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*Original Article*

# Optimizing Alginate: Advances and Prospective Modifications for Superior Impression Materials

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Alginate is a routinely used impression material which is widely used across the globe. The popularity mainly comes from being economical, ease of use and good surface reproducibility due to its physical and chemical properties. Apart from having these advantages there are certain critical disadvantages such as low tear strength, dimensional instability, poor water retention capacity etc. makes newer materials and techniques superior to the conventional alginate. Despite the disadvantages, alginate can be easily modified to a wide extent without changing its properties, allowing to overcome these disadvantages. This article focuses on the origins of alginate followed by, how to use, and discusses its advantages and disadvantages. The review article also highlights all the modifications done with alginate up till present day and the potentially possible modifications to improve the properties of alginate.

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## Introduction

Alginates are sodium or potassium ions bonded Alginic acid or Algin. Algin is a naturally occurring substance found in the Phaeophyceae family of algae. Commonly known as the brown algae, it is considered to be the second most abundant multicellular marine algae [1]. It is also found in certain bacterias as well. Alginate was first discovered by British chemical scientist E.C.C. Stanford in the early 1890's. Due to its properties, the formulation and extraction process was patented in the same year [2]. It has a yellowish brown color in its natural solid powdered state. The bulk extraction of commercial Alginate is an easy but long process involving many steps and reagents to extract it from the cell wall of the algae [3].

Alginate as an impression material, despite being considered as a close to ideal material, it possesses certain critical disadvantages and drawbacks [4]. These includes poor dimensional stability, dust formation of finer particles, In recent years, due to advancements in knowledge and technology, there has been a significant improvement in impression materials by development of newer materials such as polyvinyl siloxane, poly ether and other silicone based elastomeric impression compounds [5] They have excellent recordability, longer shelf life, moisture independence and dimensional stability of impressions, overcoming the drawbacks of alginate, but are certainly not economical for day to day use [6].

Technological advancements have introduced newer materials such as rubber based elastomeric impression material, and newer techniques such as digital impression [7] that have started to gain popularity in dentistry. These newer materials and techniques have accurate surface reproducibility but are still far from being commercially and affordable for everyday practice [8]. Hence, to overcome the disadvantages of existing alginate, by further modifying alginates to increase its properties such as strength, flexibility, tear resistance, improved shelf life, and dimensional stability, remains the most practical outcome for the existing technological limitations. This review discusses the chemical structure, reactions, clinical use, advantages and disadvantages of existing commercially available Alginate impression material. The primary focus lies in describing already incorporated existing commercial modifications, as well as discussing potential modifications which can further enhance the material.

## Chemical Structure and Properties

Alginate is a polysaccharide that is composed of β-d-mannuronate (M) and its epimer α-l-guluronate (G). In alginate polymers, the residues are arranged in a block structure of a homopolymer

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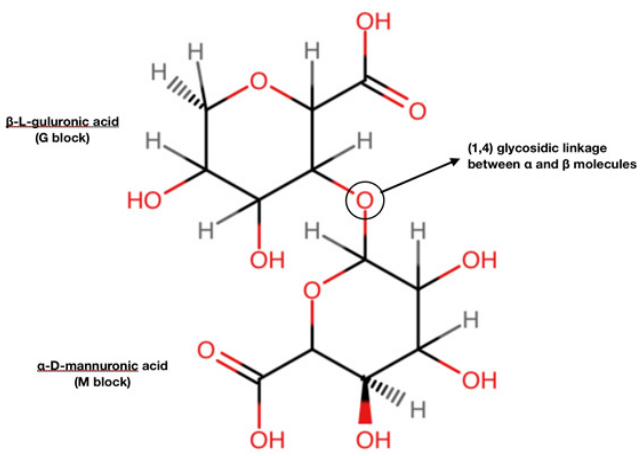


**Figure 1. Molecular structure of alginate**

(polymannuronate (PM) or polyguluronate (PG)) or heteropolymer (a mixed sequence like MG, MGM, MGMG, MGGM etc.) [9], as shown in figure 1.

Alginate is an irreversible hydrocolloid type of material and is popularly and extensively used in a wide range of industries including food, agricultural, and biomedical. In the biomedical industry, its uses include extracellular matrix biodegradable scaffold development for tissue engineering [10], dressing of wounds [11] and targeted drug delivery device [12]. This is mainly due to its properties such as nontoxic, hygroscopic, biodegradable, rapid ionic gelation, biocompatible, easy usability and economic feasibility as shown in figure 2. In dentistry, alginate is used as an impression material that contributes to a major bulk of clinical practice since the beginning of learning dentistry across the globe for almost a century. Commercially available Alginate impression material is popular and is an indispensable part in dental practice [13]. Present day Commercially available Alginate consists of several compounds, some of which were already added in the past to modify the Alginate's properties. The primary basic ingredient that takes part in the reaction includes sodium/potassium Alginate, calcium sulfate, trisodium phosphate. Apart from these, there are other compounds that do not take part in the reaction, but are added for various other reasons such as glycerol, potassium titanium fluoride, coloring and flavoring agents. In the commercially available Alginate, each chemical has its own specific ratio and functions for increased efficiency for commercial use [14], which can be summarized in detail in the table 1.

