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The effect of commonly used pediatric iron supplements on the color stability of restorative materials

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ABSTRACT

Aims: This in vitro study aimed to evaluate the effect of commonly prescribed pediatric iron supplements-ferric polymaltose (Ferrum®) and ferrous sulfate (Ferro Sanol B®)-on the color stability (ΔE) of different restorative materials.

Methods: One hundred eighty specimens from composite resin, compomer, flowable composite resin, and glass ionomer cement were assigned to distilled water (control), ferric polymaltose, or ferrous sulfate groups (n=15). All samples were stored at 37°C, immersed in the test solutions for 2 minutes daily, and evaluated at baseline, 7 days, and 28 days. Between immersions, specimens were kept in distilled water. Color measurements were performed using a spectrophotometer (VITA Easyshade, Germany) in the CIE Lab* system and ΔE values were calculated. Data were analyzed using Kruskal-Wallis and Mann-Whitney U tests ($p<0.05$).

Results: Both iron supplements caused significant discoloration in all restorative materials compared to the control ($p<0.05$). GIC exhibited the highest color change, while composite resin showed the lowest. Ferric polymaltose produced greater discoloration than ferrous sulfate in most material groups, particularly in GIC.

Conclusion: Pediatric iron supplements have a high potential for discoloration of restorative materials, with the iron's chemical form influencing the extent of staining. The development of formulations with reduced staining potential may contribute to improved esthetic outcomes in pediatric dental care.

Keywords: Color stability, dental materials, iron supplements, pediatric dentistry, spectrophotometry

INTRODUCTION

In recent years, advancements in pediatric restorative dentistry have increasingly emphasized both functional and esthetic outcomes.[1] Achieving a restoration that closely mimics the natural appearance of primary teeth is essential for both psychological and clinical success, particularly in anterior regions.[2] Due to anatomical differences such as thinner enamel and dentin layers, flat proximal contacts, and short retention periods, restorative procedures in primary teeth require materials that are not only durable but also esthetically pleasing and minimally invasive.[3]

Fluoride-releasing materials with favorable esthetic properties-including compomers, resin-modified glass ionomer cements (RMGICs), and composite resins-are widely preferred in pediatric clinical practice.[1] However, among the various criteria for successful outcomes, color stability remains a critical factor.[4] The optical behavior of restorative materials is influenced by intrinsic properties such as filler distribution, polymer matrix composition, and surface texture, as well as clinical factors like finishing/polishing techniques.[5] Over time, discoloration can occur due to environmental influences such as plaque accumulation, dietary pigments, and acidic conditions. These changes may present as external, superficial, or intrinsic staining and can compromise the longevity and esthetic quality of restorations.[6]

Iron deficiency anemia, frequently encountered during childhood, often necessitates treatment with oral iron supplements in the form of syrups or drops.[7] While these preparations are effective in restoring systemic iron levels, they may also have undesirable oral side effects.[8] Among them, tooth discoloration is of particular concern in pediatric patients. Ferric ions can form dark precipitates (such as Fe_2S_3) through chemical interactions in the oral environment, leading to both enamel staining and potential alterations in restorative materials.[9] In addition to extrinsic effects, oxidative reactions and ion complexation may also influence the material's optical properties and surface chemistry.[4]

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Although several studies have investigated the staining potential of iron supplements on both natural dentition and restorative materials, there remains a scarcity of research directly comparing the discoloration effects of different iron formulations across multiple commonly used pediatric restorative materials under standardized in vitro conditions.[6,10-13] The present study addresses this gap by simultaneously evaluating ferric polymaltose and ferrous sulfate on four distinct restorative materials, providing a clinically relevant comparative analysis.

Therefore, this in vitro study aimed to evaluate the effect of exposure to two commonly prescribed pediatric iron supplements (Ferrum® and Ferro Sanol B®) on the color stability of four restorative materials; composite resin, compomer, flowable composite resin, and conventional glass ionomer cement. By measuring the color change (ΔE) using spectrophotometry, this study seeks to provide evidence-based guidance for material selection in pediatric patients frequently receiving iron therapy.

