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Review article

WATER SORPTION AND WATER SOLUBILITY OF 3D PRINTED AND CONVENTIONAL PMMA DENTURE BASE POLYMERS

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ABSTRACT

Background: Patients who cannot afford more expensive prosthetic restorations, such as implant-supported fixed prostheses, prefer removable dentures. Removable dentures have been manufactured with different types of acrylics, including conventional polymer polymethyl methacrylate (PMMA) and the popular nowadays three–dimensional (3D) printed resins. Water sorption and water solubility often occur because these prosthetic restorations are constantly immersed in saliva and always have interactions with oral fluids.

Review results: Alternating processes of imbibition and drying of acrylics lead to internal stresses and fatigue. As a result, dental resins undergo significant dimensional changes. The water diffuses into the dental resin and inflicts a gradual expansion and volume increase, which may cause aging of the material and discomfort during masticatory function.

Denture base resins have low water solubility, which results from the leaching out of unreacted monomer and soluble additives into the oral cavity. This is an undesired property and may cause soft tissue reactions.

Conclusion: The affinity of dental resins for water degrades their mechanical and physical properties and causes dimensional changes in the denture base, which results in internal stresses that have a negative impact on the denture's long-term success.

Keywords: water sorption, water solubility, digital dentistry, 3D printing, CAD/CAM, dimensional stability, acrylic resins, removable dentures

BACKGROUND:

Nowadays, different types of dental resins are used for manufacturing removable dentures. The most common material has been the polymer polymethyl methacrylate (PMMA), which shows a number of disadvantages, such as imbibition, water solubility, high polymerization shrinkage, and dimensional changes. The conventional method for fabricating includes several clinical and laboratory steps, which consumes a lot of time for the dentist and the dental technician.

The increasingly popular CAD/CAM (computer-aided-design computer–aided–manufacturing) methods save a lot of effort and provide more comfort for the patient. They are divided into two main groups – additive and subtractive manufacturing. With the subtractive method, the denture base is milled from a pre-polymerized resin block. 3D printing, or additive manufacturing (AM), is based on stereolithography (SLA) and encompasses techniques that fabricate objects layer by layer.

Dental resins for removable dentures must be resistant to volume changes under all conditions and not change their dimensions over time. Volumetric changes are expressed in polymerization shrinkage, which is compensated by the significant water sorption of this type of material. This might seriously affect the stability of the denture during chewing function and might lead to the aging of the dental resin used for its manufacturing.

REVIEW RESULTS:

Water sorption is the property of dental materials to absorb liquids and change their volume and weight. It is measured by the weight of the maximum amount of liquid absorbed by a unit area of a given material and expressed as mg/cm2. Acrylic plastics tend to absorb water and expand slowly over time [1]. This corresponding expansion is expressed in three dimensions and is of great importance [2]. The expansion of dental resins is proportional to the time of immersion in water until equilibrium is reached. However, the average equilibrium water content (water content at saturation) must not exceed the value of 32μg / mm3. The absorption of water can also release the inherent stresses developed during the processing of acrylic resin, mainly the heat–cured acrylics, and a change in the shape of the removable denture is possible [3].

Constant wetting and drying of the removable dentures should be avoided because it causes aging of the material and may be the reason for the deformation of the prosthetic restoration [4]. As the dental resin dries, the water is eliminated, and the polymer chains return to their original position. If rewetting follows, the polymer chains expand again [5,6]. In this way, a cycle of micro excursions of the chains is created, and microcracks appear between the individual macromolecules, which after mechanical loading, can lead to fracture of the removable denture. Saliva absorbed for one month leads to a linear expansion of 0.03%, and after nine months - by 0.04%. According to the ISO standard, the degree of water sorption in dental resins for prosthetic bases can be determined through certain laboratory tests [7].

Regarding PMMA, Miessi et al. report that after 180 days immersed in water, removable dentures experienced large dimensional changes and problems with adaptation to the prosthetic field [8]. The degree of imbibition of heat-cured acrylics is significant (0.7mg/cm3), and they increase in volume, the process being irreversible. It is most intense during the first 24 hours, after which it significantly weakens [9]. Some authors have reported that water uptake by acrylic denture bases leads to expansion due to water sorption [10, 11]. In this process, macromolecules are separated and lead to expansion [12]. This process compensates for the polymerization shrinkage of the acrylic resin and improves the adaptation of the denture bases to the underlying tissues [13]. Another study also confirmed this finding and showed that in both experimental groups, 12 days of storage in water led to a significant increase in size and compensated for the shrinkage due to the polymerization process [14].

Several studies have shown that the application of 3D-printed resins in prosthodontics has had a significant increase in recent years [15]. Digital fabrication, also known as 3D printing, is an increasingly used method, applied widely for the manufacturing of crowns, dentures, surgical guides, implants, orthodontic splints, and aligners [16, 17]. The major focus is on the mechanical and physical properties of 3D-printed resins, and the main purpose is to overcome the limitation of their clinical use [18]. Gad et al. investigated that the water sorption/solubility values of 3D-printed resins were lower than the ISO recommendation for maximum water sorption. Hence, the results for the 3D-printed resins demonstrate that they are acceptable for clinical application [19]. According to the manufacturer, NextDent™ denture base resin experiences less polymerization shrinkage and lower value of water sorption than conventionally processed PMMA [20].

Solubility is the reduction in the volume and/or weight of materials when in contact with liquids or solvents [21]. It leads to a change in the shape, volume, and qualities of the dental materials in the oral cavity. It is observed in contact with saliva, gingival fluid, and fluid in the dentinal tubules. Acrylic resins are practically insoluble in water and oral fluids [22]. They are soluble in ketones, esters, and aromatic and chlorinated hydrocarbons, such as chloroform and acetone. Residual monomers increase water solubility, consequently leading to dimensional instability [23]. According to ISO, the solubility of plastics should not exceed 1.6 μg/mm3 for type 1 (after polymerization) and 8.0 μg/mm3 for type 2 (self-polymerizing plastic) [24].

According to Perea-Lowery L, et al. [25], the water solubility of 3D printed resins was higher than that of heat-cured material. This might be related to the polymerization process of conventional polymers, which are developing at a higher temperature for a longer period. Thus, it causes reduced water sorption, solubility, and residual monomer concentration, which has been proved in previous reports [26]. In addition, the differences in the chemical composition of the 3D-printed and PMMA denture base materials must be considered since the type of dental resin played a significant role in the level of water sorption and solubility [27].

CONCLUSIONS:

The treatment with complete dentures poses important questions to clinicians [28-32], the solution of which advocates different scientific directions in prosthetic dentistry [33-37]. Scientific researches examine water sorption and water solubility of 3D printed and conventional PMMA denture base polymers. 3D printed denture base resins offer numerous benefits, compared to conventional materials, such as short-term clinical performance, positive patient-related results, and reasonable cost-effectiveness. According to recent studies, 3D printed denture base resins had shown lower water sorption and solubility values in comparison with the heat–cured acrylics, improving the dimensional stability of the prosthetic restoration and making them a suitable option as a material choice for removable dentures.

Abbreviations:

AM – additive manufacturing
CAD/CAM - computer-aided-design/computer-aided – manufacturing
PMMA – polymer polymethyl methacrylate
SLA - stereolithography
3D - three – dimensional

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