## Setting Reaction and Parameters

The ion exchange reaction occurs between the sodium alginate and calcium sulfate, leading to formation of calcium alginate and sodium sulphate with a specific, predetermined mixing time and setting time [1] as shown below.

$$\text{Na Alginate} + CaSO_4 \longrightarrow \text{Ca Alginate} + Na_2SO_4$$

The time required to complete the setting reaction is flexible and can be adjusted as per suitability. Alginates allow a good flexibility of the setting time of the reaction by a variety of methods such as changing water powder ratio, addition of other compounds or materials to enhance or reduce the reaction speed, by using water with varying temperatures to affect gelation of alginate etc [4]. The American Dental Association (ADA) divides the alginate setting time into two types having different working time and gelation or setting time. Type I is also known as fast setting Alginate with a working time of about 75 seconds and setting time of about 1-2 mins.

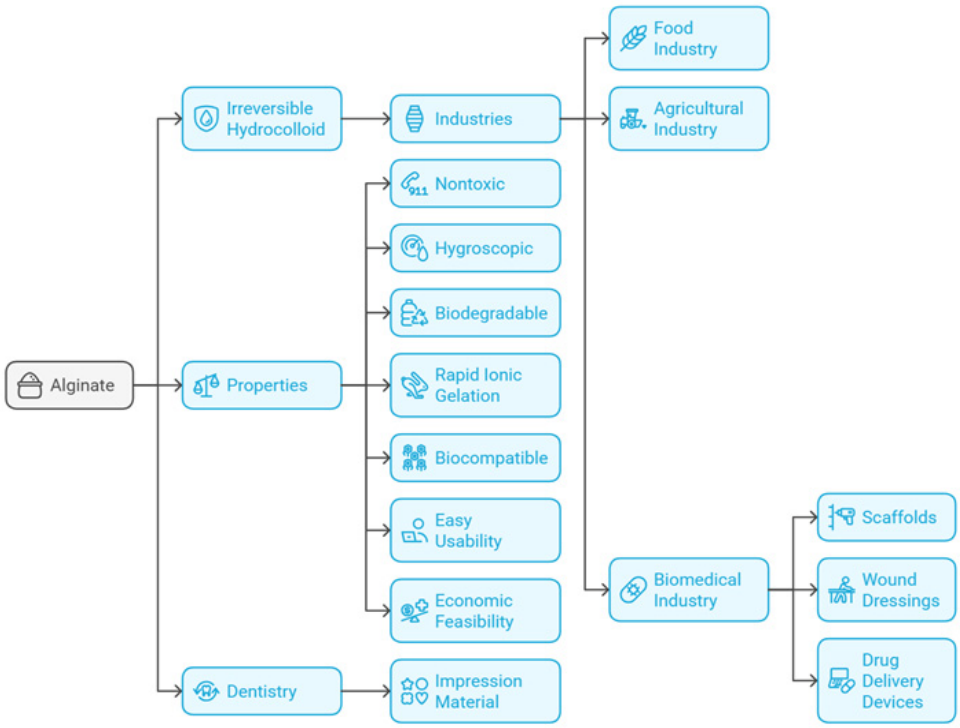


**Figure 2. Diverse applications and properties of alginate**

**Table 1: Composition of Alginate Impression Material with function of each ingredient**

| | Compounds | Composition | Function |
|---|---|---|---|
| 1 | Sodium / Potassium alginate | 12-15% | Derived from Phaeophyceae family seaweed. Primary active gel forming ingredient that reacts with calcium ions, in presence of water, to form irreversible gel. |
| 2 | Calcium sulfate | 8-12% | Reactor/cross linking molecule that reacts with Alginate to form calcium alginate and is responsible for gelation reaction or setting of the material |
| 3 | Trisodium phosphate | 2-3% | Slows down / Retards the gelation reaction to provide sufficient working time for mixing, loading, and taking impression before setting of material. |
| 4 | Diatomaceous earth and Zinc Oxide | 60-75% | Filler particles that provide stiffness and bulk to the material, controls the flow and improves the strength of the material post impression. |
| 5 | Potassium titanium fluoride | 1-3% | Enhances Smoothness improving the compatibility between the alginate and gypsum, ensuring accurate reproducibility of impression details on the cast. |
| 6 | Glycerol | 0-1 % | Plasticizer that gives smoother texture and better handling properties and reduces dust while mixing the material. |
| 7 | Flavoring agents | 0-1 % | Added to make the material more pleasant for patients, improving patient comfort during the process of taking impressions. |
| 8 | Coloring pigments | 0-1 % | Provide characteristic color that indicates reaction mixing and setting time to proper handling and ease to use. |

*Note: # Common compounds mentioned for commercially available alginate impression material. * Composition given in (weight/weight) %*

On the other hand, type II is also known as normal setting alginate with 2 minutes working time and 2-4 minutes setting time due to addition of retarder molecules reducing the rate of the reaction(15).

