. doi:10.1155/2016/7186140.
3. Yilmaz Atali P, Dogu Kaya B, Manav Ozen A, Tarcin B, Senol AA, Tuter Bayraktar E, et al. Assessment of Micro-Hardness, Degree of Conversion, and Flexural Strength for Single-Shade Universal Resin Composites. Polymers (Basel). 2022;14(22). doi:10.3390/polym14224987.
4. Sarosi C, Moldovan M, Soanca A, Roman A, Gherman T, Trifoi A, et al. Effects of Monomer Composition of Urethane Methacrylate Based Resins on the C=C Degree of Conversion, Residual Monomer Content and Mechanical Properties. Polymers (Basel). 2021;13(24). doi:10.3390/polym13244415.
5. Wang WJ, Grymak A, Waddell JN, Choi JJE. The effect of light curing intensity on bulk-fill composite resins: heat generation and chemomechanical properties. Biomater Investig Dent. 2021;8(1):137–151. doi:10.1080/26415275.2021.1979981.
6. Arocha MA, Mayoral JR, Lefever D, Mercade M, Basilio J, Roig M. Color stability of siloranes versus methacrylate-based composites after immersion in staining solutions. Clin Oral Investig. 2013;17(6):1481–1487. doi:10.1007/s00784-012-0837-7.
7. Reis AF, Vestphal M, Amaral RCD, Rodrigues JA, Roulet JF, Roscoe MG. Efficiency of polymerization of bulk-fill composite resins: a systematic review. Braz Oral Res. 2017;31(suppl 1):e59. doi:10.1590/1807-3107BOR-2017.vol31.0059.
8. Domingos PA, Garcia PP, Oliveira AL, Palma-Dibb RG. Composite resin color stability: influence of light sources and immersion media. J Appl Oral Sci. 2011;19(3):204–211. doi:10.1590/s1678-77572011000300005.
9. Aguiar FH, Braceiro A, Lima DA, Ambrosano GM, Lovadino JR. Effect of light curing modes and light curing time on the microhardness of a hybrid composite resin. J Contemp Dent Pract. 2007;8(6):1–8. doi:10.5005/jcdp-8-6-1.
10. Ozan G, Sancakli HS, Tiryaki M, Bayrak I. Effect of light curing modes on the color stability of a nanohybrid composite immersed in different beverages. Odovtos-Int J Dent Sc. 2020;22(2):71–81. doi:10.15517/ijds.2020.38726.
11. Selivany BJ. The Effect of Different Immersion Media, Polymerization Modes, and Brushing on the Color Stability of Different Composite Resins. Int J Periodontics Restorative Dent. 2023;43(2):246–255. doi:10.11607/prd.6427.
12. Paolone G, Formiga S, De Palma F, Abbruzzese L, Chirico L, Scolavino S, et al. Color stability of resin-based composites: Staining procedures with liquids-A narrative review. J Esthet Restor Dent. 2022;34(6):865–887. doi:10.1111/jerd.12912.
13. Gomez-Polo C, Portillo Munoz M, Lorenzo Luengo MC, Vicente P, Galindo P, Martin Casado AM. Comparison of the CIELab and CIEDE2000 color difference formulas. J Prosthet Dent. 2016;115(1):65–70. doi:10.1016/j.prosdent.2015.07.001.
14. Lang-Salas MG, Villarreal-Romero LA, Domínguez-Monreal JA, Cuevas-González JC, Donohué-Cornejo A, Reyes-López SY, et al. Evaluation of adhesion of total etch adhesive systems on bovine dental enamel using a deproteinizing agent: an in vitro study. Revista ADM. 2020;77(1):22–27. doi:10.35366/OD201E.
15. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, et al. Color difference thresholds in dentistry. J Esthet Restor Dent. 2015;27 Suppl 1:S1–9. doi:10.1111/jerd.12149.
16. Ernst CP, Brand N, Frommator U, Rippin G, Willershausen B. Reduction of polymerization shrinkage stress and marginal microleakage using soft-start polymerization. J Esthet Restor Dent. 2003;15(2):93–103; discussion 104. doi:10.1111/j.1708-8240.2003.tb00323.x.
17. Munchow EA, Meereis CTW, de Oliveira da Rosa WL, da Silva AF, Piva E. Polymerization shrinkage stress of resin-based dental materials: A systematic review and meta-analyses of technique protocol and photo-activation strategies. J Mech Behav Biomed Mater. 2018;82:77–86. doi:10.1016/j.jmbbm.2018.03.004.
18. Lu H, Stansbury JW, Bowman CN. Impact of curing protocol on conversion and shrinkage stress. J Dent Res. 2005;84(9):822–826. doi:10.1177/154405910508400908.
19. Taubock TT, Feilzer AJ, Buchalla W, Kleverlaan CJ, Krejci I, Attin T. Effect of modulated photo-activation on polymerization shrinkage behavior of dental restorative resin composites. Eur J Oral Sci. 2014;122(4):293–302. doi:10.1111/eos.12139.
20. Zanchi CH, de Carvalho RV, Rodrigues Junior SA, Demarco FF, Burnett Junior LH. Shrinkage stress of three composites under different polymerization methods. Braz Oral Res. 2006;20(2):137–142. doi:10.1590/s1806-83242006000200009.
21. Ilie N, Jelen E, Hickel R. Is the soft-start polymerisation concept still relevant for modern curing units? Clin Oral Investig. 2011;15:21–29. doi:10.1007/s00784-009-0354-5.
22. Checchi V, Forabosco E, Della Casa G, Kaleci S, Giannetti L, Generali L, et al. Color Stability Assessment of Single- and Multi-Shade Composites Following Immersion in Staining Food Substances. Dent J (Basel). 2024;12(9). doi:10.3390/dj12090285.
23. Kobayashi S, Nakajima M, Furusawa K, Tichy A, Hosaka K, Tagami J. Color adjustment potential of single-shade resin composite to various-shade human teeth: Effect of structural color phenomenon. Dent Mater J. 2021;40(4):1033–1040. doi:10.4012/dmj.2020-364.
24. Ertas E, Guler AU, Yucel AC, Koprulu H, Guler E. Color stability of resin composites after immersion in different drinks. Dent Mater J. 2006;25(2):371–6. doi:10.4012/dmj.25.371.
25. Topcu FT, Sahinkesen G, Yamanel K, Erdemir U, Oktay EA, Ersahan S. Influence of different drinks on the colour stability of dental resin composites. Eur J Dent. 2009;3(1):50–56. doi:10.1055/s-0039-1697405.
26. Alex A, Venkatesh V. Comparative Evaluation of Surface Roughness and Color Stability Between Single-Shade Composite and Multi-Shade Composite: An In Vitro Study. Cureus. 2024;16(7):e65396. doi:10.7759/cureus.65396.
27. Chen S, Zhu J, Yu M, Jin C, Huang C. Effect of aging and bleaching on the color stability and surface roughness of a recently introduced single-shade composite resin. J Dent. 2024;143:104917. doi:10.1016/j.jdent.2024.104917.
28. Ersoz B, Karaoglanoglu S, Oktay EA, Aydin N. Resistance of Single-shade Composites to Discoloration. Oper Dent. 2022;47(6):686–692. doi:10.2341/21-156-L.
29. Cumhur A, Özkoçak BBC. Evaluation of the Color Stability and Surface Roughness of a Novel Single-Shade Composite Resin: A Smart Chromatic Technology. Evaluation. 2024;9(1):28–35. doi:10.4274/cjms.2023.2023-37.
30. Fidan M, Yagci O. Effect of aging and fiber-reinforcement on color stability, translucency, and microhardness of single-shade resin composites versus multi-shade resin composite. J Esthet Restor Dent. 2024;36(4):632–642. doi:10.1111/jerd.13125.
31. Tepe H, Çeliksöz O, Biçer Z, Yaman B. Evaluating the effects of bleaching on color stability and surface roughness in single-shade and multi-shade resin composites. ACMJ. 2024;6(6):372–381. doi:10.38053/acmj.1543644.
32. Bilgili Can D, Ozarslan M. Evaluation of color stability and microhardness of contemporary bulk-fill composite resins with different polymerization properties. J Esthet Restor Dent. 2022;34(6):924–932. doi:10.1111/jerd.12879.

European Annals of Dental Sciences
Official Publication of Ankara University, Faculty of Dentistry

*EADS*, 2025, 52 (1), 41–44

e-ISSN : 2757-6744
Article Received/Accepted : January, 6 2025 / February, 27 2025
doi : 10.52037/eads.2025.0006
Ethical Committee No : 06-15/2019

ORIGINAL RESEARCH ARTICLE

# Evaluation of Patients Preferences for Dentists' Clinic Attire: A Cross-Sectional Study

Yasin Akbulut [1] and Semih Ercan Akgün [2], *

[1]Department of Orthodontics, Faculty of Dentistry, Kocaeli Health and Technology University, Kocaeli, Türkiye and [2]Department of Dentistry Services, Health Services of Vocational School, Ondokuz Mayıs University, Samsun, Türkiye

*Corresponding Author; semihercanakgun@gmail.com

## Abstract

**Purpose:** To evaluate the preferences of pediatric, adolescent, and young adult patients regarding dentists' clothing.
**Materials and Methods:** Five hundred and forty patients admitted to the Orthodontics and Pediatric Dentistry Departments of Fırat University Faculty of Dentistry who wanted to participate in the study were randomly selected. The patients were grouped as children (7-11 years; n=180; Group 1), adolescents (12-17 years; n=180; Group 2), and young adults (18-25 years; n=180; Group 3). Patients were shown a template consisting of eight different types of clothing, and their preferences were recorded. Uniforms with different colors between uniform no. 3-8 were classified as a single preference under the name of 'colored uniform' to determine general preferences and were evaluated separately under the title of general preferences.
**Results:** The white coat was the most preferred clothing among eight preferences by the participants (23.5%). Uniform number 3, uniform number 5, and white coat were the most preferred clothing in Group 1 (26.1%), Group 2 (22.8%), and Group 3 (55%), respectively. The general preference among the 3 groups was statistically significant ($p < 0.001$). In general preferences, colored uniforms were preferred the most (68.1%), and civilian clothing was preferred the least (8.3%). Colored uniforms were preferred mostly in Groups 1 and 2 (92.2% and 79.4%, respectively), and a white coat was the most common preference in Group 3 (55%).
**Conclusions:** Dentists' wearing the attire most preferred by patients of different ages can significantly increase patient satisfaction and patients' perceptions of the care they receive.

