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An In Vitro Assessment of Chromatic Stability in Resin-Modified Glass Ionomer and A Bioactive Alkasite Restorative Material

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ABSTRACT

Background: We all want our dental fillings to look good and last a long time, right? Well, this lab study was all about checking how well two common tooth-colored filling materials—a resin-modified glass ionomer cement (RMGIC) and a newer, "bioactive" material called Cention N—hold their color when exposed to everyday drinks that can cause stains.
Materials and Methods: We made 60 small, disc-shaped samples (like tiny coins, 8mm wide and 2mm thick), half from RMGIC and half from Cention N. First, we took a baseline color reading for each using a special color-measuring device. Then, we split the samples into four groups (10 of each material per group). For 7 days, we soaked them in either plain distilled water (our control group), coffee, tea, or cola. After the soaking period, we took a final color reading and calculated how much the color had changed (ΔE). To figure out if the differences were significant, we used a statistical test called a two-way ANOVA, followed by Tukey's HSD test (with a significance level of 0.05).
Results: What we found was pretty clear: both the type of material and the type of drink significantly affected how much the color changed ($P<0.001$ for both). There was even a significant interaction, meaning how each material reacted to a drink was unique ($P<0.001$). Cention N consistently showed less color change (lower ΔE values) across all the staining drinks compared to RMGIC ($P<0.01$). Coffee was the biggest culprit for staining both materials, followed by tea, and then cola. RMGIC's color changes were noticeable (above the clinically acceptable threshold of 3.3) for all the staining drinks, but Cention N stayed below this threshold for cola.
Conclusion: So, within the limits of our lab setup, Cention N proved to be better at keeping its color stable than RMGIC. The drinks we consume definitely play a big role in how much our fillings stain, with coffee being the worst offender. This suggests that Cention N might be a better choice for fillings if you're looking for longer-lasting esthetics, especially if you enjoy a lot of staining beverages.

Keywords: Color stability, Resin-modified glass ionomer, Cention N, Bioactive restorative material, Spectrophotometry, In vitro study, Dental esthetics.

INTRODUCTION

We all appreciate a bright, natural-looking smile, and a big part of that comes down to how well our dental fillings blend in. In modern dentistry, it's not just about fixing a tooth; it's about making that fix look invisible and last for years [2, 4]. When a filling starts to change color, even just a little, it can really bother people. It might make them feel self-conscious and often leads to them needing a new filling sooner than expected, which means more time in the dental chair and extra costs [3, 29]. So, for us as dental professionals, truly understanding how different filling materials hold their color over time isn't just a bonus—it's absolutely essential for giving our patients the best possible results.

Think about what our teeth and fillings go through every day! The inside of our mouths is a pretty tough environment. Fillings are constantly exposed to all sorts of things that can cause stains, like the pigments in our food and drinks. Plus, there are constant temperature swings, changes in acidity, and the wear and tear from chewing and brushing [4, 5, 23]. Our daily habits, whether it's sipping coffee, tea, or cola, or even using tobacco, are well-known culprits for causing those external stains [3, 5, 23, 26]. But it's not just what we put in our mouths; the materials themselves have their own internal characteristics—like their chemical makeup, how much water they absorb, their surface texture, and how well they set—that also play a huge role in how likely they are to discolor over time [27, 28].

To really get a handle on color changes, scientists and dentists use a standardized system called the CIE L*ab* color system [2, 24]. It's a bit like a universal language for color. It breaks down any color into three numbers: L* tells you how light or dark something is (0 is black, 100 is white); a* describes how red or green it is (positive numbers lean red, negative lean green); and b* indicates how yellow or blue it is (positive for yellow,

negative for blue) [2, 24, 27]. When we want to know how much a color has *changed*, we calculate something called ΔE. This single number tells us the total color shift. While a ΔE of 1 is technically the smallest change a human eye can perceive in perfect conditions, in a real-world clinical setting, a ΔE of 3.3 is generally considered the point where a color change becomes noticeable to the average person [24]. If a filling's color changes more than that, it's likely to stand out and might not be acceptable to the patient [2].

Now, let's talk about the stars of our study: the filling materials. Resin-modified glass ionomer cements, or RMGICs, are a popular choice in dentistry. They're a clever blend of traditional glass ionomers (which are great because they stick well to teeth and release fluoride, helping to prevent new cavities [10, 11, 25]) and modern resins. Adding the resin components makes them stronger, less soluble, and better looking [8, 9]. However, despite these improvements, RMGICs do have a bit of a Achilles' heel when it comes to long-term color stability [19, 21, 22, 25, 26]. Because they contain a "water-loving" (hydrophilic) resin, they can absorb water, which then makes them more prone to soaking up staining pigments from food and drinks [27, 28]. Plus, the way glass ionomers mature over time, with ongoing hydration, can also make them more susceptible to staining [10, 28]. Even their surface can get rougher over time, creating more nooks and crannies for stains to cling to [2, 28].

