Chapter

Hydrocolloids in Dentistry: A Review

Stanley Onwubu and Chibuzor Stellamaris Okonkwo

Abstract

Hydrocolloids are complex polysaccharides that disperse or dissolve in aqueous solution to give thickened or vicious effects. Also hydrocolloids possess high molecular weight. Owing to these characteristics, hydrocolloids have been widely used in various applications. In dentistry, for example, most intricate and precise procedures are made of hydrocolloids and are found in its simplest material to the most complex material such as impression making, fillings, separating media, electro-polishing etc. The two common hydrocolloids widely used in dentistry are reversible (agar) and irreversible (alginate) materials. Hence, this chapter bring to the forefront their preparations, uses and storage for optimal results and application.

Keywords: agar, alginate, dentistry, hydrocolloids, impression materials

1. Introduction

Hydrocolloids are colloidal systems wherein the colloid particles are hydrophilic polymers dispersed in water and depending on the quantity of water available that can take place in different states, e.g., gel or sol (liquid) It is an intermediate between a solution and a suspension which can be distinguished from solutions using the Tyndall effect [1]. Hydrocolloids materials are available in the form of viscous liquids in the "sol" state or the form of semi-solid substances of a gelatinous consistency. Without a filler, the gel would lack stability and would have a slimy surface covered with synerate exudate [2]. They can be either irreversible (single-state) or reversible hydrocolloids (transiting from gel-sol-gel on the application of heat) [3]. Owing to their unique properties, hydrocolloids have found wide and useful applications in various fields including, dentistry, medicine and the food industries. For instance, hydrocolloids such as Xanthan, gum Arabic, Pectin are added to food as additives due to their gelling, viscosity, and stabilizing properties [4, 5]. The aforementioned hydrocolloids could significantly reduce human appetite in acute settings due to the ability to form gelation in the stomach when ingested. An important rheological property of fibers within the intestine is viscosity, which is thought to account for beneficial physiological responses in relation to appetite regulation, glycemic and lipidemic control [4, 5]. In Medicine, studies have been carried out with different strategies and approaches or a combination of both as hydrocolloid gels have found some potentials in bone regeneration in the delivery of osteo-inductive factors, bone-forming cells, or a combination of both [2].

Recently, hydrocolloid (alginate) gels have also been actively investigated for their ability to mediate the regeneration and tissue engineering of different tissues and organs, including skeletal muscle, nerves, the pancreas, and liver. Current strategies for skeletal muscle regeneration include cell transplantation, growth factor delivery, or a combination of both approaches [6, 7]. Also, Studies within the pharmacological field have demonstrated how alginate-antacid formulations can decrease post-prandial symptoms by neutralizing the acidity of gastric contents by forming a gel-like barrier to displace the "acid pocket" from the oesophagogastric junction and protect the oesophageal and gastric mucosa with controlled released drug products used as model system for mammalian cell culture in biomedical studies [6]. In Dentistry, for example, hydrocolloids are widely used in the fabrication of dental and maxillofacial prostheses impression due to their biocompatibility with the tissues, ease of use, physical properties and hydrophilicity with the oral tissues [8]. Other areas of hydrocolloids applications include orthopaedic structures and stone models in surgical cases [8]. This chapter aims to discuss the different hydrocolloids used in dentistry, their preparations, uses and storage for optimal results and application.

1.1 Overview of hydrocolloids application in dentistry

Hydrocolloids were the first elastic materials to be used in the Dentistry [2]. Elastic impression materials commonly used in the dental field include reversible hydrocolloids (agar-agar), irreversible hydrocolloids (alginate), and other synthetic and elastomeric materials such as polysulfide, polyether's, and silicone [2]. The properties and abilities of hydrocolloids materials enables the replication of the oral tissue with little or no deformity on withdrawal while abiding to both manufacturer and mechanical stipulations of its manipulation prior to being loaded on a tray to produce the gel or sol form [3].

Agar discovered by Sears in 1937 was the first hydrocolloids used in dentistry for making impressions to circumvent the cumbersome procedure and oral lacerations of using impression compound [9]. Agar is a vegetable colloid derived from seaweed found on the sea coast of Japan, a jelly-like substance softened when heated and solidifies when cooled [9]. However, the technique of using agar was complicated because of the need for special heaters and tempering Jars for heating and holding prior to use, syringes and water-cooled trays, even though it could be used severally without losing its chemical and physical properties before been discarded [10].

In 1947, alginate was introduced during the second world war as a result of the scarcity of agar from Japan by the extraction of alginic acid from marine seaweed [10]. Unlike agar which reaction is reversible; alginate reaction was chemical which resulted in irreversible hydrocolloids when the alginate gels are mixed with water [10]. Furthermore, the physical, mechanical, biocompatibility and fatigue properties and most importantly the hydrophilic nature that allows hydrocolloids to capture accurate impressions in the presence of some saliva or blood [10].