**Keywords**: Clinic clothing; Dentist; Patient preference

## Introduction

The high number of dentists in the current medical field has led professionals to seek ways to attract more patients under these competitive conditions. Some professionals try to distinguish themselves in this competitive area by increasing their investment in professional appearance.[1] A good-looking appearance of a doctor in the first appointment creates a favorable first impression in the patient, while developing a more successful and better relationship between the doctor and patient.[2] In addition, it has been claimed that patients' first impressions also affect their expectations of care and thoughts about the competence level of doctors.[3] Therefore, the clothing of a doctor can be evaluated by patients while preferring the doctor.[4–6]

The physical appearance and clothing of doctors have long been considered important issues. Hippocrates stated that a doctor should dress well, be well-groomed, and clean so that people can trust more easily.[7] Some studies have claimed that doctors' clothing is an important pre-indicator of trust and satisfaction for patients.[8,9] For instance, a nicely and neatly dressed doctor gives a professional, knowledgeable, and precise impression, whereas a doctor dressed in improper and untidy clothes may create a negligent and careless impression.[5] However, it has been claimed that the appearance of a doctor also increases patients' willingness to describe their symptoms.[10]

Since the 19th century, the white coat has become a strong symbol of authority and healing. The decrease in the popularity of white coats over time has led many medical specialists to wear more formal clothes, such as suits.[11] They prefer wearing jackets, suits, and ties in the pediatric setting, and colored coats in less formal places. Therefore, the physical appearance and clothing of dentists are of great importance.

There are limited studies in the literature regarding patients' preference for dentists' clothing during the first dental examination. This study aimed to evaluate the preferences of pediatric, adolescent, and young adult patients regarding the clothing of dentists.


**Figure 1.** Photos of clothing shown to patients (no.1-8)

The H0 hypothesis of our research stated that patients preferences for dentists' clinical attire are similar.

## Material and Methods

The ethical principles of medical research on human subjects in the World Medical Association (WMA) Declaration of Helsinki were followed. The study was approved on 17/10/2019, meeting no. 15, and decision no. 06 by the Non-Interventional Studies Ethics Committee of Fırat University.

Patients admitted to the Orthodontics and Pediatric Dentistry Departments of Fırat University Dentistry Faculty who wanted to participate in the study were selected randomly. An informed consent form was obtained from the patients and parents before the study. The sample consisted of 540 participants. Group 1 included 180 children between ages 7 and 11, Group 2 included 180 adolescents between ages 12 and 17, and Group 3 included 180 young adults between ages 18 and 25. Individuals with systemic diseases such as psychiatric diseases, cognitive disorders, color blindness, or visual impairment were excluded from the study.

Photographs shown to the patients were taken by the same photographer, on the same date and time, from the same angle, and with the same exposure for standardization purposes. Accessories, hairstyles, and facial expressions were the same in each photograph. Clinical clothing was the only variant in all the photographs. A template was then created to be shown to the patients by numbering the photographs (Figure 1). The template included a shirt, tie, and white coat in photograph 1; civilian clothing with shirts, ties, and jackets in photograph 2; and uniforms with different colors in photographs 3-8. Consisting of eight different photographs of a dentist, this template was shown to the participating patients, and their opinions were recorded. The photographs on this template were shown to the patients. The patients were asked the question, 'What clothing would you prefer your dentist to wear during your first dental examination?' The responses were recorded according to the group, age, and gender of the individuals. Patients' clinical clothing preferences were evaluated based on eight photographs. Afterward, five different colored clinical clothing were combined into a single parameter as 'colored uniform' and examined under the general preferences heading of white coat, civilian clothes, and colored clinical clothing.

### Statistical Analysis

IBM SPSS for Windows (Statistical Package for Social Sciences, version 24.0, Illinois, USA) was used for statistical analysis. The Shapiro-Wilk test was used to check the conformance of the digital variants to a normal distribution. Pearson's chi-square test was used to analyze categorical data. The descriptive statistics of the data are presented as mean ± standard deviation for variants with a continuous measurement value. The frequency for categorical variants was expressed as a percentage [n (%)]. The results were considered statistically significant at a 95% confidence interval ($p < 0.05$).

**Table 1.** Distribution of groups by gender

| Gender | | Group 1 | Group 2 | Group 3 | Total | p value |
|---|---|---|---|---|---|---|
| Man | n | 83 | 99 | 86 | 268 | 0.200* |
| | % | 46.1 | 55.0 | 47.8 | 49.6 | |
| Woman | n | 97 | 81 | 94 | 272 | |
| | % | 53.9 | 45.0 | 52.2 | 50.4 | |
| Total | n | 180 | 180 | 180 | 540 | |
| | % | 100.0 | 100.0 | 100.0 | 100.0 | |

*Chi-square test; n: number of participants who selected the relevant photo; $p<0.05$ was considered statistically significant.

**Table 2.** Distribution of preferences by groups

| Preferences | | Group 1 | Group 2 | Group 3 | Total | p value |
|---|---|---|---|---|---|---|
| 1 | n | $6^a$ | $22^b$ | $99^c$ | 127 | 0.001* |
| | % | 3.3 | 12.2 | 55.0 | 23.5 | |
| 2 | n | $8^a$ | $15^b$ | $22^c$ | 45 | |
| | % | 4.4 | 8.3 | 12.2 | 8.3 | |
| 3 | n | $47^a$ | $23^b$ | $7^c$ | 77 | |
| | % | 26.1 | 12.8 | 3.9 | 14.3 | |
| 4 | n | $19^a$ | $19^a$ | $12^a$ | 50 | |
| | % | 10.6 | 10.6 | 6.7 | 9.3 | |
| 5 | n | $17^a$ | $41^b$ | $29^b$ | 87 | |
| | % | 9.4 | 22.8 | 16.1 | 16.1 | |
| 6 | n | $21^a$ | $15^a$ | $6^b$ | 42 | |
| | % | 11.7 | 8.3 | 3.3 | 7.8 | |
| 7 | n | $23^a$ | $18^a$ | $3^b$ | 44 | |
| | % | 12.8 | 10.0 | 1.7 | 8.1 | |
| 8 | n | $39^a$ | $27^a$ | $2^b$ | 68 | |
| | % | 21.7 | 15.0 | 1.1 | 12.6 | |
| Total | n | 180 | 180 | 180 | 540 | |
| | % | 100.0 | 100.0 | 100.0 | 100.0 | |

*Chi-square test; n: number of participants who selected the relevant photo; $p<0.05$ was considered statistically significant. Among the numbers in the left column of the table, 1 indicates 'white coat,' 2 indicates 'civilian clothes,' and no. 3 to 8 indicate 'colored uniform' preference. $^{a-c}$: There is no difference between groups with similar superscripts on the same row.

## Results

Of the five hundred and forty patients included in the study, 272 (50.4%) were female and 268 (49.6%) were male. There was no statistically significant difference between the groups according to gender ($p > 0.05$) (Table 1).

The most preferred clothing was a white coat (23.5%), and the least was civilian clothing (8.3%), uniform no. 7 (8.1%), and uniform no. 6 (7.8%). The uniform number 3, number 5, and white coat were preferred mostly in Group 1 (26.1%), Group 2 (22.8%), and Group 3 (55%), respectively. There was a statistical difference in clothing preferences between the groups ($p < 0.001$) (Table 2).

According to the general preference, the most preferred clothing was colored uniform no. 3 (68.1%), and the least was civilian clothing (8.3%). Colored uniforms were preferred in Groups 1 and 2 (92.2% and 79.4%, respectively), and a white coat was the most common preference in Group 3 (55%). The general preference of the groups was statistically significant ($p < 0.001$) (Table 3).

**Table 3.** Distribution of general preferences by groups

| General Preferences | | Group 1 | Group 2 | Group 3 | Total | p value |
|---|---|---|---|---|---|---|
| 1 | n | $6^a$ | $22^b$ | $99^c$ | 127 | 0.001* |
| | % | 3.3 | 12.2 | 55.0 | 23.5 | |
| 2 | n | $8^a$ | $15^b$ | $22^b$ | 45 | |
| | % | 4.4 | 8.3 | 12.2 | 8.3 | |
| 3 | n | $166^a$ | $143^a$ | $59^b$ | 368 | |
| | % | 92.2 | 79.4 | 32.8 | 68.1 | |
| Total | n | 180 | 180 | 180 | 540 | |
| | % | 100.0 | 100.0 | 100.0 | 100.0 | |

*Chi-square test; n: number of participants who selected the relevant photo; $p<0.05$ was considered statistically significant. Among the numbers in the left column of the table, 1 indicates 'white coat,' 2 indicates 'civilian clothes,' and 3 indicates 'colored uniform' preference. $^{a-c}$: There is no difference between groups with similar superscripts on the same row.

## Discussion

Various factors are involved in the search for dentists by both patients and parents. A dentist who wants to reach new patients and maintain a positive relationship should be aware of the patient's opinions. This study employed a scientific approach to determine the preferences of pediatric, adolescent, and young adult patients related to dentists' clothing.

Nonverbal communication, likewise clothing and the appearance of a dentist, can have an important effect on patients. A favourable first impression created by a dentist's physical appearance may significantly affect the relationship between the dentist and the patient. The positive attitude of patients can increase information exchange between doctors and patients, which is consistent with the data reported by Gjerdingen et al.[10]

While relatives of pediatric patients prefer a doctor based on criteria such as age and gender, the doctor should also take into account the opinions of their patients regarding the clinical attire. Patients tend to prefer conventionally dressed doctors over a comfortable look.[12] In many studies, a white coat was preferred as dentists' clinical clothing.[13–17] de Souza-Constantino et al.[1], Budny et al.[5], Alsarheed et al.[4], and McKenna et al.[17] reported similar results. In our study, all patients, especially the young adult group, preferred white coats (23.5% and 55%, respectively) in general preferences. Therefore, the H0 hypothesis of our study, "Patients' preferences regarding the dentists' clinical attire will be similar," was rejected. Different clothing preferences are consistent with studies in the literature. In a study conducted by Aitken et al.[11], the most preferred option was casual clothing, followed by a white coat. Similarly, Kelly et al.[6] reported that patients preferred dentists who wore more formal attire or surgeons' uniforms. The fact that different clothing preferences were chosen by patients in the studies may be related to the differences in preferences of patients in different age groups.

While doctors with white coats are considered more reliable, experienced, and competent, younger patients prefer doctors who wear less formal clothing.[17] Likewise, in this study, patients in children and adolescent groups mainly preferred colored uniforms (92.2% and 79.4%, respectively). The most preferred clothing was colored uniform no. 3 (68.1%), and the least was civilian clothing (8.3%) overall preference. Our H1 hypothesis, "Pediatric patients will prefer colored uniforms more," was accepted because the dentist uniforms preferred by pediatric (92.2%) and adolescent (79.4%) patients were colored. These results align with the study results of McKenna et al.[17], Ahmad et al.[18], Kastelic et al.[19], Arslan et al.[20], Mohebbi et al.[21], and Sujatha et al.[22]. However, Alsarheed et al.[4] stated in their study that young participants mostly (90.2%) preferred a white coat, and colored clothing preference was at a low level (9.8%). Furthermore, Kuscu et al.[14] reported that 45.6% of the children preferred white coats in their study. A study conducted by de Souza-Constantino et al.[1] reported that adolescents mostly prefer the white coat. In addition, Oliveira et al.[23] reported in their study that the preferences for white coats and colored uniforms were similar. The differences in results may have been due to study designs for different dental procedures (initial examination, restorative procedures, surgical procedures, etc.).

