Investigating the potential use of polymeric materials in the preparation of temporary cosmetic teeth painting veneers

Hasan Nazha
Department of Applied Materials Engineering, Faculty of Technical Engineering, University of Tartous, Syria
E-mail: hasannazha15@gmail.com

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Abstract
Dental whitening techniques and materials have become one of the most important non-surgical methods used to improve the appearance of teeth and to make them whiter and brighter, as well as to hide blemishes of the teeth. Since the veneer do not last forever and may fail due to fracture or adhesion failure or wrong selection of the appropriate design, removing large thickness of the outer layer of the tooth may make it vulnerable to weakness and long-term failure. This study aims to reach the polymeric combination that enables us to prepare temporary cosmetic teeth painting veneers, and to improve their properties, in order to get the veneers that work to maintain as much tooth structure as possible, hide defects and beautify teeth in the easiest ways and at least costs. The results showed that it is possible to prepare a paint mixture based on cheap and available raw materials consisting of sodium alginate as a polymeric matrix material in this mixture, titanium dioxide as a coloring additive, and calcium chloride solution as a bonding for sodium alginate molecules and improving for their properties. It is recommended to use the fourth combination (sodium alginate 2% + titanium dioxide 4%) immersed in a solution of calcium chloride (11.11% concentration) in the preparation of temporary paints due to its highest chemical stability and having appropriate physical and optical properties that enable them to use possibly as temporary cosmetic teeth painting veneers.

1. Introduction
Polymeric materials used in cosmetic dentistry have become one of the most important materials studied due to their distinctive characteristics that improve the appearance, hide the defects, and restore of teeth in some cases [1–3]. Permanent veneers that made of porcelain or ceramic do not last forever [4, 5], and their use may be unsuccessful due to adhesion failure or even fracture [6]. Therefore, removing large thickness of the tooth enamel may make it vulnerable to weakness and failure in the long term [7].

Alqahtani [8] carried out a literary review on Tooth-bleaching procedures and their controversial effects. To reduce the risk of teeth bleaching, the researcher concluded: It is necessary to stop using OTC products and reduce the excessive use of other whitening products and techniques. Koudriavtsev et al [9] studied of the effect of tooth-bleaching agents on phosphate concentration in dental enamel by means of Raman spectroscopy. They found that the use of a whitening gel containing 9.5% hydrogen peroxide showed minimal loss of phosphate molecules in the teeth. They also found that when the specimens treated with hydrogen peroxide (concentration of 14%) showed a loss of phosphate molecules by about 22%, while specimens treated with a carbamide peroxide (concentration of 38%) showed the greatest loss of phosphate molecules by about 45%.

In term of the biocompatibility of polymeric materials, Lee and mooney [10] conducted a study of alginate, its properties and biological applications. Alginate (especially alginate gel formed by the addition of calcium chloride to produce calcium alginate) has the benefits and potentials to be used as biomaterials in many biomedical applications. Especially in drug delivery, in vitro cell culture and tissue engineering. Kwon et al [11] studied the toxicity of zinc oxide-eugenol and zinc oxide-without eugenol using different types of fibroblast. The researchers pointed to the use of these materials as temporary cement in dentistry and that these materials were
safe and successful for this use. Hoshyari et al. [12] conducted a study in which they discussed the biocompatibility of calcium chloride and titanium oxide. They have found a significant biocompatibility of these materials.

As it previously mentioned, the paint-on gels whitening technique used on the face of the tooth and contain effective bleaching agents (carbamide peroxide and hydrogen peroxide) has a negative effect on the teeth, which is presenting the loss of phosphate molecules in tooth enamel and a decrease in the hardness of this layer after prolonged use of paint-on gels [13]. Accordingly, there was a need for the availability of safe materials that meet the demand in terms of ease of use and relatively low cost.