## Manipulation and Recording Impression

The appropriate quantity of alginate impression material to water ratio is measured with a universally available alginate measuring scoop and alginate measuring cylinder made out of plastic, that measures the powder and water quantity respectively. The manufacturer predetermines and mentions the alginate to water ratio on the pack for the most appropriate mix. The ideal ratio consists of equal parts of Alginate and water for the best output [16]. Basic dental equipment such as a rubber bowl, wide blade spatula, P water and perforated impression trays of desired size is all that is required. The mixing is started by adding a quantity of water into the bowl, followed by the addition of a proportioned quantity of powder. The variation of the setting time also depends on the type, amount and the temperature of water used. Mixing must be quick with a wide-blade spatula in a "figure of 8 motion" against the wall of the bowl [17]. This results in a mixture which should be non-dripping and creamy consistency mix, when lifted by spatula from the bowl. The mix is then loaded to Specialized perforated stock trays and appropriately placed in the oral cavity before reaching setting time. These perforated trays allow mechanical adhesion of the alginate and also prevent ingestion of excess alginate by allowing the excess material to flow through perforations in the tray [18]. Necessary lip movements are done after interesting the tray and before reaching the setting time to ensure that the material flows and accurately record the vestibule areas for a precise replication of in the patient's oral cavity [19]. It is recommended to remove the stock tray using sudden jerking movement to prevent tearing and distortion of the details that are recorded from the oral cavity.

## Advantages and Disadvantages of Alginate

The widespread use is due to its low manufacturing cost and economical market price with respect to its shelf life. On an average, it has a decent shelf life of 2-3 years. Environmental Factors, such as sunlight or humidity exposure, can decrease the shelf life and increase the chances of failure in setting reactions [20]. Hence, It is recommended to store Alginate in an air-tight container away from direct sunlight exposure. Unlike some other materials, It has a better tolerability in patients during clinical application. This is further enhanced by addition of flavoring agents, making the taste of the material more tolerable and reducing gag reflexes [21]. Natural flavors such as peppermint oil or artificial Fruit Flavors such as Strawberry, Orange, Bubblegum, Cherry, Vanilla, Spearmint are commonly used, making it tolerable specially for young patients. As discussed earlier, Alginate is relatively one of the easiest to mix and manipulate. This makes Alginate a less technique sensitive impression material and has easy execution technique. Specialized color indicators that are added in the powder which provide a visual aid to analyze the setting reaction of the mix [22]. The commonly used coloring agents in Alginate are synthetic dyes used for Food, Drug, and Cosmetic Dyes (FD&C dyes). Uncommonly used Natural Pigments such as Annatto seed extract or beet juice powder have also shown to improvise the color of alginate making it visually more acceptable among patients. The Temperature of the water used allows the operator to control reaction speed by a few seconds [23]. Using low temperature or cold water results in a slower reaction process, increasing the setting time of the mix and vice versa. The

most advantageous property of Alginate, is its ability to capture a detailed impression of the oral cavity, even during presence of undercuts [24].

Despite having all these advantages and overcoming certain older existing disadvantages, there still are certain critical disadvantages that limit the potential of alginates [25]. One of the main disadvantages of alginate is its poor tear resistance. Alginate after setting is soft and easy to tear even under low forces that is usually experienced while retrieval of the impression tray, especially when the water-powder ratio is inappropriate. The second major drawback of Alginate turns out to be its dimensional instability over longer durations. Once the impression is retrieved and washed, it is recommended to immediately pour cast by pouring gypsum [17]. This is due to the fact that alginate can only maintain its dimensions under a 100% moisture environment. that prevents it from shrinkage and dimensional changes [26]. Hence if cast cannot be immediately poured, it is recommended to cover the entire impression with moist cotton to prevent dimensional changes to a certain extent. Another minor drawback is the uncontrollable limited working time making it difficult for beginners and slow paced operators [27]. However, this can be overcome by repeated practice which subsequently increases the exposure to the material and speed of the operator. Newer silicone based impression materials such as addition and condensation silicone have shown significant accuracy and surface reproducibility of the patient's oral cavity with the only disadvantage of being uneconomical for everyday use [28].

## Modifications in alginate Impression Material

Until recent years, numerous modifications have been done with alginate since its introduction as an impression material to enhance its physical and chemical properties by addition of various compounds to enhance its functioning. A few methods to enhance alginate are listed below in the **table 2.**

## Modifications of alginate till date

### Chromatic alginate

Commercial alginates are now being added with pH indicators such as cresol red, α-naphtholphthalein, thymol blue, phenolphthalein, tropaeolin OOO. Dyes such as alizarin and anthocyanin can also be used but are less popular in comparison to the previously mentioned.