Age is an important factor in personal development. In the literature, patient perspectives varied depending on age. While pediatric patients generally prefer colored uniforms, as age progresses, individuals prefer white uniforms, which look clean and hygienic and make one feel knowledgeable and confident due to increased cognitive capacity. In the current study, white uniforms were the most preferred among the eight groups, and in line with the literature, patients in the older age group preferred white uniforms more.[24,25]

This study has some limitations. Patients from different age groups stated their preferences regarding the clinic attire of the dentist during the first dental examination. Patients' preferences for different treatment procedures, such as restorative treatments or surgical treatments, were not investigated in our study. Additionally, the effects of socioeconomic status differences, different mustache and beard styles of males on patient preference, the hairstyle of both male and female dentists, and parents' education level must be investigated in further studies.

## Conclusion

According to our study, young adult patients preferred a white coat, whereas pediatric and adolescent patients preferred colored uniforms. This information may encourage dentists to adopt their preferred clothing styles. Dentists wearing clothing most preferred by patients of different age groups can substantially increase patient satisfaction and perception of care received by patients.

## Ethical Approval

This study was reviewed and approved by the Ethics Committee of the Fırat University (Decision No: 06-15/2019). Informed consent was obtained from all participants.

## Acknowledgements

Not applicable.

## Financial Support

The authors declared that this study has received no financial support.

## Author Contributions

Idea/Concept : All Authors
Design : Y.A.
Control/Supervision : All Authors
Data Collection and/or Processing : Y.A.
Analysis and/or Interpretation : Y.A.
Literature Review : S.E.A.
Writing the Article : All Authors
Critical Review : Y.A.
References and Fundings : S.E.A.
Materials : Y.A.

## Conflict of Interest

The authors declare that they have no conflict of interest.

## Authors' ORCID(s)

Y.A. 0000-0002-3828-2483
S.E.A. 0000-0001-7266-8593

## References

1. de Souza-Constantino AM, Conti ACdCF, Capelloza Filho L, Marta SN, de Almeida-Pedrin RR. Patients' preferences regarding age, sex, and attire of orthodontists. Am J Orthod Dentofacial Orthop. 2018;154(6):829–834. e1. doi:10.1016/j.ajodo.2018.02.013.
2. Brosky ME, Keefer OA, Hodges JS, Pesun IJ, Cook G. Patient perceptions of professionalism in dentistry. J Dent Educ. 2003;67(8):909–915. doi:10.1002/j.0022-0337.2003.67.8.tb03678.x.
3. Cha A, Hecht BR, Nelson K, Hopkins MP. Resident physician attire: does it make a difference to our patients? Am J Obstet Gynecol. 2004;190(5):1484–1488. doi:10.1016/j.ajog.2004.02.022.
4. Alsarheed M. Children's perception of their dentists. Eur J Dent. 2011;5(02):186–190.
5. Budny AM, Rogers LC, Mandracchia VJ, Lascher S. The physician's attire and its influence on patient confidence. J Am Podiatr Med Assoc. 2006;96(2):132–138. doi:10.7547/0960132.
6. Kelly GR, Shroff B, Best AM, Tufekci E, Lindauer SJ. Parents' preferences regarding appearance and attire of orthodontists. Angle Orthod. 2014;84(3):404–409. doi:10.2319/071113-510.1.
7. Brandt LJ. On the value of an old dress code in the new millennium. Arch Intern Med. 2003;163(11):1277–1281. doi:10.1001/archinte.163.11.1277.
8. Bianchi MT. Desiderata or dogma: what the evidence reveals about physician attire. J Gen Intern Med. 2008;23:641–643. doi:10.1007/s11606-008-0546-8.
9. Chung H, Lee H, Chang DS, Kim HS, Lee H, Park HJ, et al. Doctor's attire influences perceived empathy in the patient–doctor relationship. Patient Educ Couns. 2012;89(3):387–391. doi:10.1016/j.pec.2012.02.017.
10. Gjerdingen D, Thorpe W, List-Holt P. The physician's appearance and professionalism. Resid Staff Physician. 1990;36(1):65–6, 71.
11. Aitken SA, Tinning CG, Gupta S, Medlock G, Wood AM, Aitken MA. The importance of the orthopaedic doctors' appearance: a cross-regional questionnaire based study. the surgeon. 2014;12(1):40–46. doi:10.1016/j.surge.2013.07.002.
12. Kanzler MH, Gorsulowsky DC. Patients' attitudes regarding physical characteristics of medical care providers in dermatologic practices. Arch Dermatol. 2002;138(4):463–466. doi:10.1001/archderm.138.4.463.
13. Keenum AJ, Wallace LS, Stevens ARB. Patients' attitudes regarding physical characteristics of family practice physicians. South Med J. 2003;96(12):1190–1195. doi:10.1097/01.SMJ.0000077011.58103.C1.
14. Kuscu O, Caglar E, Kayabasoglu N, Sandalli N. Preferences of dentist's attire in a group of Istanbul school children related with dental anxiety. Eur Arch Paediatr Dent. 2009;10:38–41. doi:10.1007/BF03262666.
15. Lill MM, Wilkinson TJ. Judging a book by its cover: descriptive survey of patients' preferences for doctors' appearance and mode of address. Bmj. 2005;331(7531):1524–1527. doi:10.1136/bmj.331.7531.1524.
16. Major K, Hayase Y, Balderrama D, Lefor AT. Attitudes regarding surgeons' attire. Am J Surg. 2005;190(1):103–106. doi:10.1016/j.amjsurg.2005.04.003.
17. McKenna G, Lillywhite G, Maini N. Patient preferences for dental clinical attire: a cross-sectional survey in a dental hospital. Br Dent J. 2007;203(12):681–685. doi:10.1038/bdj.2007.1109.
18. Ahmad MS, Alruwaili AAM, Alruwaili KHA, Alanazi AKM, Alarjan LMM, Alanazi AMM, et al. Evaluation of Child Preference for Dentist Attire and Usage of a Camouflage Syringe in Reduction of Anxiety. J Pharm Bioallied Sci. 2024;16(Suppl 1):S757–S760. doi:10.4103/jpbs.jpbs_997_23.
19. Kastelic DR, Volpato LE, de Campos Neves AT, Aranha AM, Martins CC. Do children and adolescents prefer pediatric attire over white attire during dental appointments? A meta-analysis of prevalence data. Int J Clin Pediatr Dent. 2021;14(1):14. doi:10.5005/jp-journals-10005-1861.
20. Arslan I, Aydinoglu S. Child and parent preferences for the appearance of dentists with respect to personal protective equipment in paediatric dentistry. Int J Paediatr Dent. 2022;32(5):702–713. doi:10.1111/ipd.12949.
21. Mohebbi SZ, Razeghi S, Mizanian F, Kharazifard MJ. Perspectives and Preferences of Preschoolers and Their Parents Regarding Dentist's Attire and Gender. Front Dent. 2022;19:4. doi:10.18502/fid.v19i4.8512.
22. Sujatha P, Nara A, Avanti A, Shetty P, Anandakrishna L, Patil K. Child Dental Patient's Anxiety and Preference for Dentist's Attire: A Cross-sectional Study. Int J Clin Pediatr Dent. 2021;14(Suppl 2):S107. doi:10.5005/jp-journals-10005-1940.
23. Oliveira LB, Massignan C, De Carvalho RM, Savi MG, Bolan M, Porporatti AL, et al. Children's perceptions of dentist's attire and environment: A systematic review and meta-analysis. Int J Clin Pediatr Dent. 2020;13(6):700. doi:10.5005/jp-journals-10005-1839.
24. Kamata K, Kuriyama A, Chopra V, Saint S, Houchens N, Petrilli CM, et al. Patient preferences for physician attire: a multicenter study in Japan. J Hosp Med. 2020;15(4):204–210. doi:10.12788/jhm.3350.
25. Yamada Y, Takahashi O, Ohde S, Deshpande GA, Fukui T. Patients' preferences for doctors' attire in Japan. Intern Med. 2010;49(15):1521–1526. doi:10.2169/internalmedicine.49.3572.

European Annals of Dental Sciences
Official Publication of Ankara University, Faculty of Dentistry

*EADS*, 2025, 52 (1), 45–49

e-ISSN : 2757-6744
Article Received/Accepted : November, 5 2024 / March, 20 2025
doi : 10.52037/eads.2025.0007

ORIGINAL RESEARCH ARTICLE

# Impact of Adhesive Application Modes on Shear Bond Strength of Resin Composites to Biodentine

Ceren Değer [1], *, Miraç Doğan Evcin [2] and Zümrüt Ceren Özduman [1]

[1]Department of Restorative Dentistry, Faculty of Dentistry, Bezmialem Vakif University, Istanbul, Türkiye and
[2]Department of Restorative Dentistry, Faculty of Dentistry, Kocaeli Health and Technology University, Kocaeli, Türkiye

*Corresponding Author; cerendeger@outlook.com

## Abstract

**Purpose:** This in-vitro study aimed to evaluate the impact of the adhesive application mode on the shear bond strength of various resin composites to Biodentine.
**Materials and Methods:** A total of 60 acrylic blocks, each with a central hole (2 mm x 5 mm), were made for the study (n = 60). The holes were filled with Biodentine (Septodont), and the samples were randomly divided into three groups based on the type of restorative material used: 1) conventional posterior composite, Estelite Posterior Quick (EP)(Tokuyama); 2) bulk-fill composite, Filtek Bulk Fill (FB) (3M ESPE); and 3) short fiber-reinforced composite, EverX Posterior (EX)(GC). Additionally, each group was subdivided into two categories depending on the adhesive application method: self-etch or total-etch. A universal adhesive (Single Bond Universal, 3M ESPE) was applied to the Biodentine specimens, and subsequently, the resin composites were applied and light-cured for 20 s. The shear bond strength was measured using a universal testing machine (AGS-1000D, Shimadzu) at a crosshead speed of 1 mm/min. The shear bond strength data (MPa) were analyzed using a two-way ANOVA and the Bonferroni test ($p < 0.05$).
**Results:** For the self-etch application mode, a statistically significant difference was observed among the material groups ($p = 0.005$). Group EP exhibited higher shear bond strength compared to Group FB. There were also significant differences among the groups for the total-etch application mode ($p = 0.009$), with Group EP again showing the highest shear bond strength. However, when comparing the two etching modes within each material group, there were no significant differences in shear bond strength.
**Conclusions:** The conventional posterior composite used significantly affects the strength of the shear bond to Biodentine. In contrast, the choice between self-etch and total-etch modes does not notably impact the bond strength.