The null hypothesis (H_0) of this study was that exposure to pediatric iron supplements would not cause a significant color change (ΔE) in any of the tested restorative materials.

The alternative hypothesis (H_1) was that exposure to pediatric iron supplements would result in a significant color change (ΔE) in at least one type of restorative material.

METHODS

Study Design

This in vitro experimental study was conducted at the Department of Pediatric Dentistry, Kocaeli Health and Technology University, Turkiye. Ethical approval was not required as the study involved only in vitro procedures using restorative dental materials, with no human or animal subjects. All procedures were carried out in accordance with the ethical rules and the principles. The aim was to evaluate the color stability of four different restorative materials after exposure to commonly prescribed pediatric iron supplements (Table 1, 2).

Sample Preparation

Four direct restorative materials were used: a conventional composite resin, a compomer, a flowable composite resin, and a conventional glass ionomer cement (GIC). A total of 180 cylindrical specimens were prepared (5 mm diameter × 3 mm height), with 15 specimens in each subgroup (n=15/group). Each material was divided into three subgroups based on the immersion medium:

- Control (immersed in distilled water)
- Ferrum® pediatric iron supplement
- Ferro Sanol B® pediatric iron supplement

This resulted in twelve experimental groups. For resin-based materials, specimens were placed in cylindrical silicone molds, covered with a glass slide to ensure a flat surface, and light-cured for 20 seconds using an LED curing device, following the manufacturer's instructions. GIC specimens were self-cured according to manufacturer guidelines (Table 3).

Sample Size Calculation

The sample size was determined using G*power software (version 3.1.9.4). Based on an assumed effect size of f=0.294, with α=0.05 and a desired statistical power of 90%, the

Table 1. Restorative materials used in this study

Material	Classification	Composition	Manufacturer
3M ESPE Filtek Z250 universal composite resin	A conventional composite resin	UDMA + Bis-EMA + Bis-GMA resin matrix; silane-treated ceramic fillers (approx. 75-85% wt)	3M ESPE, Dental products 2510 Conway Avenue St. Paul, MN 55144-1000 USA
Imicryl nova compomer flow	Compomer (flowable)	Resin-modified glass ionomer (compomer); resin matrix+fluoride-releasing glass ionomer components (ticarboxylic acid, glass powder)	Imicryl, Turkiye
3M ESPE filtek ultimate flowable composite	Flowable composite resin	Flowable composite Nanofiller composite: resin matrix with nanotechnology fillers for high polishability, radiopacity	33M ESPE, Dental products 2510 Conway Avenue St. Paul, MN 55144-1000 USA
Imicryl nova glass F glass ionomer filling cement	Conventional glass ionomer cement	Powder-liquid system: silicate glass powder+polyalkenoic acid; self-curing, radiopaque, high fluoride release	Imicryl, Turkiye

Table 2. Iron supplements used in this study

Product	Composition	Manufacturer
Ferrum®	Ferric (III) hydroxide polymaltose complex as iron source; excipients include sucrose, sorbitol, and flavoring agents	Vifor Pharma, Switzerland (or local license holder)
Ferro Sanol B®	Iron (II) glycine sulfate complex; formulation may also contain riboflavin, sodium phosphate, thiamine hydrochloride and pyridoxine hydrochloride depending on presentation	UCB Pharma, Germany (or local license holder)

Table 3. Specimen preparation and polymerization procedures recommended by the manufacturer for the restorative materials tested in this study

Material	Specimen preparation	Polymerization procedures
3M ESPE Filtek Z250 Universal Composite Resin	Placed into cylindrical silicone molds (5 mm×3 mm), covered with a glass slide to obtain a flat surface	Light-cured with an LED curing unit for 20 s
Imicryl nova compomer flow	Placed into molds, surface flattened with a glass slide	Light-cured with an LED curing unit for 20 s
3M ESPE Filtek ultimate flowable composite	Injected into molds, surface flattened with a glass slide	Light-cured with an LED curing unit for 20 s
Imicryl nova glass F glass ionomer filling cement	Hand-mixed powder and liquid placed into molds; surface flattened with a glass slide	Self-cured (setting time per manufacturer's instructions)

required sample size was calculated to be 168. To compensate for potential specimen loss, the final sample size was increased to 180, with 15 specimens allocated to each subgroup.