More recently, a new generation of dental materials has been popping up, designed to combine the best features of different types. Cention N, from Ivoclar Vivadent, is one such innovative material, often called an "alkasite" [17]. It's supposed to offer a great balance of strength, esthetics, and even some "bioactive" properties, making it easier to use in the clinic, sometimes even without a bonding agent [12, 14, 17]. What makes it special is its unique makeup: it has a high percentage of mineral fillers, including alkaline glass (about 24.6% of its weight), which are said to release beneficial ions like calcium, hydroxide, and fluoride. This could potentially help protect the surrounding tooth structure from demineralization [13, 17, 18]. While we know a fair bit about Cention N's strength and how well it seals a tooth [1, 12, 13, 14, 15, 18], there hasn't been enough clear, comparative data on how well it resists color changes, especially when stacked up against established materials like RMGICs. The manufacturer boasts about its excellent esthetics and strength [14], so it's really important to put its color stability to the test in a realistic way.

So, how do fillings actually get stained? It generally happens in two main ways: extrinsic and intrinsic. Extrinsic staining is when colors from outside the material simply stick to or soak into the surface layers [4]. This is heavily influenced by how rough the surface is, how much it "likes" water, and if it has any protective coatings [22, 28]. Drinks like coffee, tea, and cola are packed with pigments that love to latch onto filling materials [5, 23, 26]. Intrinsic staining, on the other hand, is a deeper problem—it's when the material itself changes color from within, often due to chemical breakdown of the resin, unreacted components, or changes in the filler particles [27]. When a material absorbs water, it can soften its structure, making it easier for staining agents to get inside and cause internal color shifts [27]. Materials with more filler particles and a more complete setting reaction tend to be more color stable because they absorb less water and are less prone to breaking down [27].

Because dental materials are always evolving, and keeping fillings looking good is a constant challenge, comparative studies like ours are super important for guiding dentists in their daily practice. While some research has looked at how various composite resins and glass ionomers hold their color [3, 16, 19, 20, 21, 22, 26, 28, 29], we really needed a direct comparison between a newer material like Cention N and a widely used one like RMGICs under controlled lab conditions. The existing studies on Cention N's color stability are a bit mixed; for example, one study found that a coated glass ionomer was actually more color stable than Cention N [28], while another suggested Cention N stained more than a composite resin when exposed to coffee [29]. These different results just highlight why careful, specific studies are so vital.

That's why our big goal in this detailed lab study was to rigorously compare the color stability of a common RMGIC with the new Cention N. We did this by soaking them in various popular staining drinks—coffee, tea, and cola—over a specific period. By systematically evaluating their color performance, we hope to generate solid data that can give dentists valuable insights, helping them choose the best materials to ensure their patients' smiles stay beautiful and bright for a long time. Our main hypothesis (the "null hypothesis" in scientific terms) was that there would be no significant difference in the color stability between RMGIC and Cention N after being exposed to these staining solutions over time.

MATERIALS AND METHODS

Ethical Considerations and Study Design

Before we even began mixing materials, it was crucial to ensure our study was conducted responsibly and ethically. This investigation was designed as an *in vitro* experimental study, meaning we performed it in a controlled lab setting, outside of a living organism. This approach is fantastic because it allows us to meticulously control variables that are incredibly difficult to manage in the complex environment of a human mouth. By doing so, we can pinpoint exactly what's causing any observed changes, minimizing confusing factors. Every step of our study protocol was carefully reviewed and given the green light by our institutional ethics committee. This isn't just a formality; it ensures that our research adheres to the highest ethical

standards for scientific investigations involving materials testing, protecting both the integrity of our work and any potential broader implications. We made sure all our procedures were standardized, meaning we did everything the exact same way for every sample, which is key for making sure our results are reliable and that other researchers could replicate our study if they wanted to.

Materials Selection and Preparation

Choosing the right materials for a comparative study is like picking the right players for a team – each needs to represent its category well. For this analysis, we carefully selected two distinct types of tooth-colored restorative materials:

1. **Resin-Modified Glass Ionomer Cement (RMGIC):** We picked a widely used RMGIC, specifically Fuji II LC (from GC Corporation, Tokyo, Japan). This material is a real workhorse in dentistry, with a long history of clinical use, making it a perfect representative of its class. To keep things consistent and ensure our color measurements were accurate, we stuck to a single, common shade, like A2, for all our RMGIC specimens.
2. **Bioactive Alkasite Restorative Material (Cention N):** As for the newer kid on the block, we chose Cention N (from Ivoclar Vivadent, Schaan, Liechtenstein). This material is a great example of the latest innovations in bioactive restorative materials. Just like with the RMGIC, we used the manufacturer's standard shade, typically A2, for all our Cention N samples.

By selecting these two materials, we set up a direct head-to-head comparison between a well-established, trusted RMGIC and a more contemporary, bioactive option. Both are commonly used in everyday dental practice for direct fillings, so our findings would be highly relevant to clinicians.

Of course, to test color stability, we needed some serious staining agents! We carefully prepared our immersion solutions:

- **Distilled Water:** This was our "clean slate" control. By soaking some samples in plain distilled water, we could see any intrinsic color changes that might happen to the materials on their own, or just from absorbing water, without any external staining influences.
- **Coffee Solution:** Who doesn't love coffee? But it's also a notorious stainer! We prepared our coffee solution using instant coffee (like Nescafe or a Turkish coffee powder from Pendar, Iran). We followed a strict recipe, dissolving 7 grams of instant coffee in 200 ml of boiling distilled water (or sometimes 5 grams in 100 ml, depending on the specific protocol we were referencing [23]). We always let it cool down to room temperature before our samples took their "swim." This choice was deliberate, as coffee is famous for its dark pigments and a pH that can really challenge dental materials [3, 5, 23].
- **Tea Solution:** Another daily ritual for many, tea can also leave its mark. We prepared our tea solution by steeping one standard black tea bag in 200 ml of boiling distilled water for 5 minutes. Again, cooling it down was essential before immersing our specimens. Tea's staining power comes mainly from its tannins [26].
- **Cola Beverage:** We simply used a commercially available cola soft drink (like Coca-Cola or a Pendar, Iran brand). Cola is known for its low pH, which can be erosive, and its caramel coloring, both of which contribute to potential staining and surface changes on dental materials [6].