These pH indicators are chemical compounds which are weak acid or base in nature and show different colors in their protonated and deprotonated form. When added to any chemically reacting

**Table 2: The various types of modifications in the alginate impression material**

| Invention | Modification | Mechanism | Applications | Ref. |
|---|---|---|---|---|
| Chromatic / Color changing alginates | Addition of pH dependent color indicators | Changing pH value while setting reaction of Alginate is seen with the help of pH indicators | Visualization of the reaction during mixing and setting of the impression material improving timing and reducing material wastage. | (29), (30) |
| Flavouring alginates | Addition of natural / synthetic flavouring agents | Improvising the taste of Alginate impression material | Increase in the acceptance rate & patient tolerability, and reduce gag reflex, especially in pediatric patients | (21) |
| Dustless/ Dust free alginates | Addition of glycol and organic binders to Alginate powder | Clump formation of small Alginate particles, causing binding and preventing from being airborne. | Prevention of dust formation and airborne while mixing, improving safety of the operator and patient. | (31), (32) |
| Self-disinfecting alginate | Addition of antimicrobial agent to Alginate powder | Prevention of microbial contamination of the impression by bactericidal action | Prevention and control of infectious microbes and reducing additional post infection disinfecting step | (33), (34) |
| Alginate / Titanium Dioxide | Incorporation of titanium dioxide nanoparticles to Alginate in a fixed quantity | Antimicrobial properties by controlling biofilm formation and helps maintain structural integrity | Improves antimicrobial property, along with hardness, opacity, and surface smoothness | (35), (36) |
| Addition of plasticizer to alginate | Incorporation of glycerol or polyethylene glycol into alginate | Modification in the physical properties by enhancing the chemical structure | Softens the material, increasing flexibility, elasticity, and elongation break | (37), (38), (39) |
| Nanoparticles infused alginate | Incorporation of nano silica, nano clay, or carbon nanotubes | Formation of covalent bonds with Alginate to improve the physical properties | Increases tensile strength and hardness of material | (40), 41), (42), (23) |
| Alginate / polymer incorporation | Polymer addition such as polyvinyl Alcohol, polyurethane and carboxymethyl cellulose | Alginate polymer bonds adding polymeric properties in alginates | Increases tear strength, flexibility, stretchability, mechanical stability and accuracy of impressions | (43), 44), (45). |
| Cotton fiber infused alginate | Incorporation of small length of cotton Fibers into alginates | Mechanical adhesion of Alginate and high water retention of cotton fibers | Increases tear resistance, mechanical reinforcement, elastic recovery and dimensional stability | (46), 47), (48), 49). |
| Virucidal alginate | Incorporation of magnesium ion concentration | Alters pH to prevent growth of virus in alginate | Prevention of viral transmission while treating patients with viral infection | (50), 51). |

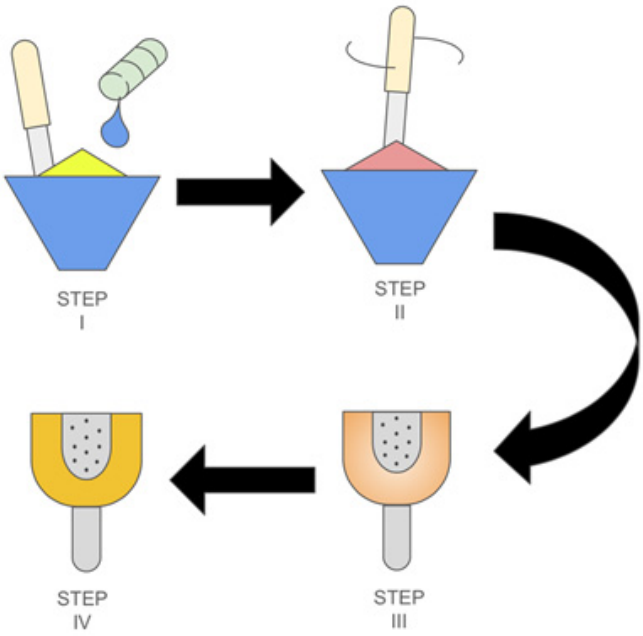


**Figure 3: Schematic representation of Chromatic alginate. STEP I. Dispense impression material into rubber bowls. STEP II. Addition of water changes the materials colour indicating initiation of reaction. STEP III. The material is transferred to the stock tray and impression is taken before reverting the colour change. STEP IV. Stock tray with Primary impression with completely finished reaction**