Each material group was randomly divided into three subgroups according to the immersion medium: a control group (immersed in distilled water), a group exposed to Ferrum® iron syrup, and a group exposed to Ferro Sanol B® iron syrup. As a result, twelve experimental groups were established, each comprising 15 specimens.

Immersion Protocol

Following specimen preparation, all samples were stored in an incubator at 37°C until the immersion procedures commenced. For the 1-day evaluation, specimens were immersed in their respective test solutions for 2 minutes on day 1, after which immediate color measurements were performed. For the 7-day evaluation, specimens were immersed for 2 minutes daily over seven consecutive days (days 1-7), with the final color measurement taken on day 7. For the 28-day evaluation, specimens underwent the same daily immersion protocol for 28 consecutive days, and the final color measurement was recorded on day 28. Representative images of the restorative material specimens immersed in pediatric iron supplement solutions (Ferrum® and Ferro Sanol B®) are shown in **Figure 1**.

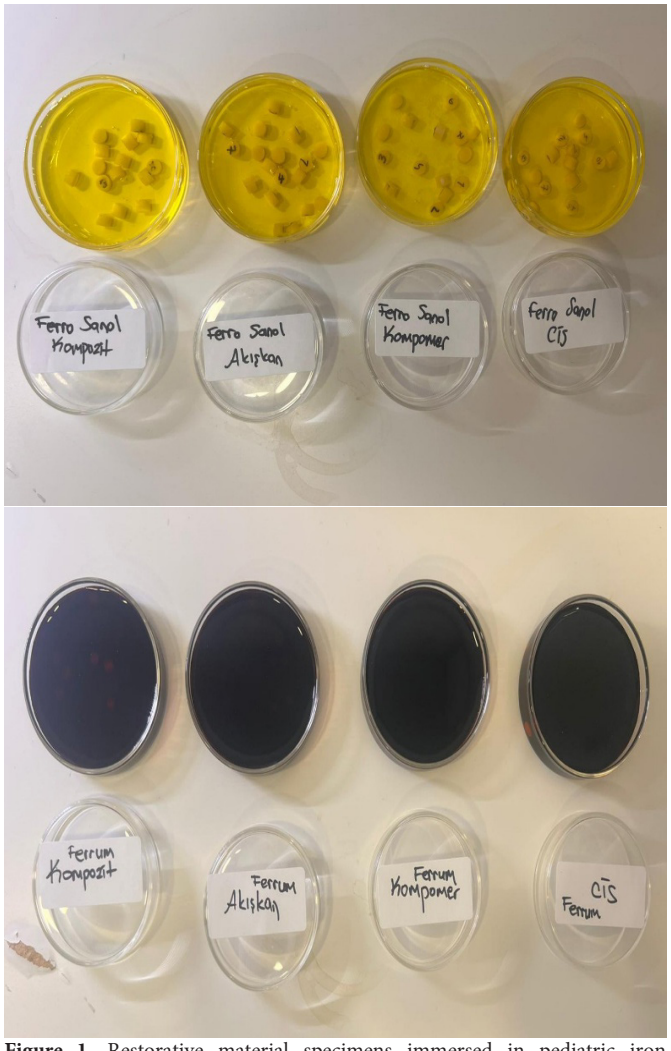

Figure 1. Restorative material specimens immersed in pediatric iron supplement solutions (Ferrum® and Ferro Sanol B®) during the experimental procedure

Between immersion periods, all specimens were stored in distilled water at room temperature to prevent dehydration and surface contamination. Prior to each color measurement, specimens were gently dried with absorbent paper to remove excess surface moisture. Measurements were performed against a standardized white background, and three consecutive readings were taken for each specimen using the spectrophotometer. The mean of these readings was used as the representative ΔE value for statistical analysis.