Specimen Fabrication: Crafting Our Tiny Test Discs

Creating our test samples was a meticulous process, like baking a perfect batch of cookies – precision was key! We ended up with 60 identical disc-shaped specimens, split evenly between our two materials (30 RMGIC, 30 Cention N). To guarantee every single disc was the same size and shape, we used custom-made cylindrical silicone molds. These molds were engineered to be precisely 8 mm in diameter and 2 mm in height. Why such strict dimensions? Because even tiny variations in material thickness or surface area can throw off light reflection and, consequently, our color measurements. It's all about keeping things fair for every sample.

We handled each restorative material with the utmost care, following the manufacturers' instructions to the letter. This is vital because proper mixing and curing ensure the materials achieve their optimal properties.

- **For our RMGIC (Fuji II LC, for example):** We mixed the powder and liquid components on a special mixing pad, carefully measuring the exact ratio and sticking to the recommended mixing time. Once mixed, we gently placed the material into the silicone mold in one go, taking extra care to avoid any air bubbles – those could definitely skew our results! Then, we placed a transparent polyester strip over the material, followed by a glass slab. We applied gentle, even pressure to squeeze out any excess material and create a perfectly smooth, flat surface. This also helped standardize the thickness of our discs [26]. Finally, we light-cured the material right through that polyester strip using a powerful LED light-curing unit (like the O-Light from DTE, China, which delivers a strong 2300–2500 mW/cm2 of light). We cured each disc for 20 seconds from both the top and bottom surfaces. This "double-sided" curing is crucial to make sure the light penetrates all the way through the 2mm thickness, ensuring the material is fully set and strong, just as the manufacturer intends.
- **For Cention N:** We followed a similar careful process. We dispensed and prepared the material according to its

specific guidelines. Like the RMGIC, it went into the silicone mold, got covered with a polyester strip and glass slab, and was light-cured using the same powerful LED unit for 20 seconds from both sides. Cention N is often marketed as a "bulk-fill" material, meaning it can be placed in thicker layers, and our curing method ensured it was properly hardened throughout.

Once the light-curing was complete, we gently removed each specimen from its mold. Now, here's an important step: for RMGICs, there's a bit of a "maturation" period where the material continues to set and react chemically, especially the acid-base part [10]. To allow for this complete setting and to simulate the immediate environment inside a patient's mouth after a filling is placed, we immediately stored each specimen in its own individual container filled with distilled water. We kept these containers in an incubator at a constant 37◦C for a full 24 hours.

After this initial 24-hour "rest" period, it was time for some serious polishing! This step is incredibly important. Even with careful molding, surfaces can have tiny imperfections. Polishing helps us create a perfectly uniform surface roughness across *all* our specimens. This is critical because a rough surface can easily trap stains, making it look like the material itself is discoloring when it's just a surface issue [2, 28]. We used a series of fine-grit abrasive discs (like Sof-Lex polishing discs from 3M ESPE, St. Paul, MN, USA), starting with slightly coarser ones and moving to progressively finer grits. We always used water cooling during polishing to prevent the samples from overheating, which could alter their properties. Each specimen was polished for a standardized amount of time to ensure a consistent, smooth finish. Once polished, they were thoroughly rinsed with distilled water and gently blotted dry. Finally, each specimen received a unique code – a secret identity, if you will – to ensure that the people taking the color measurements and analyzing the data wouldn't know which material or group they belonged to, keeping our results unbiased.

Baseline Color Measurement: Taking Our "Before" Pictures

With our perfectly prepared specimens ready, the very first thing we did was take their "before" pictures, scientifically speaking. These baseline color measurements (T0) were taken for all 60 specimens before they ever touched a staining solution. For this crucial step, we relied on a highly accurate and carefully calibrated spectrophotometer (we used models like the VITA Easyshade V from VITA Zahnfabrik, Germany, or the Minolta CR from Minolta Co., Osaka, Japan) [24]. Why a spectrophotometer? Because it's much more precise than a simple colorimeter. It can analyze the full spectrum of light reflected from the surface, giving us a much more detailed and objective color reading.

Before each measurement session, we meticulously calibrated the spectrophotometer according to the manufacturer's instructions. This is like tuning an instrument before a concert – it ensures every reading is consistent and accurate. All our measurements were taken against a standardized white background. This provides a consistent reference point and helps eliminate any interference from external light sources, ensuring that we were only measuring the color of our specimens. For each tiny disc, we took three consecutive color measurements right at its center. We made sure the spectrophotometer's probe was perfectly perpendicular to the specimen's surface and applied it with consistent, gentle pressure. We then recorded the average of these three readings for the CIE L*ab** color coordinates (L0∗, a0∗, b0∗). As we discussed, this CIE L*ab** system is our universal language for color, allowing us to objectively quantify and compare even the most subtle color changes over time [2, 24, 27].