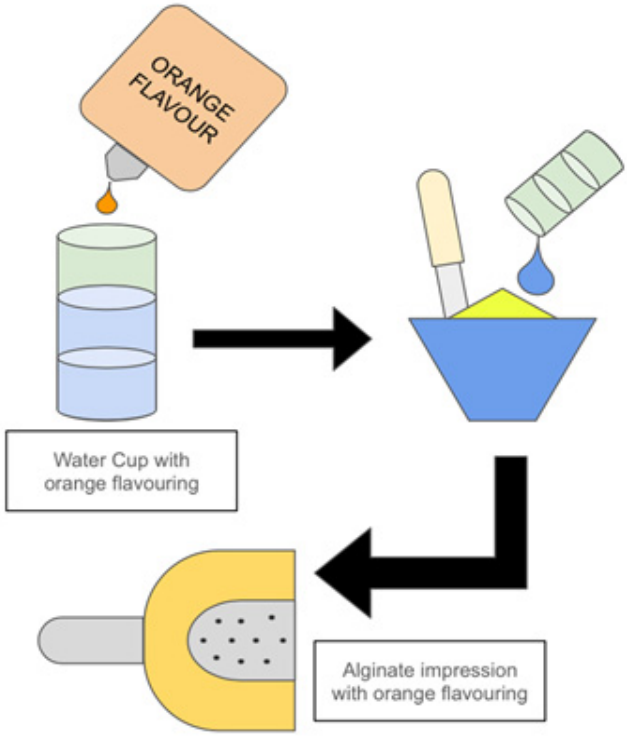


**Figure 4: Flavoured alginate by adding flavouring agents in water before mixing it with alginate impression material**

compound, these indicators shift their color as the reaction proceeds according to change in the overall pH of the reaction. The pH indicators have the property to change its colour according to the changes in pH occurring in the reaction without involving in the reaction itself as shown in figure 3. The reaction is visualised by colour changes of the indicator molecule by donation or acceptance of hydrogen ions, causing protonation or deprotonation during various phases of reaction, causing change in the molecular structure of the indicator [29]. The indicator added are pH sensitive and detects the changes in the pH of ongoing alginate setting reaction, In the case of the gelation process of alginate impression material, during the mixing being neutral to setting phase from neutral to basic respectively. This color-coding feature aids in improving the accuracy of impressions and saves time as well. It also reduces the likelihood of errors in timing, ensuring consistent results and better impressions, particularly in busy dental practices. Moreover, It helps the operator by providing visual guidance for each step to increase its efficiency and minimize repeated impression taking [30]. It is also made sure that the indicator added is biocompatible, non-toxic and also meets food and safety standards before use, and does not cause staining during or after its use. The most important property is that the indicator itself remains stable at the pH it is used at and also be unreactive to the alginate. A few examples of commercially available chromatic alginates are Septodont Plastalgin Chromatic Alginate, AGILE Chromatic Alginate, Dpi Chromatex Chromatic Alginate Powder, Cavex Dental Mecalgin Chromatic Alginate etc.

### Flavoured alginate

Early alginate had a very low patient acceptance rate especially among the younger aged patients, mainly because of its highly unpleasant taste causing many patients to refuse the use of alginate. The unpleasant taste was reported to trigger the gag reflex mechanism causing the feeling of nausea in many patients with sensitive gag reflexes. This has led to a significant reduction in the use, only restricting to a few patients who were able to tolerate the unpleasant taste. This ultimately resulted in the reduction of the patient compliance as well as the quality of the impression material [21]. Noting this, synthetic flavouring agents were then added to the alginate which significantly improved the tolerability while using alginate and reducing the incidence of gag reflex in patients as shown in figure 4. Now, alginate impression material comes in a wide range of flavours including fruity flavours such as orange, strawberry, berries, grape, fruit punch, pineapple, etc. as well in non fruity flavours such as chocolate, vanilla, peppermint, bubblegum, etc. These flavouring agents can either be added by the manufacturer during alginate manufacturing or can be sold in a separate bottle which can be added into the water before mixing it to alginate to give the desired flavour.

### Dustless alginate

Dust free alginates is one of the primarily introduced modifications in alginate impression material. GC Impreceed Dust-free Dental Alginate, and Ruthenium Alginate Dust Free are some of the commercially available dust free alginate products. These are developed by addition of binding agents into the alginate impression material. Early alginate impression materials were devoid of the binders which caused micro filler particles of alginate to go airborne during dispensing and during mixing the material. This led to creation of a mess in a hygienic environment and also caused respiratory problems and allergic reaction due inhalation of alginate particles. Introduction of binding agents include compounds such as glycols, organic binders, and surfactants, which are added to the Alginate [31]. Addition of these binding agents makes the Alginate

impression material decrease the formation of dust particles by clumping and binding the fine filler particles. This binding helps in preventing alginate from becoming airborne while removing it from the container and while mixing the Alginate to water. Addition of binding agent has significantly improved handling of the alginate and without affecting the mixing or reactive properties of Alginate. Inhalation of these particles can induce minor respiratory risks such as coughing or sneezing in some individuals including both the operator and the patient, especially while manipulating in higher volumes [32]. Dustless Alginate has significantly reduced the accidental inhalation of the fine filler dust particles and has created a cleaner and safer working environment. Apart from the operator's health, it also prevents the work area from becoming messy which can make the workplace unsafe without compromising on the quality and precision of alginate impression.