Color Measurements

Baseline color measurements (day 0) and subsequent measurements at days 1, 7, and 28 were performed using a VITA Easyshade V spectrophotometer (VITA Zahnfabrik, Bad Säckingen, Germany) in the CIE Lab* color space. Prior to each session, the device was calibrated according to the manufacturer's instructions. Measurements were taken by placing the specimens on a neutral white background to minimize reflection.

Color change (ΔE) was calculated using the formula:

$\Delta E=(\Delta L)2+(\Delta a)2+(\Delta b)2\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}\Delta E=(\Delta L)2+(\Delta a)2+(\Delta b)2$

The following perceptibility and acceptability thresholds were applied: ΔE=1.2 (perceptible to 50% of observers) and ΔE=2.7 (clinically unacceptable).[14-16]

Statistical Analysis

Data analyses were performed using SPSS software (IBM SPSS Statistics, version 30.0; IBM Corp., Armonk, NY, USA). Normality was assessed using the Shapiro-Wilk test, and homogeneity of variances was evaluated using Levene's test. When the assumption of normality was not met, the Kruskal-Wallis test was applied; when assumptions were satisfied, Welch one-way ANOVA was used. Welch's test was applied with appropriate adjustments in cases of variance heterogeneity. For the Kruskal-Wallis test, effect sizes were calculated using the η^2 formula:

$\eta2=H–k+1n–k\eta^2 = \frac{H - k + 1}{n - k}\eta2=n–kH–k+1$

Where H is the test statistic, k is the number of groups, and n is the total sample size.

For Welch ANOVA, omega squared (ω^2) was calculated as the effect size. Effect sizes were interpreted according to Cohen[17] and Tomczak and Tomczak[18] as follows:

- Small effect: η^2 or $\omega^2 \geq 0.01$
- Medium effect: η^2 or $\omega^2 \geq 0.06$
- Large effect: η^2 or $\omega^2 \geq 0.14$

When a statistically significant difference was found, post-hoc tests were performed:

- For Kruskal-Wallis: Mann-Whitney U test with Bonferroni correction.
- For Welch ANOVA: Tamhane's T2 test.

The significance level was set at $p<0.05$ for all analyses, with Bonferroni-adjusted p-values applied where appropriate.

RESULTS

The present study evaluated the color stability (ΔE) of four restorative materials-composite resin, compomer, flowable composite, and glass ionomer cement-following exposure to three pediatric iron supplement conditions (Ferrum, Ferro Sanol, control) across five-time intervals (0-1, 0-7, 0-28, 1-7, and 7-28 days) as summarized in Table 4.

In the composite group, Ferrum produced significantly higher ΔE values than control at 0-1 days (mean: 32.9±17.9 vs. 13.5±5.0; p<0.001) and 0-7 days (mean: 52.7±38.2 vs. 27.5±8.3; p=0.004). Ferrum also exceeded Ferro Sanol at 0-1 days (p=0.002). Moreover, Ferro Sanol exhibited significantly higher discoloration than control at 0-28 days (median: 29 vs. 20; p=0.020) and 7-28 days (median: 24 vs. 29; p=0.044). The largest effects in this group occurred in the early evaluation period (0-1 days; η^2=0.421, large effect).

For compomer, large differences were recorded at 0-1 days (mean: Ferrum 32.0±14.1 vs. control 37.3±88.8; p<0.001), with Ferrum surpassing Ferro Sanol (p=0.006). At 1-7 days, Ferrum again produced greater discoloration than control (p=0.005), although the magnitude of change was smaller (median: 15 vs. 39).