**Keywords**: Biodentine; Bulk fill; Shear bond strength; Short fiber reinforced composite

## Introduction

The preservation of dental pulp vitality is essential for the long-term survival of teeth. In teeth affected by trauma, caries, or restorative procedures, vital pulpal therapy (VPT) can be used to maintain the health of the pulp tissue. Specifically, VPT seeks to promote the formation of tertiary dentine to keep the tooth functional. VPT treatments range from conservative approaches such as indirect and direct pulp capping to more invasive procedures such as partial and full pulpotomy.[1]

The introduction of calcium silicate cements has revolutionized the conservative management of deep caries and VPT. Biodentine was introduced to the market in 2011 as a quick-setting bioactive dentin substitute, and the incorporation of calcium silicates into this substitute has resulted in beneficial features, such as high compressive strength and improved ease of handling. Biodentine is used extensively in both restorative dentistry and endodontics and does not cause discoloration of the treated teeth.[2,3]

Significant hard dental tissue loss is commonly observed in teeth requiring VPT. Therefore, preserving the pulp with a biocompatible material and ensuring the hermetic restoration of the remaining dental tissues are critical factors that influence treatment success. Microleakage caused by the chipping or fracturing of composite resin restorations, along with polymerization shrinkage in teeth with significant coronal damage, adversely affect the treatment prognosis.[4] For large posterior cavities, bulk-fill composite resins are advised due to their improved polymerization depth and mechanical properties, which allow them to overcome the challenges faced by conventional composite resins.[5] Another advantage of these bulk-fill resin composites is that they can be applied



**How to cite:** Deger C, Dogan Evcin M, Ozduman ZC. Impact of Adhesive Application Modes on Shear Bond Strength of Resin Composites to Biodentine. EADS. 2025;52(1): 45-49

**Table 1.** Chemical composition of adhesive system and restorative materials used in the study

| | | | |
|---|---|---|---|
| **ADHESIVE SYSTEM** | Single Bond Universal | 3M ESPE, St.Paul MN, USA | MDP phosphate monomer, dimethacrylate resins, HEMA, polyalkenoic acid copolymer,filler, ethanol, water, initiators, silane |
| **RESIN COMPOSITES** | Filtek Bulk fill | 3M ESPE, St.Paul MN, USA | AUDMA, UDMA and 1,12-dodecan-DMA, (76,5wt, %58,4vol%) non aggregated 4 to 11nm zirconia filler aggregated zirconia/silica cluster filler(comprised of 20nm silica and 4 to 11nm zirconia particles)trrerbium trfluoride filler (100nm) non aggregated 20 nm silica filler |
| | EverX Posterior | Tokuyama, Tokyo, Japan | BisGMA, PMMA, TEGDMA, Short E-glass fiber filler, barium glass |
| | Estelite Posterior Quick | GC, Tokyo, Japan | Bis-GMA, TEGDMA, Bis-MPEPP. Radical-Amplified Photopolymerization initiator technology(RAP), (83%wt, 70% vol)Silica-zirconia filler: 0.1-10 μm(2μm) |
| **CALCIUM SILICATE CEMENT** | Biodentine | Septodont, Saint-Maurdes-Fosses, France | Powder: tricalcium silicate, dicalcium silicate, calcium carbonate,zirconium oxide,iron oxide Liquid:calcium chloride, hydrosoluble polymer, water |

in increments of up to 4–5 mm.[6] In addition, the application of short fiber-reinforced composites (SFRCs), marketed for dentin replacement in direct restorations, has been shown to improve mechanical properties and reduce both restoration failures and crack propagation in the treatment of large cavities.[7]

Recently, there has been a growing trend toward using a single adhesive product for various applications. In this context, universal adhesives with the capability of bonding to different substrates have been introduced to the market. These versatile adhesives allow for flexibility in the etching technique used, as they are designed to adhere to tooth structures using total-etch (TE), self-etch (SE), or selective-etch methods.[8]

However, the adhesion of resin composites to Biodentine used in VPTs can be challenging, necessitating the identification of the optimal combinations of resin composite and Biodentine. Given the critical role of strong adhesive bonds in ensuring the success and durability of restorative treatments, this study aims to evaluate the shear bond strength of different resin composites to Biodentine using a universal adhesive with two different adhesive application modes. The null hypothesis is that there will be no statistically significant difference in the shear bond strength of different resin composites to Biodentine, regardless of the type of resin composite or the adhesive application mode used.

## Material and Methods

A total of 60 acrylic blocks, each with a central hole (2 mm in depth and 5 mm in diameter), were prepared for this study (n = 60). Biodentine (Septodont, Saint-Maurdes-Fosses, France) was mixed according to the manufacturer's instructions and placed into the holes of each acrylic block. After the holes were completely filled with Biodentine and the 12 min setting time was completed, the specimens were randomly divided into three groups based on the restorative material used: conventional posterior resin composite, Estelite Posterior Quick (EP) (Tokuyama, Tokyo, Japan); bulk-fill composite, Filtek Bulkfill (FB) (3M ESPE, St. Paul, MN, USA); and short fiber-reinforced composite, EverX Posterior (EX) (GC, Tokyo, Japan). Each material group was then further subdivided based on the adhesive application method: self-etch (SE) or total-etch (TE). A universal adhesive (Single Bond Universal, 3M ESPE, St.Paul MN, USA) was applied to the Biodentine specimens, followed by the application of the respective composite resins, which were then light-cured (Valo, Ultradent, South Jordan, USA) for 20 s. All sample preparations were carried out by a single operator (M.D.E) following a standardized procedure to avoid any inconsistencies in the samples. The adhesive system, the restorative materials used in this study, and thechemical compositions of the materials are presented in Table 1.

The shear bond strength (SBS) was assessed using a universal testing machine (AGS-1000D, Shimadzu, Japan) at a crosshead speed of 1 mm/min. The testing load was directly applied onto the Biodentine–restoration interface until failure. The SBS values were calculated by dividing the failure load (N) by the adhesion area (mm2) and converting to megapascals (MPa).

**Table 2.** Mean shear bond strength (sbs) values and standard deviations for tested groups

| | SE | TE | p |
|---|---|---|---|
| **EX** | 1,724±1,414$^{ab}$ | 1,755±0,763$^{a}$ | 0,951 |
| **EP** | 2,778±1,392$^{a}$ | 3,176±1,545$^{b}$ | 0,431 |
| **FB** | 1,079±0,531$^{b}$ | 1,808±0,588$^{a}$ | 0,152 |
| **p** | 0,005 | 0,009 | |

* Different lowercase letters indicate a statistically significant difference between groups.

### Fracture Analysis

The fracture types of the specimens were analyzed using a stereomicroscope (SMZ 1000, Nikon; Tokyo, Japan) at 15X magnification. Fractures were classified as "adhesive" if they occurred along the interface between the resin composite and Biodentine, as "cohesive" if they were within the resin composite or Biodentine, and as "mixed" if they involved both the interface and the material itself. All fracture type analyses were conducted by a single operator (Z.C.O.) who was blinded to the surface treatments applied.

### Statistical Analysis

Statistical analyses were carried out using SPSS 22.0 for Windows (SPSS Inc., Chicago, IL). The Shapiro-Wilk test was employed to assess the normality of the data, and Levene's test was used to evaluate the homogeneity of variances. Given that both normality and homogeneity of variance were confirmed, a two-way analysis of variance (ANOVA) was conducted to compare differences within and between the groups. Pairwise comparisons were performed using the Bonferroni test. A significance level of .05 was considered for all statistical analyses.

## Results

### Shear Bond Strength Test

Table 2 presents the mean shear bond strength (SBS) values with standard deviations for all of the groups.

With the SE application mode, a statistically significant difference in SBS was observed among the material groups (p = 0.005). Specifically, Group EP exhibited higher shear bond strength than Group FB.

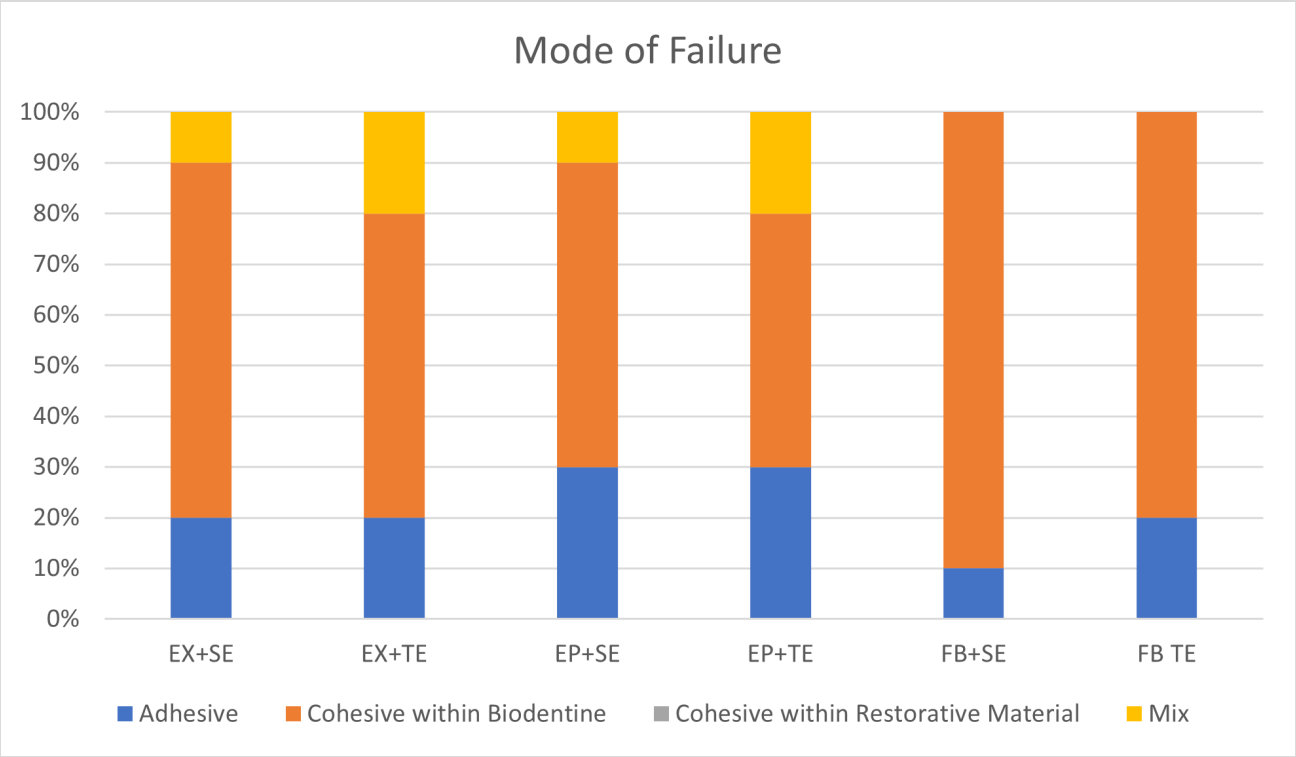


**Figure 1.** The stacked column chart illustrating the frequency distribution of the fracture mode analysis of all tested groups

Similarly, there were also significant differences in SBS among the material groups when using the ER application mode ($p = 0.009$), with Group EP again showing the highest SBS. However, when comparing the two etching modes (SE vs. TE) within each material group, there were no statistically significant differences in shear bond strength ($p > 0.05$ for all comparisons).