This study aims to reach the polymeric combination that enables us to prepare temporary cosmetic teeth painting veneers, and to improve their properties, in order to get the veneers that work to maintain as much tooth structure as possible, hide defects and beautify teeth in the easiest ways and at least costs.

2. Materials and methods

2.1. Materials

Sodium alginate was procured from Sigma-Aldrich® (Darmstadt, Germany). The bright white substance that used as a vivid colourant, titanium dioxide, was also procured from Sigma-Aldrich®. Calcium chloride powder was procured from Fluka™ (Buchs, Switzerland). The aqueous solution, Buffer pH 7.4, and the temporary dental cement base materials, zinc oxide and eugenol, were obtained from Sigma-Aldrich® (Darmstadt, Germany). Molecular structure of sodium alginate, titanium dioxide, calcium chloride, zinc oxide and eugenol is presented in figure 1.

2.2. Methods

Six alginate/TiO$_2$ tooth paint combinations were prepared and applied to extracted human teeth to obtain the required specimens. The first combination was prepared with a weight of 0.2 g of sodium alginate and dissolved in 10 ml of distilled water with continuous stirring for three minutes using the magnetic stirrer to ensure dissolution of sodium alginate. 0.2 g of titanium dioxide was weighed and mixed with the previous solution with stirred for three minutes to ensure the dissolution of titanium dioxide. Then, the tooth was painted with this material, placed on a plate and inserted into the drying oven at a temperature of 35 °C for two minutes and then take it out to get the first painted specimen.

After the first combination was prepared, a paint was applied on another tooth and immersed in a solution of calcium chloride (11.11% concentration) that work on crosslinking the sodium alginate molecules to form

![Figure 1. Molecular structure of the materials used in the study.](image-url)
calcium alginate as shown in figure 2. Then, it was placed on a plate, inserted into the drying oven for two minutes, and then taken out to get the second specimen.

0.2 g of titanium oxide was weighed and added to the first combination with mixing and stirring for three minutes, then the third tooth was painted and placed on a plate and dried in the oven for two minutes to obtain the third specimen. After the third combination was prepared, a paint was applied to another tooth and immersed it in calcium chloride solution and then put it on a plate and inserted into the drying oven for two minutes and then taken out to get the fourth specimen.

The fifth combination was prepared by mixing 0.1 g of zinc oxide with 0.1 g of eugenol with stirring for half a minute, then 0.2 g of the third combination was weighed and mixed with zinc oxide and eugenol for half a minute, then the tooth model to be treated with this combination was painted and placed on a plate and inserted into the drying oven for two minutes and then taken out to obtain the fifth specimen. After the fifth mixture was prepared, the paint was applied to another tooth model and immersed in calcium chloride solution and then placed on a plate and inserted into the drying oven for two minutes and then taken out to obtain the sixth specimen. Table 1 shows the percentages of the materials included in the composition of the previous six combinations.

It should be mentioned that the specimens were weighed before applying the paint and after applying the paint and immersion in the solution of calcium chloride, after that the specimens were immersed in a buffer solution for an hour to observe the chemical stability in a medium that simulates the salivary, and then the specimens were taken out from the solution and dried in the oven for a quarter of an hour, and then taken to the normal atmosphere for a quarter of an hour as well. All specimens were weighed to identify the percentage of weight loss, which expresses the chemical stability of the different specimen painting layers. Weight loss (w%) is calculated as a percentage according to the following formula:
Table 1. Percentages of the materials included in the composition of all combinations.

| Combination | Sodium alginate | Titanium dioxide | Zinc oxide | Eugenol | Distilled water | Calcium chloride | Immersion |
|-------------|-----------------|------------------|------------|---------|----------------|-----------------|-----------|
| First       | 2%              | 2%               | —          | —       | 100%           | —               | —         |
| Second      | 2%              | 2%               | —          | —       | 100%           | Immersion 100%  | —         |
| Third       | 2%              | 4%               | —          | —       | 100%           | —               | —         |
| Fourth      | 2%              | 4%               | 1%         | 1%      | 100%           | —               | —         |
| Fifth       | 2%              | 4%               | 1%         | 1%      | 100%           | Immersion 100%  | —         |
| Sixth       | 2%              | 4%               | 1%         | 1%      | 100%           | Immersion 100%  | —         |

\[ w_\% = \left(\frac{w_1 - w_2}{w_1}\right) \times 100 \tag{1} \]

Where \( w_1 \) specimen weight after painting, immersion in calcium chloride solution and drying, \( w_2 \) specimen weight after immersion in the buffer solution for an hour and drying.