The flowable composite demonstrated marked susceptibility at multiple intervals. At 0-1 days, both Ferrum (21.0±8.6) and Ferro Sanol (15.7±7.4) produced significantly greater ΔE than control (59.1±71.4; p=0.026 and p<0.001, respectively). At 0-7 days, Ferrum exceeded control (p=0.004) and Ferro Sanol (p=0.030). At 1-7 days, large differences were observed (η^2=0.442), with Ferrum and Ferro Sanol both differing significantly from each other (p<0.001) and from control (p=0.010). In the 7-28-day interval, all pairwise comparisons were statistically significant (p<0.05), with median values ranging from 22 in control to 53 in Ferrum, indicating a substantial long-term effect.

The glass ionomer cement group showed the highest early discoloration. At 0-1 days, Ferrum (mean: 197.1±127.7) induced significantly greater ΔE than control (92.3±101.2; p=0.011) and Ferro Sanol (37.7±21.0; p<0.001). Significant differences persisted at 0-7 days (Ferrum vs. Ferro Sanol, p<0.001) and 0-28 days (Ferrum vs. Ferro Sanol, p=0.003). Additionally, Ferro Sanol exceeded control at 0-28 days (p=0.001), despite having lower baseline values.

Overall, the most pronounced statistical differences were concentrated in the early (0-1 days) and cumulative (0-28 days) intervals. Flowable composite and glass ionomer cement exhibited the highest susceptibility to long-term (7-28 days) discoloration. Ferrum consistently induced greater ΔE values in short and medium terms, whereas the effect of Ferro Sanol varied by material type and was more prominent in extended exposure periods as detailed in Table 5, and illustrated in Figure 2.

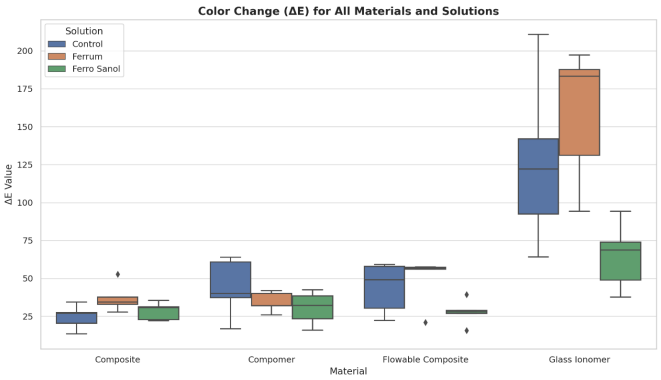

Figure 2. Boxplot representation of color change (ΔE) values for all tested restorative materials (composite resin, compomer, flowable composite resin, and glass ionomer cement) after exposure to control (distilled water), ferric polymaltose (Ferrum®), and ferrous sulfate (Ferro Sanol B®) pediatric iron supplement solutions

DISCUSSION

This in vitro study evaluated the color stability (ΔE) of four restorative materials-composite resin, compomer, flowable composite resin, and glass ionomer cement (GIC)-following exposure to two commonly prescribed pediatric iron supplements: ferric polymaltose (Ferrum Hausmann, Fe^{3+}) and ferrous sulfate (FerroSanol B, Fe^{2+}). These formulations were selected based on data from the Turkish Medicines and Medical Devices Agency, indicating that they are among the

Table 4. Descriptive statistics of the study groups (mean±SD)