Equally significant, its low wetting angle makes it easy to capture full or partial arch impressions moderate ability to reproduce the detail and costs relatively little compared with other elastomeric impression materials [10]. Despite this, hydrocolloids materials are not accurate enough for fixed partial dentures but are used for partial framework impressions to the modelling materials, ability to adapt to the oral tissues and the formation of an elastic resilient film [3, 11].

1.2 Types of hydrocolloids use in dentistry

Generally, hydrocolloids used in dentistry can be typified as either reversible (agar) and or irreversible (alginate). This section, therefore, focuses on the properties, composition and application of these two hydrocolloids materials.

1.2.1 Agar

Agar hydrocolloid has remained an excellent, cost-effective impression material since its discovery in 1937 from seaweed found on the coasts of Japan, and thus, has been used widely for the replication/duplication of models [12]. It is a reversible hydrocolloid which can repeatedly pass between highly viscous gel and low viscosity sol through heating and cooling [3]. In terms of its chemical composition and structure, agar is the sulfuric ester of a linear polymer of galactose extracted from seaweed [3].

1.2.1.1 Composition

The components of the agar gels are 12–15% agar, 1% potassium sulphate to ensure a proper set of the gypsum material poured in the impression, 0.2% borax as a strengthener for the gel, 0.1% alkyl benzoate as an antifungal during storage, and 85% water (**Table 1**). Borax and agar retard the set of gypsum products, so potassium sulphate is added to cancel out their effect [13].

The composition described in **Table 1** may differ slightly depending on the dispersing medium for the gel; which could be either loading on an impression tray or a syringe. When fine details of preparation are needed, a less concentrated gel type is used in a syringed. A more concentrated gel is used to in water-cooled tray to form the bulk of the impression. Agar possesses relatively good elastic recovery, reproduction of details, pleasant tasting and easy to clean up. But it cannot be used to produce electroplated pies due to its dissolution inside the electrolytic bath [14]. Agar is a technique sensitive impression material due to its low tear strength of 27.6 KPa. Agar is dimensionally unstable due to the loss of water from the agar gels even when stored at 100% humidity. The consequence of this is an inaccurate model if left for a while before the cast is poured [9]. Agar hydrocolloids are supplied as sticks or gel and require specific equipment for its manipulation before the impression making process. Thereby making the process cumbersome but can be reused once the setup is done. Although agar hydrocolloid is an inexpensive

Material	Composition (Approximate percentage)	Purpose
Agar	12–15%	Colloidal particle as basis of the gel
Potassium Sulphate	1%	Ensures set of gypsum material
Borax	0.2%	Strengthens the gel
Alkyl Benzonate	0.1%	Antifungal agent
Water	85%	Dispensing medium for the colloidal suspension

Table 1.
Composition of agar gels.

impression material with very good accuracy, its use has declined over the years due to the inability to pour impressions immediately, low dimensional stability, ease of manipulation and water-cooled impression trays and the inability to produce electroplated dies [9].

1.2.2 Alginate

Alginate is an irreversible hydrocolloid largely used in dentistry [15]. It is mainly used for diagnostic and planning in the rehabilitation of oral, orthodontics and maxillofacial prostheses [16–18]. The advantage of alginate materials is that it is easy to manipulate, cheap and provides a good level of comfort for patients without the need for specialized instruments and equipment [17, 19].

1.2.2.1 Composition and setting reactions

Discovered in 1945, as a substitute for agar whose importation was hampered by the outbreak of the Second World War. Alginates are salts of alginic acid, a polysaccharide extracted from the cell walls of brown algae (washed, ground and chemically treated, especially the pulp) belonging to the Phaeophyceae family, widespread especially in America [20]. Like agar, alginic acid, chemically known as anhydro-B-D-mannuronic acid has a high molecular weight (30,000 to 200,000) linear polymer [9].

The extracted alginic acid is then converted into a salt (alginate) of sodium, calcium, potassium or magnesium. Although alginate is insoluble in water, its alkaline salts are water-soluble. The production process of sodium alginate from brown algae can be done in two ways; using the calcium alginate method or the alginic acid method [21]. To extract alginic acid, the algae are placed in a sodium carbonate bath, exploiting the solubility of alkaline alginates in water. The alginic acid is recovered from the obtained solution by precipitation with hydrochloric acid or sulfuric acid [21]. The difficulty of the processes lies in the required physical separations; such as in the filtration of muddy residues from viscous solutions or in the separation of gelatinous precipitates that retain a large amount of liquid in their structure, resisting filtration and centrifugation [2].

The alginate impression materials for dental use contain several additives such as sodium alginate, calcium sulphate, trisodium phosphate, diatomaceous earth, zinc oxide, and potassium titanium fluoride, all in the form of a powder [2]. They are irreversible hydrocolloids because the picking reaction is a chemical reaction of irreversible precipitation therefore they cannot return in sol form using physical means, such as temperature, as with reversible hydrocolloids.