### Self disinfecting alginate

Traditional alginates impressions have shown the buildup of microorganisms such as bacteria, fungi, and some viruses when left over a period of time. This happens due to the fact that alginate material has no antimicrobial properties. Certain microbes such as candida species, and certain viruses, such as human simplex virus (HSV), epstein barr virus, and some variants of hepatitis (B &C), show transmission through saliva and the infection can potentially spread from the patient to others. Prevention of this transmission is crucial and requires mandatory disinfection steps after retrieving the impression tray from the oral cavity of the patient. The disinfection process can subsequently lead to distortion of the impression by reducing the surface reproducibility and consumes extra time as an additional step [33]. Disinfecting agents such as iodine, chlorhexidine, quaternary ammonium compounds, silver nitrate etc, are now being added into Alginate impression material. This incorporation has shown successful disinfection properties after taking an impression. These work by either killing or preventing microbe growth and controlling infection without compromising the chemical interaction or dimensional instability of Alginate impression material. Incorporating disinfectant agents prevents microbial colonisation and spread of infectious microbes without performing any additional steps. This has helped prevent the potential risk of infection by preventing microbes spread, from the patient to the operator that carries risk of spreading of infectious microbes [34]. Some of the commercially available self disinfecting alginates are Dental Zelgan Advanced Alginate and Zhermack Hydrogum 5 Alginate Impression Powder.

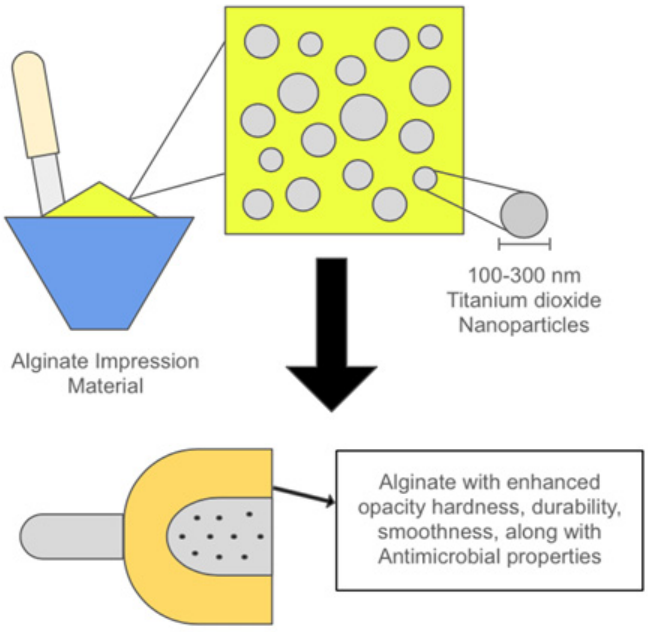


**Figure 5: Alginate impression material incorporated with $TiO_2$ enhancing the physical properties of alginate impression material**

## Recent Modification of Alginate Impression Material

### Addition of titanium dioxide

Titanium dioxide (TiO) is a white and gray odorless solid,which naturally occurs in nature abundantly, and usually exists in three different types of crystal structures. The most properties of this compound are vastly diverse which includes high environmental neutrality, high chemical resistance, extremely nontoxic in nature with high biocompatibility to oral tissues. It is well accepted by human tissues without causing adverse anaphylactic or inflammatory reactions or rejection in cases of implants. Adding to this, it has hydrophilic properties, photocatalytic properties as well as antibacterial properties making it very much compatible for use in human beings (35). Titanium dioxide particles can be incorporated into alginate impression material, with particle size ranging from 100 to 300 nanometers. Figure 5 illustrates that it is generally used in low concentrations specifically to enhance alginate impression material's opacity, surface hardness and smoothness of the material after the setting reaction resulting in better gelation of alginate impression material. Titanium dioxide nanoparticles, specifically that are spherical in shape, have proven to enhance the material by providing maximum antimicrobial activity in comparison to other shapes [36]. Moreover, it also helps to reduce wearing by maintaining overall structural integrity of the material. The enhanced structural integrity has shown to improve the materials durability during impression taking and prevents it from breaking while retrieving the impression. Apart from that, it also enhances the materials durability while pouring cast without affecting alginates chemical properties.

### Addition of plasticizers

Plasticizers are low molecular weight substances which are similar to polymers and are added to a material to make the material easy to work, by enhancing its flexibility and softness. The increase in the softness and flexibility is due to weakening of valence forces by preventing bond formations among polymer molecules improving flexibility of the material [37]. Common plasticizers such as glycerol are already being added to the Alginate by commercially producing companies. When glycerol is added to alginate formulation, it tends to increase its flexibility. It softens the material slightly, allowing it to deform while preventing it from breaking, thereby reducing the chances of tearing of the impression when removed from undercuts. Studies have shown that the addition of glycerol results in a decrease in tensile strength and Young's modulus and an increase in elongation at break [38]. However, elongation at break decreased when glycerol content exceeded 30% wt due to a major segregation phenomenon. Polyethylene Glycol (PEG) is another commonly used plasticizer in alginates. Addition of such plasticizers can also help reduce the dust particles formation that occurs due to fine filler particles. PEG also helps to improve the elasticity and flexibility by reducing brittleness and therefore enhancing the ability to withstand comparatively higher forces [39]. This will help in preventing the likelihood of damage to the impression that occurs during the retrieval of impression from patients oral cavity.