Material	Group	0-1 day change mean±SD	0-1 day change median (Q1-Q3)	0-7 day change mean±SD	0-7 day change median (Q1-Q3)	0-28 day change mean±SD	0-28 day change median (Q1-Q3)	1-7 day change mean±SD	1-7 day change median (Q1-Q3)	7-28 day change mean±SD	7-28 day change median (Q1-Q3)
Composite	Control	13.5±5	14 (9-16)	27.5±8.3	27 (22-32)	20.5±7	20 (14-28)	27±10.3	28 (18-32)	34.3±12.5	29 (27-40)
	Ferrum	32.9±17.9	27 (20-37)	52.7±38.2	36 (32-47)	27.7±15.7	26 (16-39)	37.7±36	21 (16-60)	34.4±32.2	27 (15-31)
	Ferro Sanol	22±29	13 (10-22)	35.5±9.9	32 (27-48)	31.3±12.1	29 (21-41)	30.8±17.5	26 (23-37)	22.9±7.3	24 (22-27)
Compomer	Control	37.3±88.8	10 (4-19)	63.9±82.4	43 (35-51)	60.9±83.9	40 (36-46)	40.1±10.1	39 (33-50)	16.7±6.4	15 (13-21)
	Ferrum	32±14.1	27 (23-41)	42±24.4	35 (27-50)	40.1±30.4	30 (22-44)	25.9±26.7	15 (9-43)	32±28.6	16 (12-55)
	Ferro Sanol	15.9±9.1	13 (9-20)	42.4±10.5	43 (36-47)	38.4±13	34 (31-46)	32.1±7.3	30 (28-37)	23.4±9.3	24 (16-32)
Flowable Composite	Control	59.1±71.4	27 (25-62)	49±68.6	22 (16-26)	57.9±67.9	31 (27-43)	30.3±4.9	32 (25-33)	22.3±5.5	22 (20-25)
	Ferrum	21±8.6	19 (15-26)	57.5±30.9	50 (37-72)	57.3±30	55 (30-89)	56.1±28.1	50 (36-70)	56.6±28.1	53 (29-73)
	Ferro Sanol	15.7±7.4	14 (10-21)	27.9±6.7	27 (23-34)	39.3±6.7	39 (33-44)	26.9±6.3	27 (21-29)	28.9±6.6	26 (24-33)
Glass Ionomer	Control	92.3±101.2	48 (26-123)	122.2±111.4	79 (51-177)	210.7±106.2	200 (101-301)	64.1±69.5	46 (29-64)	141.9±123.5	114 (38-247)
	Ferrum	197.1±127.7	174 (86-250)	183.2±135.3	173 (64-212)	187.7±86.8	192 (120-265)	94.2±65	78 (41-126)	131.1±103.2	94 (47-209)
	Ferro Sanol	37.7±21	38 (21-54)	48.9±23	44 (30-72)	73.9±59.8	56 (42-91)	68.7±35.5	53 (44-96)	94.2±70.3	79 (44-125)

Table 5. Summary of statistical comparisons for color change (ΔE)

Material	Time interval	H/welch	df	p-value	Eta²	Significant pairwise comparisons (p<0.05)
Composite	0-1 day	19.710	2	<0.001	0.421	Control-Ferrum (<0.001); Ferrum-Ferro Sanol (0.002)
	0-7 days	10.697	2	0.005	0.207	Control-Ferrum (0.004)
	0-28 days	4.873	2	0.016	0.085	Control-Ferro Sanol (0.020)
	1-7 days	1.930	2	0.381	-0.002	-
	7-28 days	6.410	2	0.041	0.105	Control-Ferro Sanol (0.044)
Compomer	0-1 day	16.478	2	<0.001	0.345	Control-Ferrum (<0.001); Ferrum-Ferro Sanol (0.006)
	0-7 days	2.642	2	0.267	0.015	-
	0-28 days	4.310	2	0.116	0.055	-
	1-7 days	9.798	2	0.007	0.186	Control-Ferrum (0.005)
	7-28 days	3.754	2	0.153	0.042	-
Flowable composite	0-1 day	17.540	2	<0.001	0.370	Control-Ferro Sanol (<0.001); Control-Ferrum (0.026)
	0-7 days	11.438	2	0.003	0.225	Control-Ferrum (0.004); Ferrum-Ferro Sanol (0.030)
	0-28 days	3.423	2	0.181	0.034	-
	1-7 days	20.547	2	<0.001	0.442	Control-Ferrum (0.010); Ferrum-Ferro Sanol (<0.001)
	7-28 days	13.416	2	<0.001	0.421	Control-Ferro Sanol (0.017); Ferrum-Ferro Sanol (0.006)
Glass Ionomer	0-1 day	21.271	2	<0.001	0.459	Ferrum-Ferro Sanol (<0.001)
	0-7 days	16.117	2	<0.001	0.336	Ferrum-Ferro Sanol (<0.001)
	0-28 days	16.756	2	<0.001	0.351	Ferrum-Ferro Sanol (0.003)
	1-7 days	3.888	2	0.143	0.045	-
	7-28 days	0.822	2	0.663	-0.028	-