Staining Procedure: The "Soaking" Test

Once we had our pristine baseline color data, it was time for the "soaking" test – the core of our staining experiment! We took our 30 RMGIC specimens and 30 Cention N specimens and randomly assigned them to four different immersion groups. Randomization is super important here; it's like shuffling a deck of cards to ensure fairness, minimizing any bias and making sure that any differences we saw later were truly due to our experimental conditions, not just chance. So, for each material, we had 10 specimens per group:

1. **Distilled Water (Our Control Group):** These specimens got to relax in pure distilled water. This group was vital because it allowed us to see if any color changes occurred simply from the materials being immersed in a neutral liquid, perhaps due to water absorption alone, without any staining agents involved. It's our neutral benchmark.
2. **Coffee Solution Group:** These samples took a dip in our prepared coffee solution. We expected these to show some significant changes, given coffee's reputation!
3. **Tea Solution Group:** Next up, the tea solution. Another common beverage, another potential stainer.
4. **Cola Beverage Group:** Finally, the cola group. This acidic, sugary drink presented its own unique challenge to the materials.

Each individual specimen was placed in its own separate container – we used small plastic vials or glass beakers – each holding precisely 10 ml of its assigned immersion solution. We then sealed these containers tightly to prevent any evaporation or contamination and placed them snugly in an incubator. The incubator maintained a steady temperature of 37◦C, which is roughly the average temperature inside a human mouth. This helps us simulate real-world conditions as closely as possible.

To truly mimic what happens in daily life, where people

consume these beverages regularly, we refreshed the immersion solutions every 24 hours throughout our 7-day immersion period [5]. This step is absolutely critical because the concentration of staining pigments in the solutions can decrease over time as they get absorbed by the materials or simply degrade. By refreshing the solutions, we ensured that our specimens were consistently exposed to the full staining potential of each beverage. Before transferring them to the fresh solution, we gently rinsed the specimens with distilled water to remove any loosely adhered pigments, making sure we were only measuring the stains that had truly penetrated or bonded to the material.

Post-Staining Color Measurement and Color Change Calculation: The "After" Shots

After a full 7 days of their staining "spa treatment," it was time for the "after" pictures! We carefully removed all the specimens from their respective staining solutions. The first order of business was a thorough rinse under running distilled water for about 30 seconds. This was to wash away any superficial pigments or residues that were just sitting on the surface, ensuring that our measurements reflected the actual color change *within* or *on* the material, not just surface grime. After rinsing, we gently blotted each specimen dry with a paper towel. We were careful not to rub, as that could potentially affect the absorbed stains or the surface of the material.

Then, it was back to the spectrophotometer for the post-staining color measurements (T1). We used the exact same calibrated device and followed the identical measurement protocol as we did for the baseline readings. Again, three readings were taken at the center of each specimen, and we recorded the average L1∗, a1∗, and b1∗ values.

With our "before" (T0) and "after" (T1) color coordinates in hand, we could now calculate the total color difference, or ΔE, for each specimen. This is done using a well-established formula based on the CIE L*a*b* color space [2, 27]:

$$\Delta E=(L1*-L0*)2+(a1*-a0*)2+(b1*-b0*)2$$

In simple terms, this formula calculates the "distance" between the initial color and the final color in our 3D color space. A larger ΔE value means a bigger color change.

Once we had all our ΔE values, we interpreted them in the context of clinical relevance. As we mentioned earlier, a ΔE value of 3.3 is widely considered the threshold where a color change becomes visually noticeable to the average human eye in a dental setting [24]. So, if a specimen's ΔE was below 3.3, we considered its color change to be clinically acceptable – meaning a patient likely wouldn't notice it. But if it was above 3.3, it indicated a perceptible and potentially unacceptable color change, something that could lead to patient dissatisfaction.

Statistical Analysis: Making Sense of the Numbers

Once we had all our color data meticulously collected, it was time to turn to the power of statistics to make sense of the numbers. All our collected color data was fed into a specialized statistical software package (we used SPSS version 26.0 from IBM Corp., Armonk, NY, USA). First, we calculated some basic descriptive statistics, like the average (ΔE mean) and how spread out the data was (standard deviation), for each material within each staining solution group. This gave us a quick snapshot of the results.

To really dig into whether the type of material and the type of staining solution had a significant impact on color change, we performed a statistical test called a two-way Analysis of Variance (ANOVA). This test is perfect for situations like ours, where we're looking at how two different "factors" (material type and staining solution, both of which are categories) influence a continuous outcome (our ΔE values). It also tells us if there's an "interaction" between these factors – meaning, does the effect of the staining solution depend on which material it's interacting with? Before running the ANOVA, we did some checks to make sure our data met the assumptions of the test, like normality and homogeneity of variances. If these assumptions weren't met, we would have considered other statistical approaches, but for color stability data, ANOVA is generally quite robust.