### 3. Results

The results showed that, after drying the first combination of paint that was applied to the tooth enamel, enamel acquired a light white color. All specimens were immersed in a buffer solution of moderate \( \text{pH} = 7.4 \), which is the closest \( \text{pH} \) to the oral medium, and an hour after the specimens were placed in the solution, they were taken out. Then, an attempt was made to remove the layer that was painted on the first tooth by massaging using the hand, to show how easy it was to remove this layer. After that, a try to remove the layer painted on the tooth model with a toothbrush was made, and it turned out that removing the paint with a toothbrush was easier.

After drying the paint of the second combination that was applied to the second tooth enamel, it was shown that the white color intensity was slightly more than the color of the first specimen. After immersing the specimen in a solution and taking it out, an attempt was made to remove the paint layer on the second tooth model by massaging, and it turned out that this layer was adhered to the tooth enamel more strongly than the veneer layer prepared from the first combination, and it was relatively difficult to remove it. Another attempt was made to remove the paint on the tooth model with a toothbrush. It was found that the removal of the paint layer was easier with a toothbrush, where it was removed completely.

For the third specimen, a more intense white color was shown from both previous specimens. After immersing the specimen in a solution and taking it out, attempts were made to remove the layer paint on the third tooth by massaging and using a toothbrush. It turned out that this layer was adhered to the tooth enamel in a manner similar to the adhesion of the veneer layer prepared from the second combination, and it was relatively difficult to remove it by hand. While removing the paint layer was easier with a toothbrush and it was completely removed.

After drying the paint of the fourth combination, which was applied to the fourth tooth enamel, a density of white color was found similar to the density of the third painted specimen. The specimen was immersed in a buffer solution and taken out. Then, a try to remove the paint layer on the fourth tooth by massaging using the hand was made. It appeared that this layer was adhered to the tooth enamel relatively hard and was not easy to remove. An attempt was also made to remove the paint layer on the fourth tooth model with a toothbrush, it was found that removing the paint layer was easier with a toothbrush, but the layer was not completely removed when using a normal manual speed while using a toothbrush.

As for the fifth specimen, a dense white color was shown. After immersing the specimen in a solution and taking it out, an attempt was made to remove the paint on the fifth tooth model by massaging using the hand, and it became clear that the rest was easy to remove. A try to remove the paint layer on the fifth tooth with a toothbrush was made, and it was found that removing the entire paint layer was very easy.

After drying the paint of the sixth combination, which was applied to the sixth tooth enamel, a dense white color was shown. The specimen was immersed in a solution and taken out. After that, an attempt was made to remove the layer painted on the sixth tooth by hand, so it became clear that the rest of this layer on the surface of the tooth was more difficult to remove than the fifth specimen layer. Another attempt was made to remove the painted layer on the sixth tooth with a toothbrush, and it was found that removing the entire paint layer was very easy. Figure 3 shows the chemical stability chart for the paint layer of the specimens an hour after it was immersed in the buffer solution, in terms of weight loss as a percentage and time in minutes.
Figure 3. Approximate rates of weight loss for the specimens after immersing in buffer solution.

Figure 4. Approximate rates of paint removal after massaging by the hand.

Figure 5. Approximate rates of paint removal after removing with a toothbrush.