### Fracture Mode Analysis

Figure 1 shows a stacked column chart representing the frequency distribution of fracture modes across all the tested groups. Cohesive fractures were the predominant fracture mode in all of the groups. Additionally, mixed fractures were observed in the EX + TE, EX + SE, EP + TE, and EP + SE groups.

## Discussion

Biodentine has become widely recognized for use in VPT due to its excellent sealing properties, ease of handling, biocompatibility, long-term impermeability, rapid setting time, and ability to promote the regeneration of hard tissues.[9] Ensuring a strong bond between the final restoration and Biodentine is crucial for the success of VPT. However, there remains uncertainty in the literature regarding the optimal restorative material for the final restoration and the most suitable adhesive strategy when using Biodentine. Additionally, to the best of the author's knowledge, limited data are available on the SBS values of the specific combination of resin composites and adhesives tested in this study.

This research aimed to evaluate the SBS of various resin composites to Biodentine using a universal adhesive applied in two different modes. Based on the findings, the null hypothesis was partially rejected, as significant differences in SBS values were observed among the resin composites, whereas no significant differences in SBS were found between the two different etching modes.

Several outcome variables, including SBS, microshear bond strength (mSBS), and microtensile bond strength (mTBS), are commonly used to assess the bonding strength of dental restorative materials to teeth or other substrates.[10,11] Unlike the traditional SBS test, tests of the mSBS and mTBS allow for the precise selection of standardized tooth regions for analysis. In the mSBS test, a polyethylene tube with a smaller diameter than that used in the SBS test is employed, and thus, careful handling during preparation is essential to prevent cracks or fractures when removing the tube. In contrast, the mTBS test requires sectioning the samples into specific diameters, which carries the risk of inducing unexpected microcracks during the sectioning process. Given that shear stresses are believed to weaken material adhesion and contribute to joint failures in vivo, the SBS test was selected for this study due to its straightforward protocol and direct method of sample preparation.[12]

In this study, the mean SBS values of the test samples ranged from 1.049–3.176 MPa, which falls below the recommended bond strength range of 17–20 MPa needed to ensure a gap-free restoration.[13] It has been previously suggested that the lower SBS values observed with Biodentine may be related to the material's initial low strength.[14] Indeed, calcium silicate-based cements form poorly crystallized and highly porous structures during the early setting stages, and Both the application of adhesives and resin composite shrinkage can stress these pores, thus reducing the bond strength. Biodentine requires at least 2 weeks to fully crystallize and develop the strength needed to withstand polymerization stresses. Furthermore, the lack of resin components within Biodentine indicates that the bond with the resin composite is primarily micromechanical.[14,15] In this study, bonding was performed after 12 min to replicate a single-visit clinical approach, and the low SBS strength values may be attributed to the use of this limited setting time.

In a study conducted by Abdullah et al.[16], which evaluated the bond strength of various adhesive systems and composites to Biodentine, the SBS values ranged from 6–13 MPa. Moreover, in a similar study by Odabaş et al.[17], the SBS values ranged between 15–19 MPa. However, in the present study, which examined the bond strength of Ever X Posterior, Estelite Posterior Quick, and Filtek Bulkfill to Biodentine using different adhesive strategies, the

SBS values were found to range between 1–3 MPa. The values from this study are comparable to those reported by Altunsoy et al.[18], who found the SBS of flowable composites to Biodentine to be between 1.1–1.69 MPa. These differences between studies may be attributed to variations in adhesive systems, resin materials, experimental setups, sample preparation methods, or differences among operators.

EverX Posterior is a fiber-reinforced composite designed to enhance the mechanical properties of dental restorations through the incorporation of reinforcing fibers. In the present study, EverX Posterior exhibited lower SBS values compared to Estelite Posterior in both adhesive application modes. EverX Posterior is a fiber-reinforced composite, and the presence of fibers at the adhesive interface may sometimes reduce the adhesive strength rather than enhance it. Indeed, the internal discontinuities introduced by the fibers at the interface can lead to stress redistribution and energy absorption. Consequently, the fiber content in EverX Posterior may contribute to the lower observed SBS values for this material compared to others.[19,20] However, in this study, no statistically significant differences in SBS values were observed between the she EverX Posterior and Filtek BulkFill. These results are consistent with the findings of a study by Ipek et al.[21], which also investigated the SBS values of EverX Posterior and Filtek BulkFill to Biodentine and reported no statistically significant differences between these materials. One reason for Filtek Bulk Fill exhibiting lower shear bond strength values compared to Estelite Posterior may be the absence of compression forces or pressure during application. This lack of compression is crucial for eliminating gaps at the interface, which can affect the durability of the resin.[22]

Single Bond Universal (SBU) is a versatile all-in-one adhesive system that maintains bonding efficiency across various techniques and supports selective enamel etching. SBU contains 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP), which may enable both chemical and micromechanical bonding. However, the presence of HEMA in adhesives may compete with 10-MDP for calcium binding, potentially reducing the formation of 10-MDP-calcium bonds. While 10-MDP is designed to enhance both chemical and micromechanical bonding, it is uncertain if a chemical bond forms between the Biodentine and resin composite. However, functional monomers in the adhesive may theoretically improve bonding by interacting with the calcium in Biodentine. This study found no statistically significant difference in bond strength between the self-etch and total-etch adhesive strategies. The literature lacks a consensus on whether these techniques alter bond strength outcomes. While Odabas et al.[17] reported higher bond strength values with self-etch systems, studies by Rosa et al.[8], Hashem et al., and Ünal et al.[23] found no significant differences between the two adhesive strategies, aligning with the results of the present investigation. These differences in findings may be attributed to the presence or absence of aging procedures in the experimental protocols and the interaction between the resin composite and the adhesive materials used.

Regarding fracture patterns, the present study found that cohesive fractures were the most frequently observed fracture type, consistent with previous studies. This prevalence of cohesive fractures suggests that the internal strength of the biomaterial, rather than the bond strength at the composite-biomaterial interface, plays a key role, aligning with the findings of Palma et al.[24] and Odabas et al.[17] However, the present methodology did not incorporate aging procedure, which is essential for replicating the oral environment and ensuring clinically relevant outcomes. As demonstrated by Meraji et al.[25], dynamic aging significantly influences the mechanical properties and failure patterns of biomaterials. Similar to the current findings, Meraji et al.[25] also observed predominantly cohesive failures within Biodentine, likely due to its low material strength, which may be influenced by bonding strategies, adhesive systems, and the inclusion of aging protocols.

## Conclusion

Within the limitations of this study, the results suggest that the use of different conventional posterior composites significantly influences the SBS to Biodentine, whereas the choice between self-etch and total-etch modes does not have a notable impact on bonding. These findings highlight the importance of selecting the right resin composite to optimize bond strength in restorative treatments involving Biodentine, while allowing flexibility in the choice of adhesive mode. However, given the in vitro nature of the study, further in vitro and clinical research is needed to better inform material selection and determine which materials should be prioritized for clinical use.

## Ethical Approval

Ethical approval was not required for this study.

## Acknowledgements

A part of this study was presented at 2021 CED-IADR/NOF Oral Health Research Congress, Brussels, Belgium.

## Author Contributions

Study Idea / Design : Z.C.O.
Data Collection : M.D.E.
Literature Review : M.D.E. , Z.C.O.
Analysis and/or Interpretation of Results : M.D.E. , Z.C.O.
Article Writing : C.D. , Z.C.O.
Critical Review : C.D. , Z.C.O.

## Conflict of Interest

The authors declare that they have no financial interests in any companies or products referenced in this article.

## Authors' ORCID(s)

C.D. 0000-0002-2100-8963
M.D.E. 0000-0003-3134-5362
Z.C.O. 0000-0003-2648-1730

## References

1. Iaculli F, Rodríguez-Lozano FJ, Briseño-Marroquín B, Wolf TG, Spagnuolo G, Rengo S. Vital pulp therapy of permanent teeth with reversible or irreversible pulpitis: an overview of the literature. J Clin Med. 2022;11(14):4016. doi:10.3390/jcm11144016.
2. Bhavya B, Sadique M, Simon EP, Ravi S, Lal S. Spectrophotometric analysis of coronal discoloration induced by white mineral trioxide aggregate and Biodentine: An: in vitro: study. J Conserv Dent. 2017;20(4):237–240. doi:10.4103/0972-0707.219203.
3. Camilleri J, Sorrentino F, Damidot D. Investigation of the hydration and bioactivity of radiopacified tricalcium silicate cement, Biodentine and MTA Angelus. Dent Mater. 2013;29(5):580–593. doi:10.1016/j.dental.2013.03.007.
4. Kahler B, Taha N, Lu J, Saoud T. Vital pulp therapy for permanent teeth with diagnosis of irreversible pulpitis: biological basis and outcome. Aust Dent J. 2023;68:S110–S122. doi:10.1111/adj.12997.
5. Arbildo-Vega HI, Lapinska B, Panda S, Lamas-Lara C, Khan