Note: Only statistically significant pairwise comparisons (p<0.05, adjusted) are shown. '-' indicates no significant difference

most frequently prescribed iron syrups for pediatric patients in the country, thereby ensuring the clinical relevance of the experimental design.[19]

Ferrous sulfate (Fe^{2+}) was included in this study due to its higher bioavailability compared to ferric salts, as consistently reported in clinical literature, and its well-documented potential to cause dental staining in pediatric populations.[8]

The null hypothesis (H_0), which assumed that exposure to pediatric iron supplements would not result in significant color change in any of the tested materials, was rejected, while the alternative hypothesis (H_1) was supported. Both supplements caused significant discoloration in all tested materials, with the extent of change depending on the type of material and the iron formulation. The greatest discoloration was observed in GIC, while composite resin exhibited the least. Ferric polymaltose consistently produced higher ΔE values than ferrous sulfate, particularly in GIC and compomer groups.

These results are consistent with previous findings. Kaya et al.[11] reported that Fe^{2+}-containing pediatric syrups caused greater discoloration in primary teeth than Fe^{3+} formulations, while Singh et al.[19] emphasized the role of low pH, acidic excipients, and synthetic dyes in the staining potential of pediatric liquid medications. Similarly, Pani et al.[20] observed that ferric polymaltose produced significantly higher ΔE values than ferrous fumarate after 72 h of exposure in primary teeth. The present findings align with this observation, as ferric polymaltose (Fe^{3+}) caused more intense staining than ferrous sulfate (Fe^{2+}), possibly due to the higher oxidative reactivity of ferric ions, which may promote faster pigment formation within and on the surface of restorative materials.

In addition to ion type, formulation technology also appears to play a critical role in discoloration potential. Lokhande et al.[12] demonstrated that conventional pediatric iron drops induced significantly greater discoloration (ΔE=40.6) compared to liposomal microencapsulated iron drops (ΔE=34.84), with the difference being statistically significant. This suggests that microencapsulation technology may reduce pigment adherence and penetration into dental tissues, potentially offering a clinically relevant strategy for minimizing esthetic compromise in pediatric patients requiring iron supplementation. The convergence of these findings underscores that both the chemical form of iron and its delivery vehicle substantially influence staining outcomes.

Consistent with our observations, Tüzüner et al.[6] reported that among pediatric formulations, Ferrosanol B induced the highest degree of discoloration. However, differences were observed in the ranking of restorative materials: in their study, composites exhibited the highest and glass ionomers the lowest discoloration susceptibility, whereas in the present study, glass ionomers showed the greatest color change and composites the least.

Differences among restorative materials can be explained by their intrinsic physicochemical properties. Glass ionomer cement (GIC), due to its hydrophilic polyalkenoate matrix, high surface porosity, and acid-base setting reaction, facilitates deeper penetration of chromogenic compounds and metallic ions into the material bulk, thereby increasing its susceptibility to irreversible discoloration.[21] In the present study, GIC exhibited the highest color change values at all time intervals, with ΔE values exceeding clinically perceptible thresholds as early as day 7, consistent with prior findings.[11]

Additionally, the continuous release and uptake of ions through its porous structure may act as channels for pigment infiltration, particularly in low pH environments.