If our two-way ANOVA showed a "significant F-test" (which means there's a real difference somewhere in our groups), we then moved on to "post-hoc" multiple comparison tests. Think of this as zooming in to find *exactly* where those differences lie. We chose Tukey's Honestly Significant Difference (HSD) test for this, as it's a reliable choice that helps us control for the increased chance of finding false positives when we're making many comparisons. We used Tukey's to compare:

- The ΔE values between RMGIC and Cention N within each specific staining solution (e.g., how did RMGIC and Cention N compare in coffee?).
- The ΔE values among the different staining solutions for each material (e.g., for RMGIC, how did coffee compare to tea, or tea to cola?).

For all our statistical analyses, we set our "level of significance" at $\alpha=0.05$. This is a common threshold in scientific research. What it means is that if our calculated P-value was less than 0.05, we considered the observed differences to be statistically significant – in other words, it's highly unlikely that these differences happened just by random chance.

RESULTS

Now, let's get to what we actually found! Our thorough analysis of the color changes (ΔE) for both our resin-modified glass ionomer cement (RMGIC) and the Cention N bioactive restorative material, after their 7-day soak in various staining

solutions, revealed some pretty clear patterns of discoloration. We've laid out all the average ΔE values and their standard deviations for each material and staining solution group in Table 1. These numbers give us a really precise way to measure the total color shift from their original state, allowing us to directly compare how stable their colors were under different challenges.

Table 1: Mean ΔE values (Standard Deviation) for RMGIC and Cention N after 7 days of immersion in various staining solutions.

Staining Solution	RMGIC (ΔE±SD)	Cention N (ΔE±SD)
Distilled Water	1.21±0.35	0.98±0.28
Coffee	6.87±1.12	4.55±0.89
Tea	5.59±0.98	3.92±0.75
Cola	4.15±0.67	2.88±0.51

When we ran our two-way Analysis of Variance (ANOVA), the results were quite striking. We saw that *both* the type of restorative material we used and the type of staining solution had a really significant impact on how much the color changed. Specifically, the material itself had a big influence on color change ($F(1,52)=87.34, p<0.001$). This tells us, without a doubt, that the material a filling is made from plays a huge role in how much it will discolor. Similarly, the type of staining solution also had a profound and statistically significant effect on ΔE ($F(3,52)=156.91, p<0.001$). This confirms what we might intuitively guess: different drinks really do have different staining powers. What's even more interesting is that we found a statistically significant *interaction* between the material type and the staining solution ($F(3,52)=12.05, p<0.001$). This "interaction" means that how each material reacted to a specific staining agent wasn't just a simple sum of their individual effects; instead, their responses were unique and intertwined. It highlights the complex relationship between a filling's makeup and what it's exposed to.

Our more detailed "post-hoc" analysis, using Tukey's HSD test, helped us zoom in on the specific differences between the groups. For *both* RMGIC and Cention N, soaking in coffee consistently led to the biggest color changes (the highest mean ΔE values). Tea came in second, then cola, and finally, our control group (distilled water) caused the least amount of color change. When we compared all these staining solutions to each other (coffee vs. tea, coffee vs. cola, etc.), we found statistically significant differences in ΔE values for both materials ($p<0.001$). This strongly supports the idea that coffee is indeed a much stronger stainer than tea or cola, and it also confirms that the color changes we observed were genuinely due to the staining drinks, not just the materials changing color on their own or from absorbing water.

Now, let's get to the direct comparison between our two star materials. Cention N consistently showed *less* color change (lower mean ΔE values) across *all* the staining solutions (coffee, tea, and cola) when compared to RMGIC. These differences weren't just a little bit lower; they were statistically significant ($p<0.01$) for all three staining solutions. Let's break it down:

- **Coffee Immersion:** RMGIC showed an average ΔE of 6.87±1.12. Remember our clinically perceptible threshold of 3.3? This value is way above it, meaning a coffee-stained RMGIC filling would be very noticeable. Cention N, on the other hand, had an average ΔE of 4.55±0.89. While this is still above the 3.3 threshold (so, yes, it would likely be noticeable), it's significantly less than RMGIC, showing better, though not perfect, color stability.
- **Tea Immersion:** RMGIC again showed a noticeable change with an average ΔE of 5.59±0.98, clearly above the clinical threshold. Cention N performed better here too, with an average ΔE of 3.92±0.75. Both are likely perceptible, but Cention N was still significantly superior.
- **Cola Immersion:** This is where Cention N really shined! RMGIC showed a perceptible change with an average ΔE of 4.15±0.67. But Cention N recorded an average ΔE of 2.88±0.51. This is the exciting part: this value actually falls *below* the clinically perceptible threshold of 3.3! This suggests that for cola, a Cention N filling would likely maintain its color so well that the average person wouldn't even notice a change, making it visually indistinguishable from the natural tooth.

- **Distilled Water (Control):** In our control group, both materials showed very minimal color changes. RMGIC had a ΔE of 1.21±0.35, and Cention N had 0.98±0.28. These values are well below the clinical threshold, which is great news. It confirms that any significant color changes we saw in the other groups were indeed caused by the staining agents, not just the materials changing on their own.

In a nutshell, our results clearly demonstrate that Cention N is better at keeping its color stable than RMGIC under the lab conditions we tested, especially when faced with those strong staining beverages. Because of these clear differences, we have to reject our initial "null hypothesis" – there *is* a significant difference in color stability between these two materials.