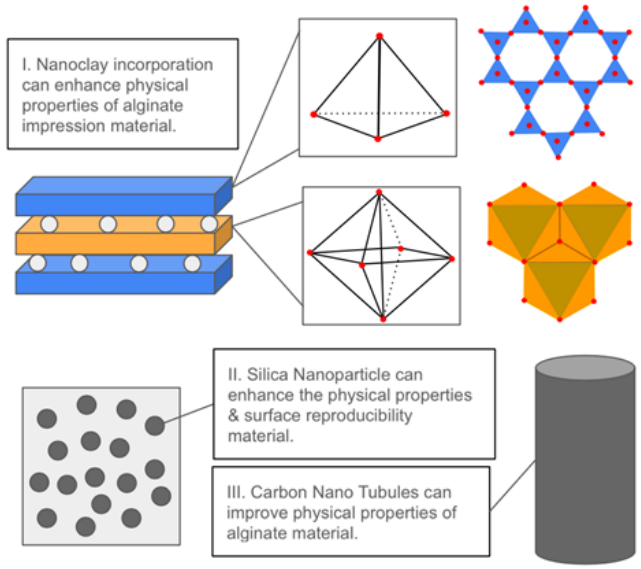


**Figure 6: Addition of Carbon and Silicon based materials such as I. Nanoclay, II. Silica-nanoparticles and III. Carbon nanotubules in alginate impression material enhance the alginate impression material by forming additional molecular bonds**

### Nanoparticles, nanoclay and carbon nanotubes

Nanoparticles are compounds or molecules of size in nanometers and have recently started to gain popularity in the biomedicine field. Nano-silica particles are fine silica particles which can be used to reinforce alginate materials as shown in figure 6. Since the major component of alginate impression material is diatomaceous earth, by incorporating the fine nanoparticles instead of conventional diatomaceous earth, the tensile strength and hardness of alginate can be significantly improved. Apart from this, Nano-silica incorporation can also enhance the surface smoothness of the set material, leading to better and more detailed reproduction of the oral cavity surfaces [40]. Nanoclay is a type of material made up of stacked layers of silicate or minerals. The molecular structure of nano clay consists of silica tetrahedral and alumina octahedral layers or sheets which are stacked one above another. The addition of nanoclay particles into alginate has been shown to improve the mechanical strength of alginate, including its tear resistance and dimensional stability. Because of the presence of layers among the molecules, Nanoclays have high surface areas and can disperse evenly through the material, providing a good mechanical reinforcement at the molecular level [41]. On the other hand, a carbon nanotube (CNT), one of the allotropes of carbon, is a tube made of carbon with a diameter in the nanometre range. Carbon Nano Tubules are mainly useful in making localized sustained drug delivery systems and in making nanocomposite scaffolds used in tissue engineering [42]. They are an advanced nanoparticle filler that, when incorporated in impression material, can enhance the material's strength and toughness, without significantly affecting its working or setting times [23].

### Polymers infused alginate blends

Polymers are large molecules made up of chemically linked smaller subunits called monomers. Monomer is a single unit of molecule which combines to form long chains by forming covalent bonds among monomer units. The properties of Alginate impression material can be enhanced by the use of polymers which can be incorporated by various materials and techniques. Numerous unreactive polymers can be incorporated into alginate by the means of blending synthetic Polymers such as Polyvinyl Alcohol (PVA) into alginate powder. On incorporating PVA to the alginate impression material, it improves the elastic properties by increasing the tear strength of the alginate [44]. PVA addition enhances flexibility and stretchability after setting, which increases its tear resistance, making it more robust in clinical applications to tackle difficult situations for eg. presence of deep undercuts. Polyurethane is an immensely versatile class of polymer which is extensively used across various industries. It can be added with alginate to enhance strength and flexibility of the final impression. Polyurethane enhances the flexibility and improves the material's resistance to tearing and distortion significantly [45]. Carboxymethyl Cellulose (CMC) is a cellulose derivative polymer that is primarily used as a scaffold material, wound dressing to improve healing and in localized drug delivery systems. Formulation and Incorporation of CMC to Alginate impression material increase the material's viscosity and improve its tear resistance. In clinical dentistry, this alginate blend can produce more accurate impressions with better mechanical stability due to improved viscosity, particularly when working with abnormal dental anatomy especially in cases of facial disorders affecting the jaws [46].