Figure 4 shows the mechanical stability chart of the paint layer of the specimens after attempting to remove it by massaging using the hand, and figure 5 shows the mechanical stability chart of the paint layer of the specimens after trying to remove it with a toothbrush.
4. Discussion

Titanium dioxide plays an important role in improving the physical and optical properties and adjusting the color of some materials [14, 15]. Sodium alginate, for instance, becomes a more color suitable for potential use as temporary cosmetic teeth painting veneers, after adding titanium dioxide. After immersing the specimens in a buffer solution, it was found that the paint layer of the first specimen had lost about 10% of its weight within an hour after immersing it in this solution as shown in figure 3. As for the paint layer of the second, third and fourth specimens, It was found that this layer was stable and that no weight loss was observed, while the fifth specimen has lost about 60% of its weight after five minutes of being immersed in a buffer solution, and after an hour has passed, it was found that the final total weight loss of the fifth specimen paint layer was about 70%. With regard to the sixth specimen, it was found that there was a weight loss equivalent to 20% after five minutes of immersion in the buffer solution, and this value did not change after an hour of immersion in the solution.

Calcium chloride plays an important role in the ionic cross-linking of the sodium alginate polymer molecules with Ca-ions [16, 17] and it works on improving the chemical properties of the polymer molecules [18], the thing that was evident when all painted specimens were immersed in a buffer solution for an hour, where not all the paints was chemically dissolved in the solution. This material also plays an important role in improving mechanical properties [19], which was evident when all painted specimens were immersed in calcium chloride solution and attempted to remove them by hand or toothbrush, where the mechanical properties improved after the emergence of three-dimensional networks between sodium alginate molecules by calcium ions, as shown in figure 2, that interacted with them to produce the three-dimensional calcium alginate [20, 21].

It should be noted that the first and fifth specimen paint layer was 100% removable by hand after one time of the frequency of massaging as shown in figure 4. As for the second and third specimen paint layer was removable by 80% after five times the frequency of massaging. The percentage of removing the fourth specimen paint layer by hand after ten times the frequency of massaging was the lowest and it reached only 10%, while the sixth specimen paint layer was removable by 85% using the same method, after five times of the frequency of massaging by hand. When using the toothbrush to remove the painting layers it was found that all of these layers were 100% removable after one time of the frequency of removing as shown in figure 5; except for the fourth painting layer whose removal rate was only 50% Using a toothbrush after ten times of the frequency of removing.

There are still some limitations in the current study and should be taken into account in preparing and applying the paint. The preparation and application of the paint was done in laboratory conditions, where no occlusal forces were applied to determine the extent of adhesion of the paint layer to the tooth under the effect of these forces. Coating is not applied directly, but is applied according to the following protocol: the teeth are painted with a mixture of sodium alginate (2%) and titanium dioxide (4%), the paint layer is dried by a dryer for 2 min, immersing the teeth using mouthwash (calcium chloride at 11.11% concentration) for 2 min, the paint layer is dried again for 2 min to get the desired result. However, this study aids in planning further in vitro and in vivo tests when used as an initial step.

Nevertheless, based on all of the above, it is recommended to use the fourth combination (sodium alginate 2% + titanium dioxide 4%) immersed in a solution of calcium chloride (11.11% concentration) in the preparation of temporary paints due to its highest chemical stability and having appropriate physical and optical properties that enable them to use possibly as temporary cosmetic teeth painting veneers.

5. Conclusion

Within the limitations of this study, it can be concluded that the fourth combination (sodium alginate 2% + titanium dioxide 4%) immersed in a solution of calcium chloride (11.11% concentration) is the most suitable to use in the preparation of temporary paints due to its highest chemical stability and having appropriate physical and optical properties that enable them to use possibly as temporary cosmetic teeth painting veneers. There is a need for further studies on different proportions of the materials involved in the composition of combinations and taking into account the effect of different drinks on the color and properties of the coatings.

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Conflict of interest

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ORCID iDs

Hasan Nazha https://orcid.org/0000-0003-1531-1824

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