AS, Lukomska-Szymanska M. Clinical effectiveness of bulk-fill and conventional resin composite restorations: systematic review and meta-analysis. Polymers. 2020;12(8):1786. doi:10.3390/polym12081786.
6. Chesterman J, Jowett A, Gallacher A, Nixon P. Bulk-fill resin-based composite restorative materials: a review. Br Dent J. 2017;222(5):337–344. doi:10.1038/sj.bdj.2017.214.
7. Alshabib A, Jurado CA, Tsujimoto A. Short fiber-reinforced resin-based composites (SFRCs); Current status and future perspectives. Dent Mater J. 2022;41(5):647–654. doi:10.4012/dmj.2022-080.
8. Da Rosa WLDO, Piva E, da Silva AF. Bond strength of universal adhesives: A systematic review and meta-analysis. J Dent. 2015;43(7):765–776. doi:10.1016/j.jdent.2015.04.003.
9. El Meligy OAES, Alamoudi NM, Allazzam SM, El-Housseiny AAM. Biodentine TM versus formocresol pulpotomy technique in primary molars: a 12–month randomized controlled clinical trial. BMC Oral Health. 2019;19:1–8. doi:10.1186/s12903-018-0702-4.
10. Alqahtani AS, Sulimany AM, Alayad AS, Alqahtani AS, Bawazir OA. Evaluation of the shear bond strength of four bioceramic materials with different restorative materials and timings. Materials. 2022;15(13):4668.
11. Kaptan A, Oznurhan F, Candan M. In vitro comparison of surface roughness, flexural, and microtensile strength of various glass-ionomer-based materials and a new alkasite restorative material. Polymers. 2023;15(3):650. doi:10.3390/polym15030650.
12. Cardoso PE, Braga RR, Carrilho MR. Evaluation of micro-tensile, shear and tensile tests determining the bond strength of three adhesive systems. Dent Mater. 1998;14(6):394–398. doi:10.1016/s0300-5712(99)00012-3.
13. Carretero V, Giner-Tarrida L, Peñate L, Arregui M. Shear bond strength of nanohybrid composite to biodentine with three different adhesives. Coatings. 2019;9(12):783. doi:10.3390/coatings9120783.
14. Bachoo I, Seymour D, Brunton P. A biocompatible and bioactive replacement for dentine: is this a reality? The properties and uses of a novel calcium-based cement. Br Dent J. 2013;214(2):E5–E5. doi:10.1038/sj.bdj.2013.57.
15. Karadas M, Cantekin K, Gumus H, Ateş SM, Duymuş ZY. Evaluation of the bond strength of different adhesive agents to a resin-modified calcium silicate material (TheraCal LC). Scanning. 2016;38(5):403–411. doi:10.1002/sca.21284.
16. Abdullah HA, Al-Ibraheemi ZA, Hanoon ZA, Haider J. Evaluation of Shear Bond Strength of Resin-Based Composites to Biodentine with Three Types of Seventh-Generation Bonding Agents: An In Vitro Study. Int J Dent. 2022;2022(1):2830299. doi:10.1155/2022/2830299.
17. Odabaş ME, Bani M, Tirali RE. Shear bond strengths of different adhesive systems to biodentine. ScientificWorldJournal. 2013;2013(1):626103. doi:10.1155/2013/626103.
18. Altunsoy M, Tanrıver M, Ok E, Kucukyilmaz E. Shear bond strength of a self-adhering flowable composite and a flowable base composite to mineral trioxide aggregate, calcium-enriched mixture cement, and Biodentine. J Endod. 2015;41(10):1691–1695. doi:10.1016/j.joen.2015.06.008.
19. Scheirs J. Compositional and failure analysis of polymers: a practical approach. John Wiley & Sons; 2000.
20. Tezvergil A, Lassila L, Vallittu P. The shear bond strength of bidirectional and random-oriented fibre-reinforced composite to tooth structure. J Dent. 2005;33(6):509–516. doi:10.1016/j.jdent.2004.11.016.
21. Ipek I, Karaağaç Eskibağlar B, Yildiz S, Ataş O, Ünal M. Analysis of the bond strength between conventional, putty or resin-modified calcium silicate cement and bulk fill composites. Aust Dent J. 2023;68(4):265–272. doi:10.1111/adj.12977.
22. Yesilyurt C, Ceyhanli KT, ALP CK, Yildirim T, TASDEMiR T. In vitro bonding effectiveness of new self-adhering flowable composite to calcium silicate-based material. Dent Mater J. 2014;33(3):319–324. doi:10.4012/dmj.2013-211.
23. Ünal M. The comparison of shear bond strenght of different bulk-fill composites to a bioactive dentine substitute. Cumhuriyet Dent J. 2018;21(4):274–283. doi:10.7126/cumudj.433716.
24. Palma PJ, Marques JA, Falacho RI, Vinagre A, Santos JM, Ramos JC. Does delayed restoration improve shear bond strength of different restorative protocols to calcium silicate-based cements? Materials. 2018;11(11):2216. doi:10.3390/ma11112216.
25. Meraji N, Camilleri J. Bonding over Dentin Replacement Materials. J Endod. 2017;43(8):1343–1349. doi:10.1016/j.joen.2017.03.025.

European Annals of Dental Sciences
Official Publication of Ankara University, Faculty of Dentistry

*EADS*, 2025, 52 (1), 50–54

e-ISSN : 2757-6744
doi : 10.52037/eads.2025.0008

Article Received/Accepted : November, 3 2024 / February, 3 2025

CASE REPORT

# Removal of a Giant Dual Sialolith Located in Right Submandibular Gland Duct: A Case Report

Nuri Mert Tayşi [1] and Aysegül Erten Tayşi [1], *

[1]Department of Oral and Maxillofacial Surgery, Istanbul University-Cerrahpasa, Faculty of Dentistry, Istanbul, Türkiye

*Corresponding Author; denterten@gmail.com

## Abstract

The prevalence of sialolithiasis in the salivary glands is reported to be 1%, with approximately 80% of cases occurring in the submandibular glands. Notably, sialolithiasis in these submandibular cases typically presents as a single solid formation. This paper aims to present a clinical case involving two sialoliths and review current treatments for sialolithiasis. A 51-year-old female patient was referred to the Istanbul University-Cerrahpaşa Faculty of Dentistry for evaluation due to swelling on the right side of the floor of the mouth. Her medical and dental history was unremarkable. The patient's physical status was classified as ASA-I, indicating she was healthy, non-smoking, did not consume alcohol, and had an appropriate BMI for her age. A cone beam computed tomography scan was requested following the assessment of orthopantomography and intraoral and extraoral physical examinations to confirm the presumptive diagnosis. The tomography revealed two sialoliths, which were surgically removed under local anesthesia via an intraoral approach. No functional sequelae were observed during the six-month postoperative follow-up period.

**Keywords**: Case report; Diagnostic imaging; Salivary Gland Calculus; Stomatognathic Diseases; Submandibular Glands

## Introduction

Sialolithiasis is one of the most common salivary gland diseases, affecting 60 million people a year.[1] Sialolithiasis has an estimated prevalence rate ranging between 0.01% and 0.003% of the population worldwide.[2,3] The primary age of diagnosis is between 30 and 60 and the prevalence of occurrence is reported to be two men for every woman.[4] The exact etiology of sialolithias is unclear; however there are two main theories for identifying their pathophysiological mechanism.[5] While first theory depends on multiple internal microcalculi within salivary gland secretory granules acting as a nidus for the formation of larger calculi, the second theory postulates an inflammatory origin resulted in bacteria or food debris within oral cavity entering the distal region of salivary gland duct. In the second theory, this organic and foreign substrate serve as a nidus for the formation of larger calculi.[5,6]

The distribution of sialoliths shows a significant preference for the submandibular gland (approximately 85%), followed by the parotid gland (15%), with the sublingual and minor salivary glands accounting for less than 5% of the cases.[7] The higher incidence of sialolith formation in the submandibular gland is attributed to several anatomical and physiological factors. Anatomical factors include a longer Wharton's duct, larger duct caliber, and tortuous course of the Wharton's duct accompanied by a slow salivary velocity. Physiological factors are related to the composition of saliva and mineral contents, such as calcium and phosphate levels.[8] Due to the submandibular gland's distinctive features, including mucinous saliva secretion and elevated levels of inorganic salts resulting in increased salivary alkalinity, there is a facilitation in the formation of sialolithiasis. Moreover, the slower salivary flow rate of the submandibular glands compared to other salivary glands is primarily attributed to the formation of a retrograde flow dynamic as the submandibular gland has two bends which is traveling upward and forward, and then its duct ascends against gravity toward its orifice in the oral cavity.[8] There are also some predisposing factors including tobacco consumption, insufficient fluid intake, and use of medications (e.g., diuretics, bendroflumethiazide) that reduce salivary output.[3] A retrospective study indicates that smoking and increased serum sodium concentrations correlate with larger sialolith formation.[9]

The analysis of sialolithiasis' laterality reveals that 75% of cases of salolithiasis are unilateral, 3% are bilateral and 2% are atrophic.[10] In a cohort study, submandibular sialolithiasis demonstrated the following distribution pattern: right-sided involvement in 55% of cases, left-sided involvement in 42%, and bilateral presentation in 2%.[3] On the other hand, the pattern of sialolith formation is



**How to cite:** Taysi NM, Erten Taysi A. Removal of a Giant Dual Sialolith Located in Right Submandibular Gland Duct: A Case Report. EADS. 2025; 52(1): 50-54

**Figure 1.** Preoperative intraoral examination revealed a firm, palpable swelling in the right floor of the mouth along the Wharton's duct.

predominantly unilateral, with single stones being the most common presentation.[11,12] Previous studies[12,13] report that while single sialoliths comprise 75.3% of cases, multiple stone formations are less prevalent, with dual and triple sialoliths occurring in 15.6% and 2.9% of cases, respectively.

In this case report, we describe the surgical removal of two pieces of sialoliths arising from the right Wharton's duct with no functional sequelae observed during the six-month postoperative follow-up period.

## Case Report

A 51-year-old female patient was referred to the oral and maxillofacial surgery department by her general dentist due to persistent swelling in her lower right jaw. She reported a tender swelling under her tongue on the right side that had persisted for two years, which temporarily subsided with antibiotic treatment but did not fully resolve. The patient's medical history was unremarkable, and recent blood work and biochemical analysis were within normal limits. The patient is a non-smoker and has never consumed alcohol. At the time of examination, she did not have a fever but reported dysphagia and pain upon palpation.

The extraoral examination indicated swelling in the floor of the mandible extending toward the neck. Bilateral examination of the lymph nodes showed unilateral enlarged, non-tender, and mobile nodes on the right side. The patient's medical and dental history did not reveal any pathological clinical data relevant to the current condition.

Subsequent intraoral examination revealed a slightly visible swelling in the middle to the posterior part of the right side of the floor of the mouth (Figure 1). Throughout the bi-manual palpation of the area, there was a large, hard mass without any fluctuation. After the examination of the panoramic radiograph (Figure 2), a radiopaque appearance with a not precise radiolucent perpendicular dividing line was observed, and the solid mass was assumed to be related to a sialolithiasis of the submandibular gland in the initial assessment.

The patient was referred to the radiology department for CBCT (Cone Beam Computed Tomography) imaging for advanced radiological assessment prior to surgery. The CBCT (MyRay, Cefla Dental Group, Imola, Italy) volumetric data sets were reconstructed to display 2D images in 0,3 mm sections in three planes: axial, sagittal, and coronal, and viewed in their dedicated software (Figure 3). Images dedicated to two- pieces of sialolithiasis with a hyperdense area of approximately 1680.5 Hounsfield Units within the right sight of the mouth floor (Figure 4). The boundaries of sialolithiasis

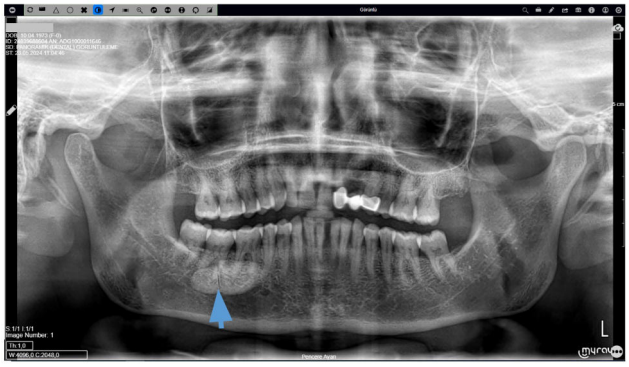

**Figure 2.** The panoramic radiograph reveals a bipartite sialolith.

**Figure 3.** Cone-beam computed tomography present exact anatomical position of the sialolith for optimal surgical planning.