In contrast, composite resins, which demonstrated the lowest ΔE values in our results, contain a predominantly hydrophobic resin matrix (e.g., bis-GMA, UDMA) and a highly cross-linked polymer network, which limits water sorption and restricts pigment uptake, thereby providing the greatest resistance to staining.[12] Compomers and flowable composites exhibited intermediate staining susceptibility, in line with their water absorption capacity being higher than that of conventional composites but lower than that of GIC.[22] In our data, compomers showed significantly less discoloration than GIC but more than composite resin, whereas flowable composites, due to their lower filler content and smaller filler size, tended to stain slightly more than compomers over prolonged exposure.

The acidic pH of pediatric iron syrups can soften and erode the resin matrix or the polysalt matrix in GIC, increasing surface roughness and creating microretentive sites for pigment deposition.[10] This synergistic effect of acidic degradation and pigment-rich solution exposure has been documented in several in vitro studies assessing the color stability of restorative materials following immersion in pediatric medications.[10-13] The present findings support these mechanisms, indicating that both material composition and the physicochemical properties of the staining agent critically determine the extent of discoloration.

Color measurements were performed using a spectrophotometer (VITA Easyshade) and the CIE L*a*b* color system, which is widely used in dentistry for its reproducibility and strong correlation with human visual perception.[23] The CIE L*a*b* system quantifies color in a three-dimensional space (L*, a*, b*), allowing objective detection of minimal changes and avoiding the subjectivity of visual assessment.[19] This methodological approach enhances the reliability of the present findings.

The measurement intervals of 0-1, 0-7, and 0-28 days were chosen to capture short-, medium-, and long-term effects. The 28-day period is widely used in in vitro color stability studies as it approximates 2-3 years of clinical service under accelerated conditions.[22] This duration allows observation of the plateau phase of pigment penetration, and in our study, prolonged exposure accentuated the differences among materials, with GIC and flowable composite exhibiting the most marked long-term discoloration.[24]

Clinically, discoloration caused by iron supplements may compromise the esthetic outcomes of restorations, particularly in anterior teeth of pediatric patients.[25] Given the psychological and social importance of esthetics in children, clinicians should consider using materials with greater color stability for patients likely to require long-term iron therapy and counsel parents about the risk of discoloration.

Limitations

The present study is subject to certain limitations that should be acknowledged. The in vitro design employed does not fully replicate the complex oral environment, where factors such as saliva composition, dental plaque accumulation, intraoral pH fluctuations, and the mechanical effects of toothbrushing may substantially influence the discoloration process of restorative materials. In addition, the scope of the investigation was limited to a specific number of iron supplement formulations and fixed exposure durations, which may not reflect the diversity of clinical scenarios. Another important aspect concerns the excipients commonly contained in pediatric iron syrups-such as flavoring agents, colorants, and pH modifiers-the influence of which on color stability could not be comprehensively assessed within the current model. Future research should therefore aim to incorporate a broader range of formulations, evaluate longer-term exposure periods, and integrate in vivo conditions to enhance both the clinical relevance and generalizability of the findings.

CONCLUSION

This in vitro study demonstrated that pediatric iron supplements possess a considerable staining potential on primary teeth and restorative materials. The chemical form of iron plays a significant role in the extent of discoloration, with ferric polymaltose (Fe^{3+}) producing greater color change than ferrous sulfate (Fe^{2+}) in most tested materials. As the formulation of iron syrups directly influences their staining potential, developing pediatric iron supplements with reduced discoloration properties may serve as an effective public health strategy to preserve the esthetic and functional integrity of restorations in pediatric patients.

ETHICAL DECLARATIONS

Ethics Committee Approval

Ethical approval was not required for this study, as it was conducted entirely in vitro using restorative dental materials and did not involve human or animal subjects.

Informed Consent

Because the study has no study with human and human participants, no written informed consent form was obtained.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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