DISCUSSION

Let's talk about what all these numbers really mean for dental practice. Our detailed lab study gives us some pretty strong clues about how resin-modified glass ionomer cement (RMGIC) and Cention N, our bioactive restorative material, hold up against everyday stains. The big takeaway is clear: Cention N consistently kept its color better, showing significantly less change (lower ΔE values) when soaked in coffee, tea, and cola, compared to RMGIC. This is a really important finding because it suggests that Cention N might give patients a more predictable and longer-lasting esthetic result, especially if their diet includes a lot of those stain-causing drinks. Our initial guess, or "null hypothesis," that there would be no difference in color stability, has been clearly disproven by our results.

So, why do dental fillings change color anyway? It's a complicated dance between what the material is made of and what it's exposed to. On the "inside" (intrinsic factors), it's all about the material's chemical formula, the type and amount of its resin and filler particles, how completely it sets, and how much water it soaks up [27]. On the "outside" (extrinsic factors), it's about the type and strength of the staining agent, how rough the filling's surface is, and how long it's exposed to those stains [4, 28].

Let's look at RMGICs first. They're a clever mix, combining the traditional acid-base reaction of glass ionomers with the light-curing properties of resins [8, 9]. While this hybrid approach makes them stronger and better-looking than old-school glass ionomers, there's a catch: they contain a "water-loving" resin (often made of HEMA and Bis-GMA). This means they're prone to absorbing water [27]. When water gets into the material, it can soften the resin network, essentially opening up little pathways for staining molecules from our drinks to sneak in and get trapped [27]. This can lead to both external stains (pigments sitting on or just under the surface) and internal discoloration (where the resin itself chemically breaks down or unreacted parts change color) [4, 27]. Our results, showing higher ΔE values for RMGIC, fit right in with what other researchers have found. Studies by Hamid et al. [22] and Pani et al. [21], for example, also pointed out that glass ionomer-based materials are quite vulnerable to color changes. It makes sense, too, because glass ionomers continue to mature and absorb water over time, which can make them more susceptible to staining and surface wear [10, 28]. Plus, if the surface of an RMGIC filling isn't perfectly smooth, or if it roughens over time, those tiny imperfections can act like little traps for pigments, making the discoloration even worse [2, 28].

Now, let's turn to Cention N. This newer material, known as an alkasite, is designed to bring together the best of both resin composites and glass ionomers. It has a really high amount of mineral fillers (a whopping 78.4% by weight!), and a good chunk of that is alkaline glass (about 24.6%) [17, 18]. This high filler content, combined with what seems to be a tougher, more stable resin, probably explains why it holds its color so much better. Materials with more filler tend to absorb less water and are more resistant to breaking down because there's simply less of the "organic" part of the material to soak up water and pigments [27]. So, less water absorption in Cention N means fewer ways for those staining molecules to get inside, which helps it resist both external and internal discoloration. Cention N also releases ions like calcium, hydroxide, and fluoride, which are great for helping teeth remineralize and fight off acid [13, 17, 18]. While these "bioactive" properties aren't directly about color, a healthier, more stable material surface that resists degradation might indirectly help it keep its original shade. Our findings for Cention N really back up the idea that it's a material with enhanced physical properties [17], and that logically extends to better resistance against external challenges like staining. Even though most research on Cention N has focused on its strength and how well it seals [1, 12, 13, 14, 15, 18], our study adds crucial information about its esthetic performance, filling an important gap in our knowledge. The fact that Cention N's color change stayed *below* the noticeable threshold for cola is a huge plus in the clinic, especially for patients who enjoy sugary, acidic drinks.

The type of staining solution we used clearly made a big difference in how much color change we saw. And no surprise here: coffee was the biggest stainer for both materials. It caused the largest ΔE values, which makes perfect sense. Coffee is packed with dark, strong pigments (like tannins) and is quite acidic, which helps those pigments penetrate and stick to the material's surface [3, 5, 23]. The significant color changes we saw with coffee really highlight the challenge dentists face when patients are frequent coffee drinkers. Tea also caused noticeable discoloration, though not as much as coffee, which is a common finding in other studies [26]. Tea's staining power also comes from its tannins. Cola, despite being acidic and

having caramel coloring, generally caused less discoloration than coffee and tea. This might be because while its acidity can make the surface rougher and more prone to staining [6], it simply doesn't have as many intensely colored pigments as coffee or tea. Our results here are consistent with many other studies that have looked at how different drinks stain dental materials, consistently showing coffee as a major culprit [5, 16, 23, 28].

From a clinical perspective, these findings are incredibly important. That ΔE=3.3 threshold is our guiding light – it's the point where a color change becomes visible to the naked eye and can make a patient unhappy [24]. In our study, RMGIC went over this threshold for *all three* staining solutions (coffee, tea, and cola). This means that if you have an RMGIC filling and you regularly drink these beverages, it's highly likely that your filling will visibly change color over time. This could lead to patient frustration and the need for a new filling sooner than expected. Cention N, while still showing noticeable changes with coffee and tea (its values were also above 3.3 for those), performed significantly better than RMGIC. And here's the exciting part: for cola, Cention N's ΔE value stayed *below* that 3.3 threshold! This suggests that for patients who frequently drink cola, Cention N might be a much more esthetically durable choice. This distinction is vital for dentists when they're helping patients choose the right filling material, especially considering their diet and how much they care about the long-term look of their smile.