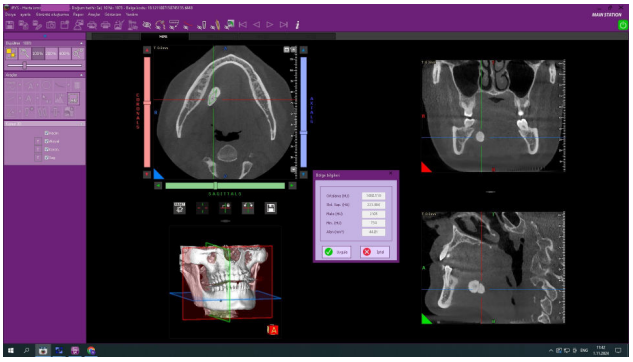

**Figure 4.** Hounsfield Units (HU) analysis demonstrates significant mineralization with a mean value of 1680.5 HU.

was examined through several sections in a step-by-step manner (Figure 5) and commenced with the tooth number of 46 and extended to the wisdom tooth area. The hyperdense mass was found to be in the lingual side of the mandible without any contact to the bony structure. This finding confirmed that our initial diagnosis of sialolith was correct. According to the physical and radiological evaluations, removal of the sialolith was planned to be performed with an intraoral approach without removing the salivary gland.

Informed consent for the removal of sialolithiasis, which includes potential complications such as transient or permanent lingual nerve dysfunction, numbness, gustatory changes, seroma, hematoma, and recurrence, was obtained from the patient. Initially, the stone was located using the bimanual palpation method. The suspected area of the stone was then infiltrated with 2% lidocaine hydrochloride combined with 1:80,000 epinephrine (Lidofast, Vem Pharma Inc., and Trading Co. Ltd.). Following administration of local anesthesia, two sutures of 2.0 silk were placed posterior to

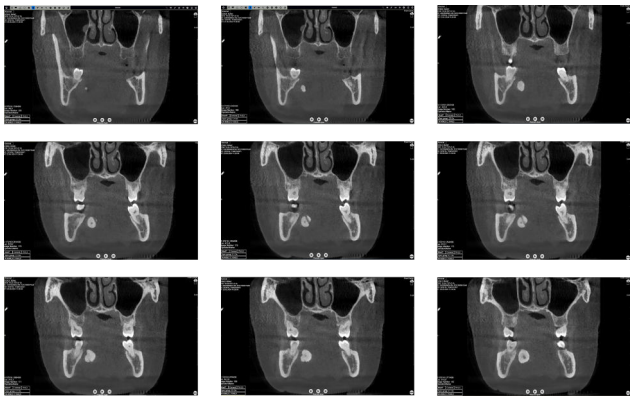

**Figure 5.** Detailed analysis with sequential cross-sectional images moving from posterior to anterior of the affected area with figure 5A being the most posterior.

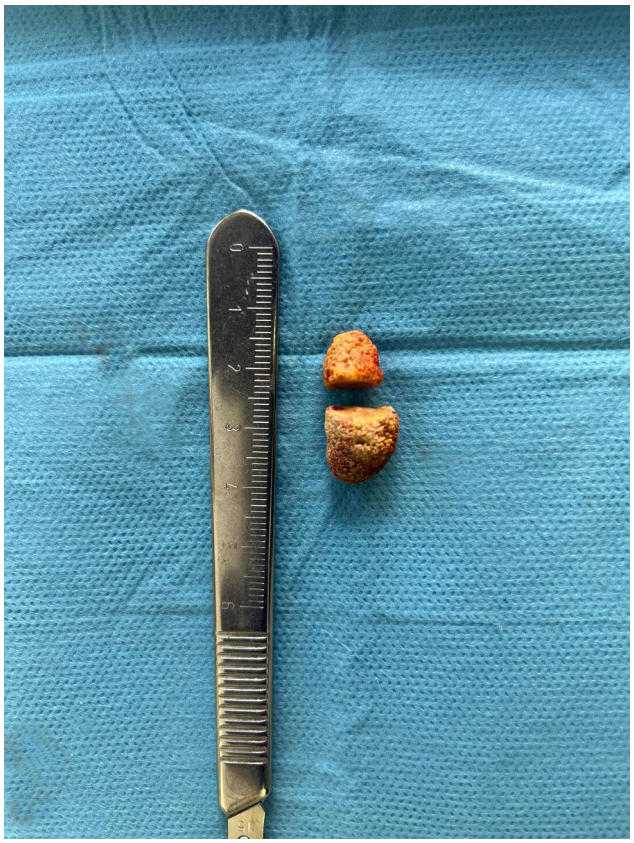

**Figure 6.** Excised specimens demonstrates a yellowish-white, rough surface texture with an irregular contour.

the most palpable portion of the sialolith to prevent displacement during the procedure. A single continuous stroke was used to make a 1.5 cm incision, followed by blunt dissection of the surrounding tissues, leading to the extraction of two pieces of sialoliths (Figure 6). After removing the sialoliths, the silk sutures were taken out, and milking the gland facilitated saliva discharge. Interrupted 3.0 silk sutures were placed to close the oral mucosa. Postoperative treatment included prescribing the patient a seven-day course of amoxicillin and clavulanic acid combination at 1000 mg twice daily orally. The patient had an uneventful recovery, and no further issues were reported at the six-month follow-up (Figure 7).

**Figure 7.** Postoperative intraoral appearance at the 6th month follow-up period.

## Discussion

To this date, the pathophysiological pathways of sialolithiasis still remain unknown, and several hypotheses have been advocated on the issue.[1] While one of the theories is related to the existence of intracellular microcalculi being discharged into the canal and then become a nidus for further calcification, the other one posits a mucous plug which occurs in the ductal system, may present the nidus.[5,14] On a common consensus of these hypotheses, it is believed that formation mechanism of the sialolithiasis is related to accumulation of calcium salts around an initial organic nidus.[1,5,14] Moreover, there is another possible hypothesis that supposes the formation of sialolithiasis may be initiated by the migration of alimentary substances or oral microorganisms into the salivary ductal system.[5,14]

The submandibular gland is most frequently involved (around 80% of cases), followed by parotid (5%-20%) and, rarely, minor glands (1%-2%). The reason for the submandibular gland being the most involved can be directly linked to its retrograde anatomical location and tortuous anatomy of the duct combined with the secretion of mucous and more alkaline saliva with a major concentration of calcium.[15] In this report, as we described a case of a two-piece sialolith of unusual size and shape that occurred in the submandibular gland duct, it could be seen that the occurrence of the sialolithiasis found in the consulted reports is in line with our case report.

The previous case reports and meta-analysis indicate that sialithiasis occurs with higher frequency in males and in individuals from 30-40 years of age.[16] However, these cases could also affect both the younger and older patients, as well as children albeit rarely.[12,17] Similarly, a recent case series report documented three cases of submandibular sialolithiasis in patients aged 19, 40, and 65 years.[18] Consistent with these findings, in a prospective non-randomized study[19], the researchers evaluated the quality of life after the treatment of sialolithiasis, and the mean age was of 44.7 years. In a case series report analyzing 46 patients with submandibular sialoliths, the mean age was 37.3 for male and 34.6 for female patients.[20] In this case report, the patient was 51- year old.

Notably, sialolithiasis predominantly occurs unilaterally and is usually found as a single formation, though multiple formations are rare.[11,12] Single sialolithiasis was detected in 75.3% of cases, while multiple sialolithiasis, including dual and triple formations, represent rare occurrences with percentages of 15.6% and 2.9%, respectively.[12,13] Multiple sialolithiasis in the submandibular duct are indeed referred to as rare entities in the literature. Additionally, it is observed that the size of sialoliths can range from less than 1mm to several centimeters.[21,22] The sialoliths that reached 1cm or surpassed 1.5 cm in any diameter are referred to as being rare

and giant or unusually large, respectively.[1,23] In a case report[21], a 49-year-old male patient was presented with 8 sialoliths each of approximately 2 mm in diameter within the submandibular duct. In the same case report, the authors cited the work of Brusati and Fiamminghi[24], who documented the removal of 2 sialoliths measuring 6 × 8 mm and 27 × 31 mm, respectively. In the present study, the sialolithiasis were identified unilaterally, representing a quite common finding in the literature. However, the current case could be considered to be rare and giant in the pertinent medical literature due to both bipartite chracterization and dimensions.

It was also observed that the present case's morphology depict a plano-convex shape rather than a cylindrical shape for the bigger piece, and it was cylindrical for the smaller piece. The sialolithiasis could be of spindle, cylindrical, or spherical shapes and exhibits a yellowish- brown hue or grayish-white hue.[12] Each of these types has the ability to show the distinctive features or characteristics associated with the anatomic location where the calculi has occurred.[12] For instance, if the sialolithiasis is lodged within the duct of the salivary gland, it tends to depict an elongated or a cylindrical morphology. However, when it is located in the salivary gland, it is more inclined to take on a circular shape.[12,25]

