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Review

How much do resin-based dental materials release? A meta-analytical approach

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ABSTRACT

Objectives. Resin-based dental materials are not inert in the oral environment, and may release components, initially due to incomplete polymerization, and later due to degradation. Since there are concerns regarding potential toxicity, more precise knowledge of the actual quantity of released eluates is necessary. However, due to a great variety in analytical methodology employed in different studies and in the presentation of the results, it is still unclear to which quantities of components a patient may be exposed. The objective of this meta-analytical study was to review the literature on the short- and long-term release of components from resin-based dental materials, and to determine how much (order of magnitude) of those components may leach out in the oral cavity.

Methods. Out of an initial set of 71 studies, 22 were included. In spite of the large statistical incertitude due to the great variety in methodology and lack of complete information (detection limits were seldom mentioned), a meta-analytical mean for the evaluated eluates was calculated. To relate the amount of potentially released material components with the size of restorations, the mean size of standard composite restorations was estimated using a 3D graphical program.

Results. While the release of monomers was analyzed in many studies, that of additives, such as initiators, inhibitors and stabilizers, was seldom investigated. Significantly more components were found to be released in organic than in water-based media. Resin-based dental materials might account for the total burden of orally ingested bisphenol A, but they may release even higher amounts of monomers, such as HEMA, TEGDMA, BisGMA and UDMA. Compared to these monomers, similar or even higher amounts of additives may elute, even though composites generally only contain very small amounts of additives.

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A positive correlation was found between the total quantity of released eluates and the volume of extraction solution.

Significance. There is a clear need for more accurate and standardized analytical research to determine the long-term release from resin-based materials. Several guidelines for standardization are proposed.

Contents

1. Introduction

In spite of 150 years' worth of good clinical performance, the use of amalgam as a tooth filling material remains controversial. The most common allegations against amalgam are environmental pollution and possible hazardous health effects due to release and systemic uptake of mercury [1–3]. The ongoing discussion about the safety of amalgam has also led to an increased focus on the safety of resin-based restorative materials [4]. The use of resin-based materials in dentistry is nowadays ubiquitous, and during the past decades composite restorations have proved to be a satisfying alternative for amalgam to restore traumatized and decayed teeth [5].

Resin-based dental materials generally consist of a polymer matrix and inorganic filler particles that are attached to the resin matrix through a siloxane coupling [6]. The most common resins used in dentistry are (meth)acrylates [7], but recently, new resin systems, such as ormocers (polysiloxane backbone with methacrylate sidebranches) and siloranes (silorane ringopening system) have been introduced [8].

Despite their growing popularity, there are concerns that resin-based materials may be toxic based on the fact that they may release components [9]. Three main routes of systemic intake of chemical substances released by resin-based restorations have been postulated: the first through ingestion of released compounds in the gastro-intestinal tract, the second through diffusion to the pulp through the dentinal tubules [9,10], and the third via uptake of volatile components in the lungs [11,12]. The last route is of special importance for the dental practitioner and the dental personnel, while the first and second route are more relevant for the patient.

Resin-based materials may release unpolymerized monomers, additives and filler components in the oral environment after placement of the restoration. Even though the patient may come into contact with large amounts of uncured monomers during the placement of the composite restoration, the release of unpolymerized monomers after polymerization causes most concerns in literature. Under clinical circumstances with a short curing time of usually not more than 40 s, and a temperature around 37 °C in the oral cavity, composites are never polymerized to a full extent as the propagation of the crosslinking reaction drastically reduces the mobility of the monomers [13]. As a result, not only unbound substances, like additives, but also uncured monomers can leach out. Depending on the resin-based material, the degree of conversion can vary between 50 and 70% [14–16]. The maximum degree of conversion is reached only after 24 h due to a post-cure process ('in-the-dark' polymerization), which signifies that the polymerization rate immediately after light-curing may be even lower (30–40%) [15–18]. Filler leachability encompasses both release of complete filler particles after hydrolysis of the filler-matrix siloxane bond, and the release of filler components, such as SiO_2, Ba, Sr, Na due to hydrolysis and ion-exchange mechanisms [19–22]. Release of filler components has mainly been associated with progressive wear of composites; however little is known regarding possible health effects.