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# Evaluating the absorption loading technique to acrylic resin for drug delivery

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**Abstract.** Acrylic resin or polymethylmethacrylate (PMMA) is one of the most attractive materials to be used for dental appliances manufacturing. It has been introduced as a biomaterial during the last century. This study aims to evaluate the compounds absorption and release through acrylic resin to be used for drug delivery as well. The study specimens were 10 pieces of heat-cured clear acrylic resin with dimensions of 10 × 10 × 2 mm. The specimens were dipped in methylene blue solution at a powder-water ratio of 1:20 for 5 days. The samples were removed and dipped in 5 ml distilled water vials for 24 hours. Then the specimens were replaced into new 5 ml vials and the process lasted for 4 days. The extracted solutions were analyzed by the visible light spectroscopy for absorbance. The statistical results showed a gradual increase in stain release from day 1 to day 4 with a significant difference between day 1 and day 4 solutions. The study showed that PMMA resin is able to absorb and release some compounds constantly and the absorption drug-loading technique is applicable to this material.

**Keywords:** absorption; methylene blue; PMMA

## 1. Introduction

Acrylic resin is one of the most popular biomaterials used in dental and medical applications for several decades. Its chemical name is polymethylmethacrylate which is usually referred to as PMMA. It is used for constructing dental appliances, dentures, and facial prostheses due to their ease of preparation and acceptable mechanical properties (Kumar *et al*. 2019, Kati and Al-Kaabi 2016, Elmadani *et al*. 2019). It is provided in the form of powder (polymer) and monomer that are mixed according a specific ratio to polymerize and become a rigid solid material. The polymerization process can be chemical, thermal, microwave-cured and light activated (Palaskar *et al*. 2019). For the last decades, many reports showed significant problems related to colonized dentures with microorganisms, mainly Candida albicans (Akpan and Morgan 2002, Darwazeh *et al*. 2001, Webb *et al*. 1998, Aljorani and Al-Kaabi 2018). A possible health risk that can be associated with Candida-infected dentures and intraoral appliances is the denture stomatitis. It results from biofilm formation at the denture surface in the oral cavity which later develops local inflammatory reactions in the oral cavity (Budtz-Jørgensen 1974, Budtz-Jørgensen *et al*. 1983, Pollack *et al*.

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1964). One of the modern approaches to prevent such problems is either by using cleaning and disinfecting solutions (Ariamanesh *et al*. 2019, Kurt *et al*. 2018), or by combining antifungal and antibacterial drugs to the denture material and these drugs are added to the material at the early stages of acrylic denture preparation (Al-Kaabi and Hamid 2020, Nawasrah *et al*. 2016, Namangkalakul *et al*. 2020, Li *et al*. 2016). According to a study conducted by Procopio and associates, it was found that when acrylic resin dentures are submerged in antimicrobial cleaning solutions overnight periodically, the materials absorb some of the solution even after rinsing with water. This results in unintended destructive elution to the oral mucosal tissues (Procópio *et al*. 2018). This pattern of impregnation could be developed further to combine suitable antimicrobial drugs to be delivered by acrylic dentures to the oral tissues. There is a possible damage that could happen to the combined drug by intervening the polymerization process between the powder and polymer of the acrylic resin or it may deteriorate due to the heat required for the curing process (Maldonado *et al*. 2018). Therefore, this study aims to evaluate compounds traffic from and into the heat-cured acrylic resin and also to examine the release rate after loading compounds to the resin by the absorption technique which could be a safer method for drug loading to acrylic resin. Methylene blue biological stain was adopted in this study as a drug surrogate for visual and optical confirmation.

## 2. Materials and methods

### *2.1 Materials and samples*

In this study, heat-cured clear acrylic resin (Veracril, Colombia) material is used to construct 10 specimens with dimensions of 10 × 10 × 2 mm. Methylene blue die solution (Xilong Chemical Industry Incorporation, China) Fig. 1 was prepared by mixing the die powder with distilled water at a ratio of 1:20 g/ml. It was used in this study as a drug surrogate to provide a better description for the absorption and release pattern from acrylic resin material in terms of spectroscopic analysis. The acrylic samples were prepared, processed and heat-cured according to the conventional curing method. The samples were then deflasked, finished and polished to be ready for the experiment procedure.

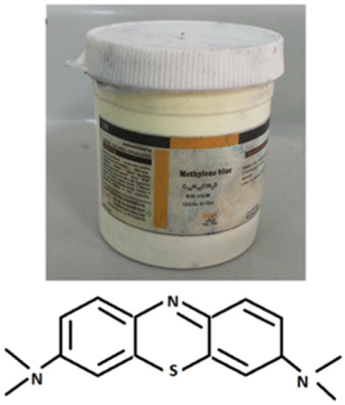


Fig. 1 Methylene blue stain

### *2.2 Absorption and extraction*

The absorption loading procedure was started by dipping the specimens in Methylene blue solution for 5 day without movement or shaking. Then, the specimens were removed and cleaned by being splashed with a washing bottle of distilled water to wash off the adsorbed superficial stain. Then the extraction procedure was started by dipping the specimens in 5 ml polystyrene vials of distilled water for 24 hours. After that, the vials were replaced and the specimens were placed in new 5 ml distilled water. This procedure continued for 4 days. The 4 extracted solutions were analyzed by visible light spectroscopy at a wavelength of 500 nm and the absorbance unites were measured for each solution. The data were statistically analyzed by ANOVA test of variance for significant difference using IBM SPSS v.20 software.