In the treatment of sialolithiasis, therapeutic approaches are categorized into traditional and modern methods.[26??] The remarkable advancement of technology in recent years has led to replacing more aggressive methods with minimally invasive procedures. Notably, the preservation of glandular function is of the utmost importance in clinical success, so clinicians need to be familiar with all techniques. In cases of small sialolithiasis, conservative management comprising sialogogues and glandular massage may be sufficient for therapeutic success; however, surgical intervention is indicated for larger ones. Regarding sialolithiasis in the submandibular duct or gland, the selection of surgical or non-surgical treatment approaches is influenced by several critical factors.[5,14,26] If a submandibular sialolithiasis located near the Wharton papilla, the sialodochoplasty as a marsupialization method is performed before the stone is removed via an intraoral sialolithotomy approach. On a general note, submandibular sialoliths located anterior to the first molar tooth may be removed through intraoral sialolithotomy when they are palpable. In line with this, Bozkurt et al.[27] emphasized that primary treatment for sialolithiasis that are easily palpable and located at the distal portion of the duct should be removed via sialolithotomy. If there are recurrent episodes of obstruction and sialadenitis subsequent to intraoral sialolithotomy, which is unlikely to resolve with a non-invasive approach alone, excision of the submandibular gland may be considered.[27] Moreover, cases requiring sialoadenectomy rather than a sialolithotomy with intraoral approach include sialolithiasis located posterior to the first molar region or located in the middle part of the Wharton's duct that cannot be bimanually palpable via intraoral examination.[26,27] Sialoadenectomy could be performed by either transcervical approach or intraoral approach; however, some researchers strongly oppose the intraoral approach because of the variable anatomical relationships between the submandibular gland, the lingual nerve, Wharton's duct, and hypoglossal nerve in the oral cavity, as well as the risk of severe hemorrhage from lingual vessels.[28] On the other hand, the transcervical approach presents some potential risks including facial symmetry related to neurological complications, and may result in visible cervical scarring.[28] In this context, the endoscopic approach stands out as both a safe and an effective alternative technique. But since endoscopic approach is generally recommended for stones that are less than 4 mm in diameter, we opted for surgical removal in this case. Alternatively, endoscopy combined with lithotripsy could have been another treatment option for this case as sialoliths of the submandibular duct measuring 5-7 mm in diameter may be fragmented using endoscopic-guided laser lithotripsy before manual removal.[29] In a comprehensive retrospective study, Ayrancı et al.30 evaluated the outcomes of minimally invasive transoral approaches for the management of sialoliths at various locations within Wharton's duct. In their study, they pointed that transoral approaches may demonstrate superior efficacy in managing Wharton's duct sialoliths because of offering both higher success rates and broader therapeutic applications compared to conservative intervention like sialendoscopy. On the other hand, as a contemporary approach, transoral robotic surgery (TORS) enables the excision of ranulas in the floor of the mouth, sialoliths, and salivary gland tumors in the submandibular gland and oropharynx.[30] The implementation of TORS represents an innovative alternative to conventional open approaches for salivary gland pathologies, offering enhanced surgical access, better cosmetic outcomes with minimal scarring, reduced blood loss, shortened hospitalization, and overall decreased morbidity.[30] This alternative treatment modality requires both a high level of dedicated experience and equipment. Unfortunately our clinic lacks these sophisticated equipment, which can be considered as a limitation for this case report. In the current case, the sialolith could be palpated easily from the intraoral region, even though it extended to the posterior region of the first molar, so an intraoral sialolithotomy was effectively performed with no injury to the lingual nerve.

## Conclusion

In conclusion, this case illustrates the management of sialolithiasis with two separate stones in the submandibular gland's duct through a traditional surgical approach. The presence of two sialoliths within the duct and thorough preoperative planning make this case notable. The positive outcome was due to detailed diagnostic imaging before surgery, a careful surgical approach tailored to the anatomical location of the sialoliths during the operation, and maintenance of normal gland function postoperatively. This case aligns with literature advocating for minimally invasive approaches when possible and emphasizes the importance of long-term follow-up. Long-term follow-up showed no recurrence and complete resolution of symptoms, indicating that proper surgical planning and removal of the sialolith can lead to favorable outcomes in complex cases of multiple sialoliths.

## Ethical Approval

Ethical approval was not obtained for this case report. However, the patient voluntarily agreed to participate and signed a written informed consent form.

## Acknowledgements

We thank our dental assistant and nurse (Mumine Uzuncaok) from Istanbul University-Cerrahpaşa Faculty of Dentistry, Department of Oral and Maxillofacial Surgery Clinic.

## Author Contributions

Diagnosed the condition : N.M.T.
Surgical planning and study design : All Authors
Wrote the manuscript : All Authors
Read and approved the final manuscript : All Authors

## Conflict of Interest

No potential conflict of interest relevant to this article was reported.

## Authors' ORCID(s)

N.M.T. 0000-0002-5595-9302
A.E.T. 0000-0002-9156-9109

## References

1. Oliveira Tde P, Oliveira IN, Pinheiro EC, Gomes RC, Mainenti P. Giant sialolith of submandibular gland duct treated by excision and ductal repair: a case report. Braz J Otorhinolaryngol. 2016;82(1):112–115. doi:10.1016/j.bjorl.2015.03.013.
2. Hammett JT, Walker C. In: Sialolithiasis. Treasure Island (FL): StatPearls Publishing Copyright © 2025, StatPearls Publishing LLC.; 2025. .
3. Huoh KC, Eisele DW. Etiologic factors in sialolithiasis. Otolaryngol Head Neck Surg. 2011;145(6):935–939. doi:10.1177/0194599811415489.
4. Rosales Diaz Miron D, Castillo B, Rodriguez-Pulido J. Gland excision in submandibular sialolithiasis: A case report. Journal of Oral Research. 2015;4:270–274. doi:10.17126/joralres.2015.052.
5. Marchal F, Kurt AM, Dulguerov P, Lehmann W. Retrograde theory in sialolithiasis formation. Arch Otolaryngol Head Neck Surg. 2001;127(1):66–68. doi:10.1001/archotol.127.1.66.
6. Harrison JD. Causes, natural history, and incidence of salivary stones and obstructions. Otolaryngol Clin North Am. 2009;42(6):927–947, Table of Contents. doi:10.1016/j.otc.2009.08.012.
7. Rzymska-Grala I, Stopa Z, Grala B, Gołębiowski M, Wanyura H, Zuchowska A, et al. Salivary gland calculi - contemporary methods of imaging. Pol J Radiol. 2010;75(3):25–37.
8. Mao JS, Lee YC, Chi JC, Yi WL, Tsou YA, Lin CD, et al. Long-term rare giant sialolithiasis for 30 years: A case report and review of literature. World J Clin Cases. 2023;11(22):5382–5390. doi:10.12998/wjcc.v11.i22.5382.
9. Yiu AJ, Kalejaiye A, Amdur RL, Todd Hesham HN, Bandyopadhyay BC. Association of serum electrolytes and smoking with salivary gland stone formation. Int J Oral Maxillofac Surg. 2016;45(6):764–768. doi:10.1016/j.ijom.2016.02.007.
10. Sonar PR, Panchbhai A, Dhole P. Sialolithiasis in the Left Submandibular Gland: A Case. Cureus. 2023;15(11):e48999. doi:10.7759/cureus.48999.
11. Jáuregui E, Kiringoda R, Ryan WR, Eisele DW, Chang JL. Chronic parotitis with multiple calcifications: Clinical and sialendoscopic findings. Laryngoscope. 2017;127(7):1565–1570. doi:10.1002/lary.26386.
12. Silveira Junior JBd, Matias Neto JB, Andrade Junior I, Capistrano HM. Multiple sialolithiasis in submandibular gland duct: a rare case report. RGO - Rev Gaúcha Odontol. 2020;68. doi:10.1590/1981-86372020000920180103.
13. Foletti JM, Graillon N, Avignon S, Guyot L, Chossegros C. Salivary Calculi Removal by Minimally Invasive Techniques: A Decision Tree Based on the Diameter of the Calculi and Their Position in the Excretory Duct. J Oral Maxillofac Surg. 2018;76(1):112–118. doi:10.1016/j.joms.2017.06.009.
14. Marchal F, Dulguerov P. Sialolithiasis management: the state of the art. Arch Otolaryngol Head Neck Surg. 2003;129(9):951–956. doi:10.1001/archotol.129.9.951.
15. Aoun G, Maksoud C. Sialolith of Unusual Size and Shape in the Anterior Segment of the Submandibular Duct. Cureus. 2022;14(4):e24114. doi:10.7759/cureus.24114.
16. Sigismund PE, Zenk J, Koch M, Schapher M, Rudes M, Iro H. Nearly 3,000 salivary stones: some clinical and epidemiologic aspects. Laryngoscope. 2015;125(8):1879–1882. doi:10.1002/lary.25377.
17. Krishnappa BD. Multiple submandibular duct (Wharton's duct) calculi of unusual size and shape. Indian J Otolaryngol Head Neck Surg. 2010;62(1):88–89. doi:10.1007/s12070-010-0018-4.
18. Uğur TA, Yılmaz S. Üç Varyasyonuyla Submandibular Tükürük Bezi Taşları: Olgu Serisi. Akd Dent J. 2023;2(2):110–114.
19. Melo GM, Neves MC, Rosano M, Vanni C, Abrahao M, Cervantes O. Quality of life after sialendoscopy: prospective non-randomized study. BMC Surg. 2022;22(1):11. doi:10.1186/s12893-021-01462-2.
20. Buyruk A, Bozkuş F. Submandibular Bez Cerrahi Sonuçlarımız. Harran univtıp fak derg. 2020;17(1):45–49. doi:10.35440/hutfd.651611.
21. Leung AK, Choi MC, Wagner GA. Multiple sialoliths and a sialolith of unusual size in the submandibular duct: a case report. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999;87(3):331–333. doi:10.1016/s1079-2104(99)70218-0.
22. Moon PP, Bankar M, Kalambe S, Badge A, Kukde MM, Bankar NJ. An Unusually Large Submandibular Sialolith: A Case Report. Cureus. 2024;16(9):e70356. doi:10.7759/cureus.70356.
23. Huang TC, Dalton JB, Monsour FN, Savage NW. Multiple, large sialoliths of the submandibular gland duct: a case report. Aust Dent J. 2009;54(1):61–65. doi:10.1111/j.1834-7819.2008.01091.x.
24. Brusati R, Fiamminghi L. Large calculus of the submandibular gland: report of case. J Oral Surg. 1973;31(9):710–1.
25. Xiao JQ, Sun HJ, Qiao QH, Bao X, Wu CB, Zhou Q. Evaluation of Sialendoscopy-Assisted Treatment of Submandibular Gland Stones. J Oral Maxillofac Surg. 2017;75(2):309–316. doi:10.1016/j.joms.2016.08.023.
26. Cumpston E, Chen P. In: Submandibular Excision. Treasure Island (FL): StatPearls Publishing Copyright © 2025, StatPearls Publishing LLC.; 2025. .
27. Bozkurt P, Kolsuz M, Erdem E. Large Sialolith of the Submandibular Gland: Report of a Case and Comparison of Sialolithotomy VS Sialoadenectomy. SDU J Health Sci. 2016;7(1):41–43. doi:10.22312/sbed.28024.
28. Singh PP, Goyal M. Our Experience with Intraoral Submandibular Gland Excision. Indian J Otolaryngol Head Neck Surg. 2020;72(3):297–301. doi:10.1007/s12070-019-01784-x.
29. Kahveci K, Ayrancı F. Retrospective Evaluation of the Treatment of Wharton's Duct Stones with Transoral Approach. Middle Black Sea J Health Sci. 2019;5(2):74–78. doi:10.19127/mbsjohs.555748.
30. Özen AB, Kırkpunar A, Karaca IR. Siyalolitiyazis Vakalarında Cerrahi Yaklaşımlar ve Klinik Çalışmalar. ADO J Clin Sci. 2024;13(2):388–394. doi:10.54617/adoklinikbilimler.1379003.