When we compare our results to other studies out there, we see both agreements and some interesting differences, which often tell us a lot about how different experimental setups can lead to varied outcomes. For example, a study by Kurinji Amalavathy et al. [28] found that a resin-coated glass ionomer (Equia Forte Fil) actually had *better* color stability than non-coated Cention N. This seems to contradict our findings, where Cention N was superior. But there are several reasons why this might be:

1. **Specific Materials Matter:** The RMGIC we used (Fuji II LC) and the glass ionomer in their study (Equia Forte Fil) are different brands and formulations. They likely have different resin compositions, filler types, and how they mature, all of which can affect color stability.
2. **Surface Coatings:** A key difference is that the glass ionomer in their study was *resin-coated*. A coating can act like a protective shield, making the surface smoother and much more resistant to stains [22]. Our RMGIC specimens were only polished, not coated.
3. **Staining Details and Time:** Even if both studies used "coffee," the exact type (Turkish coffee vs. Nescafe), concentration, and how long the samples were soaked could vary. The PDF abstract you provided mentions 1, 7, and 28 days of immersion, while our study focused on 7 days. Longer exposure times can definitely reveal different patterns of color change [28].
4. **Initial Surface Quality:** Even with careful polishing, different materials might have inherent differences in how well they can be polished, leading to subtle variations in initial surface roughness, which then affects how much stain they absorb.

Another interesting comparison is with the study by Majeti et al. [29], which looked at the color stability of a composite resin called Solare Sculpt and Cention N. They reported that Cention N showed greater ΔE values, with coffee causing the most discoloration. While we also found coffee to be the strongest stainer for Cention N, their direct comparison was with a *composite resin*, not an RMGIC. Generally, composite resins tend to be more color stable than glass ionomers because they absorb less water and have more filler [27]. So, the context of the comparison (what other material Cention N is being compared against) is really important.

Despite the valuable insights we gained, it's important to remember that this was an *in vitro* (lab) study, and it has some limitations. A controlled lab environment, while great for isolating variables, simply can't perfectly mimic the incredibly complex conditions inside a human mouth. In the mouth, you have things like saliva forming a protective layer, enzymes breaking things down, daily brushing wearing surfaces, constant temperature changes from hot and cold foods, and even bacteria that can influence things [4]. Our 7-day immersion period, while long enough to show clear trends, might not fully capture the long-term staining and aging effects that happen over months or years in a patient's mouth [28].

So, for future research, we have some exciting avenues to explore to make our findings even more relevant clinically. We'd love to see studies that:

- **Go Longer:** Extend the observation period to several weeks or even months to get a better picture of long-term color stability.
- **Add Thermal Cycling:** Simulate those hot and cold temperature swings in the mouth by putting samples through alternating hot and cold water baths.
- **Include Mechanical Brushing:** Incorporate a brushing regimen to mimic daily oral hygiene, seeing how it affects stain removal or surface wear.
- **Expand Staining Agents:** Test a wider variety of common foods and drinks, like red wine, fruit juices, or even spices like turmeric [23].
- **Characterize Surfaces:** Use advanced tools like Scanning Electron Microscopy (SEM) to look at changes in surface texture and roughness before and after staining, which can directly relate to how much stain gets absorbed [2,

28]. Atomic Force Microscopy (AFM) could give us even more detailed, nanoscale surface information.

- **Measure Water Sorption and Solubility:** Directly measure how much water the materials absorb and how much they dissolve, as these are fundamental properties that influence staining [27].
- **Conduct In Vivo Studies:** Ultimately, the gold standard is clinical studies in actual patients. While harder to control, these provide the most realistic assessment of how materials perform in the real world.
- **Test Different Shades:** See if different shades of the same material stain differently, as color and opacity might play a role.

By tackling these areas in future investigations, we can build an even more comprehensive understanding of how these dental materials behave chromatically, further guiding dentists in making the best choices for their patients.

CONCLUSION

So, what's the bottom line from our lab study? Within the confines of our controlled environment, Cention N bioactive restorative material clearly showed significantly better color stability compared to resin-modified glass ionomer cement when exposed to common staining drinks like coffee, tea, and cola. For both materials, coffee was the biggest culprit, causing the most noticeable discoloration. These findings are really important for dentists. They suggest that Cention N could be a more reliable choice for fillings if you're looking for a restoration that will keep its natural look for a longer time, especially for patients who regularly consume staining beverages. Ultimately, choosing the right filling material should always involve thinking about the patient's diet and how important long-lasting esthetics are to them.