### Cotton fiber incorporation

Cotton Fibers are naturally occurring, biodegradable, based plant cellulose fibers. They have been incorporated into Alginate to enhance properties of cotton fibers such as for making fire resistant clothings. When incorporated in dressing gauze it can be used as a hemostatic agent for improvising wound healing in specialized situations [47]. Cotton fibers act as a reinforcing agent that helps in improving the overall strength and durability of the material. Cotton fibers can help improve the tear resistance of the alginate material, ideally when incorporating small lengths that provide mechanical and structural reinforcement in the matrix structure [48].

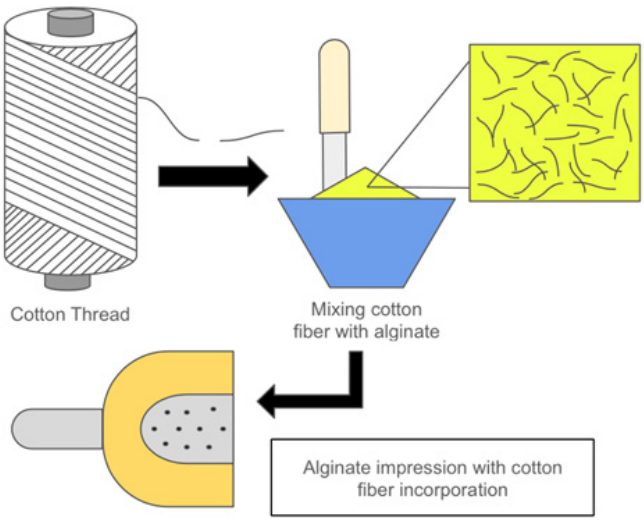


**Figure 7: Cotton Fiber incorporation in the alginate impression material improves the materials tensile strength and tear resistance**

Evenly dispersed cotton fibers throughout the alginate matrix as shown in figure 7, provides a structural reinforcement, making the material less prone to tearing during removal from the patient's mouth, especially in areas with deep undercuts or sharp edges. Alginate incorporated with cotton has shown improved flexural strength, tensile strength and improved elastic recovery of alginate along with reduced degradation of cotton fibers [49]. This allows the material to slightly bend or flex which is particularly useful while removing impressions from the patient's mouth. Syneresis is one of the prominent drawbacks which is loss of water molecules into the environment from the set alginate. But, due to water retention capacity of cotton fibers, this incorporation can also increase dimensional stability of the material, post setting and minimising distortion by reducing shrinkage of the alginate caused due to syneresis, that is the process that occurs in gel which involves contraction of the material due to expelling of water [50].

**Alginate with virucidal properties**

Working in patients having viral infections becomes a challenging task for dentists. Viral infections can spread through oral routes by the means of saliva and droplets, increasing the risk of infection spread from patients coming for dental treatment. Long standing asymptomatic viral infections remain undiagnosed in many cases and can transmit infection from one person to another. Preparation and testing of a number of experimental alginates demonstrated that pH modification through manipulation of magnesium ion concentration confers antiviral property to the alginate [51]. Experiments show successful achievement of antiviral properties of the Alginate Impression materials, without the addition of therapeutic antimicrobial agents or currently employed chemical disinfection processes. The materials hold the ability to self-disinfect against virulent viruses such as HSV-1, Hepatitis A, B, HIV, etc. This helps in eliminating the need for chemical disinfection procedures and ensures enhanced safety for the operator in preventing the spread of viral infections while working with patients with viral infection [52]. Some Metal ions (such as silver or copper) are known for their antimicrobial and antiviral properties. These can also be incorporated into Alginate in the form of infusion of nanoparticles to provide antimicrobial effects. Addition of commonly used Antiviral drugs or bioactive compounds will also provide similar results without affecting the property of Alginate impression material. This will ensure operators safety from infections and will help in preventing accidental infection spread.

## Conclusion

Alginate hydrocolloid is an everyday and easy-to-use impression material which gives good quality impressions and is economically feasible. The main drawbacks include poor tear resistance and dimensional instability caused due to shrinkage because of its high sensitivity towards water. To overcome these drawbacks, it allows a wide variety of Modifications, as discussed in the literature. Present day commercially available Alginate impression materials have successfully incorporated some of the modifications such as addition of fillers, titanium dioxide, calcium sulfate, etc, to improvise the material.

The possible challenges that can occur in the practical scenario are high cost of incorporation of nanoparticles, defining the concentration of polymers, uniform distribution of cotton fibers. There can also be an impact on surface detail reproduction after taking impression, handling and mixing difficulties, and deciding optimal quantity of fibers. As technology advances, the most accurate impression method by digital scanning has now started to become commercial, providing the most accurate output with minimum effort.

Digital impression requires specialized software and technique learning and has started to undergo modifications to provide more accurate results. Further extensive research and technological advancement will require more time in investigation to make it more feasible for use in everyday clinical practice among a wide range of population across the globe. Until then, the potential lies in the newer modifications of existing impression materials that can be easily improvised using current knowledge and technology.

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