## 3. Results

The descriptive statistics showed mean absorbance values that increase gradually with time as well as the standard deviation values as reported in Table 1 and shown in (Fig. 2). The ANOVA statistical test and Tukey HSD for multiple comparison data showed there was a significant difference between the 1st day of extraction and the 4th day (P-value < 0.05. However, the 2nd and 3rd days did not show any significant difference between each other and among the rest of days (P-value > 0.05) despite the increase in their mean values as shown in Tables 2 and 3.

Table 1 Descriptive Statistics (absorbance units)

| | N | Mean | Std. Deviation | Std. Error | 95% confidence interval for mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower bound | Upper bound | | |
| **1st day** | 10 | 0.00040 | 0.000843 | 0.000267 | -0.00020 | 0.00100 | < 0.001 | 0.002 |
| **2nd day** | 10 | 0.00090 | 0.001524 | 0.000482 | -0.00019 | 0.00199 | < 0.001 | 0.004 |
| **3rd day** | 10 | 0.00190 | 0.001729 | 0.000547 | 0.00066 | 0.00314 | < 0.001 | 0.004 |
| **4th day** | 10 | 0.00300 | 0.003018 | 0.000955 | 0.00084 | 0.00516 | < 0.001 | 0.009 |
| **Total** | 40 | 0.00155 | 0.002124 | 0.000336 | 0.00087 | 0.00223 | < 0.001 | 0.009 |

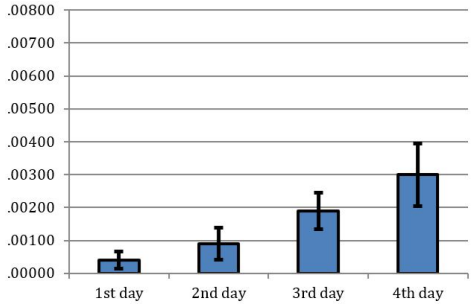


Fig. 2 Mean absorbance values for the study groups

Table 2 One Way ANOVA test results

| | Sum of squares | df | Mean square | F | Sig. |
|---|---|---|---|---|---|
| **Between groups** | < 0.001 | 3 | < 0.001 | 3.498 | 0.025 |
| **Within groups** | < 0.001 | 36 | < 0.001 | | |
| **Total** | < 0.001 | 39 | | | |

Table 3 Tukey HSD for Multiple Comparisons

| Groups | N | Subset for alpha = 0.05 | |
|---|---|---|---|
| | | **1** | **2** |
| **1st day** | 10 | 0.00040 | |
| **2nd day** | 10 | 0.00090 | 0.00090 |
| **3rd day** | 10 | 0.00190 | 0.00190 |
| **4th day** | 10 | | 0.00300 |
| **Sig.** | | 0.326 | 0.092 |

## 4. Discussion

This study was conducted to evaluate a drug loading by absorption method to acrylic resin material used for making oral restorations, and to understand the pattern of release of the absorbed compounds later on for the purpose of drug delivery. A biological stain material was used in this study to provide both visual and digital observation for the elution procedure. The biological stain was Methylene blue which was selected because of the same hydrophilic property that it shares with PMMA resin. The stain was loaded to all the acrylic resin samples at a specific concentration for a specific period of time by absorption method. When the acrylic samples were extracted in distilled water for four days respectively, the extracted solutions were analyzed by visible light spectroscopy to evaluate the stain elution pattern.

The absorbance analytical results showed a gradual increase in methylene blue release day after day of extraction, although there was no visually observable difference among the solution. This might be due to the limited ability of the PMMA polymer to absorb relatively large molecules like methylene blue, (Fig. 1) at intermolecular level. Therefore, only small amount was taken up by the acrylic samples during dipping procedure which was lasted for 5 days.

However, the statistical analysis and the AVOVA test of variance showed there was a statistically significant difference in the absorbance data among the groups which was later confirmed by the Tukey HSD test for multiple comparisons, Tables 2 and 3. The results revealed that there was a significant difference in stain elution between the 1$^{st}$ and 4$^{th}$ days. However, both 2$^{nd}$ and 3$^{rd}$ day's solutions were not significantly different from 1$^{st}$ and 4$^{th}$ day's solution. This means that drug's burst release is not likely to happen when using absorption loading technique for drug incorporation which is a serious issue in the field of drug delivery (Di Francesco *et al*. 2020, Ahmed *et al*. 2012). For some oral restorations such as maxillary surgical obturators that are made from PMMA resin, it would benefit from such release behavior especially when it is incorporated with anti-inflammatory drug during the healing process after surgery. Another important benefit from this phenomenon is that acrylic restorations can be reloaded with the drug by this absorption method to be used repetitively without the need for making new loaded restorations.

## 5. Conclusions

The study groups showed a gradual increase in methylene blue stain release from acrylic resin samples which confirms that acrylic resin is able to both absorb and release some compounds which is an important quality since this material is used extensively for medical appliances and oral applications. Further experiments are necessary to evaluate the controlled absorption and release traffic by controlled solutions concentration, as well as drug reloading procedure.

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