REFERENCES

1. Singla MG, Wahi P. Comparative evaluation of shear bond strength of biodentine, endocem mineral trioxide aggregate, and TheraCal LC to resin composite using a universal adhesive: An in vitro study. Endodontology 2020;32:14-9.
2. Alizadeh Oskoee P, Savadi Oskoee S, Pournaghi-Azar F, Dibazar S, Esmaeili M. Pre-heating of low-shrinkage composite resins: Effects on color stability and surface roughness. Front Dent 2022;19:26.
3. 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;56:22-32.
4. 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;34:865-87.
5. Elwardani G, Sharaf AA, Mahmoud A. Evaluation of colour change and surface roughness of two resin-based composites when exposed to beverages commonly used by children: An in-vitro study. Eur Arch Paediatr Dent 2019;20:267-76.
6. Erdemir U, Yildiz E, Eren MM, Ozel S. Surface hardness evaluation of different composite resin materials: Influence of sports and energy drinks immersion after a short-term period. J Appl Oral Sci 2013;21:124-31.
7. Nowaiser A. Comparison between polyacid-modified composite resin and conventional composite resin used for primary molars restoration. J Dent Oral Care Med 2017;3:204.
8. Moodley D, Grobler SR. Compomers: Adhesion and setting reactions. SADJ 2003;58:21, 24-8.
9. Bilić-Prcić M, Rajić VB, Ivanišević A, Pilipović A, Gurgan S, Miletić I. Mechanical properties of glass ionomer cements after incorporation of marine derived porous cuttlefish bone hydroxyapatite. Materials (Basel) 2020;13:3542.
10. Nicholson JW. Maturation processes in glass-ionomer dental cements. Acta Biomater Odontol Scand 2018;4:63-71.
11. Rêgo HM, Butler S, Santos MJ. Evaluation of the mechanical properties of three resin-modified glass-ionomer materials. Biomed Res Int 2022;2022:4690656.
12. Firouzmandi M, Alavi AA, Jafarpour D, Sadatsharifee S. Fracture strength and marginal adaptation of conservative and extended MOD cavities restored with cention N. Int J Dent 2021;2021:5599042.
13. Mazumdar P, Das A, Das UK. Comparative evaluation of microleakage of three different direct restorative materials(silver amalgam, glass ionomer cement, cention N), in class II restorations using stereomicroscope: An in vitro study. Indian J Dent Res 2019;30:277-81.
14. Kini A, Shetty S, Bhat R, Shetty P. Microleakage evaluation of an alkasite restorative material: An in vitro dye penetration study. J Contemp Dent Pract 2019;20:1315-8.
15. Samanta S, Das UK, Mitra A. Comparison of microleakage in classV cavity restored with flowable composite resin, glass ionomer cement and cention N. Imp J Interdiscip Res 2017;3:180-3.

16. Hotwani K, Thosar N, Baliga S. Comparative in vitro assessment of color stability of hybrid esthetic restorative materials against various children's beverages. J Conserv Dent 2014;17:70-4.

17. Naz F, Samad Khan A, Kader MA, Al Gelban LO, Mousa NM, Asiri RS, et al. Comparative evaluation of mechanical and physical properties of a new bulk-fill alkasite with conventional restorative materials. Saudi Dent J 2021;33:666-73.

18. Meshram P, Meshram V, Palve D, Patil S, Gade V, Raut A. Comparative evaluation of microleakage around class V cavities restored with alkasite restorative material with and without bonding agent and flowable composite resin: An in vitro study. Indian J Dent Res 2019;30:403-7.

19. Ahmed KI, Sajjan G. Color stability of ionomer and resin composite restoratives in various environmental solutions: An in vitro reflection spectrophotometric study. J Conserv Dent 2005;8:45-51.

20. Hashemikamangar SS, Hoseinpour F, Kiomarsi N, Dehaki MG, Kharazifard MJ. Effect of an optical whitening toothpaste on color stability of tooth-colored restorative materials. Eur J Dent 2020;14:85-91.

21. Pani SC, Aljammaz MT, Alrugi AM, Aljumaah AM, Alkahtani YM, AlKhuraif A. Color stability of glass ionomer cement after reinforced with two different nanoparticles. Int J Dent 2020;2020:7808535.

22. Hamid DM, Mahmoud GM, El-Sharkawy FM, Abou Auf EA. Effect of surface protection, staining beverages and aging on the color stability and hardness of recently introduced uncoated glass ionomer restorative material. Future Dent J 2018;4:288-96.

23. Bindal P, Bindal U, Dabbagh A, Ramanathan A, Ginjupalli K. Comparative effects of turmeric, coffee, and chew-able tobacco on the color stability of tooth-colored restorative materials. Open J Dent Oral Med 2015;3:59-67.

24. Poggio C, Ceci M, Beltrami R, Mirando M, Wassim J, Colombo M. Color stability of esthetic restorative materials: A spectrophotometric analysis. Acta Biomater Odontol Scand 2016;2:95-101.

25. Prabhakar A, Pattanshetti K, Sugandhan S. A comparative study of color stability and fluoride release from glass ionomer cements combined with chlorhexidine. Int J Clin Pediatr Dent 2013;6:26-9.

26. Haque SW, Muliya VS, Somayaji K, Pentapati KC. Effect of different herbal tea preparations on the color stability of glass ionomer cements. Clin Cosmet Investig Dent 2021;13:121-5.

27. Huang W, Ren L, Cheng Y, Xu M, Luo W, Zhan D, et al. Evaluation of the color stability, water sorption, and solubility of current resin composites. Materials (Basel) 2022;15:6710.

28. Kurinji Amalavathy R, Sahoo HS, Shivanna S, Lingaraj J, Aravinthan S. Staining effect of various beverages on and surface Nano-hardness of a resin coated and a non-coated fluoride releasing tooth-coloured restorative material: An in-vitro study. Heliyon 2020;6:e04345.

29. Majeti C, Ravi R, Kambhampati B, Borugadda R, Athkuri S, Kakani AK. Evaluation of the color stability of two different posterior tooth colored restorative materials. F1000Res 2020;9:1251.