The chemical reaction occurs two times: a first phase called 'slowing' and a second phase called 'setting'. Initially, the powder is mixed with water, a sol is formed and the sodium or potassium salts of alginic salts react with the calcium sulphate [2] to allowing crosslinking of the alginic salts [9, 22, 23]. After the sodium phosphate has reacted, the remaining calcium sulphate reacts with sodium alginate to form insoluble calcium alginate that forms a gel with water which acts as a catalyst. There are many commercial variations of alginate that vary in consistency, setting time, elasticity, strength, and dimensional stability; manufacturers also add fillers, which impact on its properties, application, setting time, and pouring time [22]. The standard composition of alginate is as described in **Table 2**.

The alginates available on the market can be of two types: fast setting (hardening time of 1–2 min) or normal setting (setting time between 2 and 5 min). The setting time depends on the composition (water/powder ratio, where increasing the powder accelerates the hardening reaction) and the temperature at which mixing

Material	Percentage (Approximate)	Purpose
Sodium or potassium alginate	15–20%	Colloidal particles as basis of the gel
Calcium sulphate dihydrate	14–20%	Creates irreversible gel with alginate
Potassium sulphate	10%	Ensures set of gypsum materials
Trisodium phosphate	2%	Retarder to control setting time
Diatomaceous earth	55–60%	Filler to increase thickness and strength
Other additives: chemical indicators	Very small quantities	Colour change
• Organic glycols • Flavoring agents • Coloring agents • Disinfectants		Reduce dust when powder is handled Improve taste of material Provide pleasant colors Cause antibacterial action

Table 2.
Composition and properties of alginate use in dentistry.

takes place [2]. The reaction that causes the alginate impression materials to form makes use of the different solubilities of the sodium, potassium, ammonium and calcium H_2O % Na & alginate % $CaSO_4$ ÿ (paste) Ca & alginate % Na_2SO_4 (gel) salts of alginic acid in water.

The setting reaction is a chemical reaction between Sodium Alginate and Calcium Sulphate, where:

$$2Na_3PO_4 + 3CaSO_4 \rightarrow Ca_3\left(PO_4\right)2 + 3Na_2SO_4 \quad (1)$$

This reaction (1) can be retarded with Calcium Phosphate, which acts as a retarder, thereby increasing the setting time and obtain a type I (fast set) or type II (Normal set) setting time [20].

The irreversible hydrocolloids, which are the most commonly used, are a mixture of manual or mechanized techniques through the union of powder and water [2]. Alginate impression materials are easy to use and manipulate without specialized equipment but can be mixed manually or mechanically, it is less expensive and has more rapid setting times. The reaction time and the setting time can be controlled with the temperature of the water used. They are slightly flavoured and in recent formulations, have colour indicators according to the phases of the chemical reaction [2].

1.3 Summary

What started as a trial in the 19th century gradually became a benchmark in the history of dentistry and has today found its way into different aspects of medical, pharmaceutical and food industries with more studies on how to improve its effectiveness for optimal use. We are currently in a technologically advanced era which is gradually employing the use of CAD/CAM technologies for the diagnosis and treatment of patients which is still very expensive due to the cost of the equipment and specialized training required for the operators to interface with it. Amid all these, studies are still being carried out on convectional irreversible hydrocolloids to improve their physical, mechanical and biological properties [24].

Recent studies have shown that the dimensional stability of hydrocolloids has been improved upon with the materials which have extended cast pouring times [25]. The incorporation of disinfectant gels into the powder which when mixed with water will dissolve thereby preventing surface inaccuracies when soaked/sprayed with disinfectants [25]. Dust-free particles with the use of glycerine making the powder denser and the two-sol system like elastomeric materials to reduce inaccuracies due to annual mixing [25]. Chromatic products to indicate the different chemical reactions within the sol [25].

An important advancement is the use of agar-alginate laminate for making impressions which give better accuracy, thereby, eliminating the water-cooled trays for agar impressions. Certainly improving the quality and definition of these materials would be possible to expand their use with benefits for patients. Also, the reduced setting time and their single-footprint technique will provide added benefits for dentists in terms of time available for manipulation. The prospect is that these materials will continue to evolve as has happened since the 40s, thus producing high-performing impression materials [2].

1.4 Conclusion and recommendation

Despite the advancement in science and technology, hydrocolloids have remained relevant in dentistry, particularly as an impression material. The resilient properties of hydrocolloids coupled with the simplicity of use and biocompatibility with the oral tissues had endeared it in dental practices. While hydrocolloids had some inherent disadvantage in its properties, the advancement in material science and modification of hydrocolloids with other additivities has improved their properties and usefulness in the oral care practice.

Conflict of interest

The authors declare no conflict of interest.

Author details

Stanley Onwubu[1]* and Chibuzor Stellamaris Okonkwo[2]

1 Department of Dental Sciences, Durban University of Technology, South Africa

2 Shehu Idris College of Health Sciences and Technology, Makarfi Kaduna, Nigeria

*Address all correspondence to: profstan4christ@yahoo.com

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