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Evaluation of dimensional changes in irreversible hydrocolloids and plasters that affect dental prosthetic rehabilitation

Abstract

Introduction: Poor handling of irreversible hydrocolloids (alginates) and dental plasters by dental offices, laboratory technicians, and dentists causes differences in dimensional accuracy, affecting dental prosthetic rehabilitation. To obtain optimal results, the manufacturers' instructions regarding the handling variables of each product must be followed to the letter. Are there differences in the dimensional accuracy of working models made under different handling variables?

Objective: To evaluate the differences in dimensional accuracy of irreversible hydrocolloids and plasters that affect dental prosthetic rehabilitation.

Methodology: An experimental in vitro, prospective, cross-sectional, comparative study was conducted. The variables taken into account were: High and low dimensional stability alginate, water-powder ratio of alginate, casting in type III plaster, water-powder ratio of plaster, type of water and pH, imbibition, syneresis, plaster pouring time, type of mixture. The sample size was 40 models, similar to the oral cavity with their respective teeth. A duplicate of the master model was made in alginate and these were then poured and set in type III plaster. The procedure was performed following an established protocol with the manufacturer's instructions and without following any protocol. Then, measurements of three identical pieces of the master model and the duplicate model were taken with a digital caliper. The data obtained were tabulated in Excel, and significant differences between the models were sought according to each of the established variables.

Results: The analysis of the information allowed the development of a protocol with the ideal technical instructions for handling these materials in order to optimize the processes and achieve more precise results and adaptability of the prosthetic devices in the short and medium term.

Keywords: dental prostheses, alginates, dental plaster, dimensional stability, dental impression techniques

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Introduction

There are many commercial brands of irreversible hydrocolloids (alginates) and dental plasters worldwide, each with its respective handling instructions and physical properties as indicated by the manufacturer, where the objective is to offer high-quality products for the preparation of working models for dental prosthetic rehabilitation that meet the requirements of functionality, biocompatibility and aesthetics.

To obtain optimal results, the manufacturers' instructions regarding the handling variables for each product must be followed strictly.

Hydrocolloids are elastic impression materials that form a heterogeneous mixture of two phases, where the dispersing phase is water, called *SOL,* this phase presents liquid in a continuous form, and the particles are isolated from each other. The other phase of the hydrocolloids is called *GEL*, in which the particles form a network of fibrils that are held together by secondary molecular forces, giving rise to a semi-solid solution.

Alginate used for dental impressions in the oral cavity is part of the irreversible hydrocolloids, polymers of organic origin extracted from seaweed, where the active ingredient is sodium or potassium alginate, in addition the powder has incorporated calcium sulfate as a reagent, zinc oxide and diatomaceous earth as filler particles, potassium titanium fluoride as a plaster hardener and sodium phosphate as a retarder.[1] In Alginate the transformation from the sol phase to the gel phase occurs by a chemical reaction, the dimensional instability of these materials is mainly due to the phenomena of syneresis and imbibition that occur within them. Syneresis occurs when the gel loses water on the surface, due to evaporation or exudate of the liquid, which produces contraction. Imbibition occurs if the gel lacks water and is placed in contact with it, because it absorbs water and therefore swells or expands, until it recovers its original content.[1] In addition, dimensional changes may occur, that is, changes in its physical form due to different factors such as: emptying time, storage[2] and the addition of disinfecting agents or something as simple as the dosage there of, that is, varying the powder/liquid ratio indicated by the manufacturer when mixing the Alginate with water.

Dental plaster is a mineral chemically formed by dihydrated calcium sulfate. $CaSO_4.2H_2O$. Various types of plaster are used to make molds and models on which dental prostheses and restorations are built. Plaster models in prosthetic rehabilitation must have the following properties: accuracy and precision: they must faithfully reproduce the patient's intraoral condition without any distortion. Dimensional stability, not expanding or contracting over time due to water loss. Micro-surface hardness to resist scratching during preparation of the final restoration. Mechanical and wear resistance. To withstand the force of manipulation during laboratory procedures,[3] compatibility with impression materials, and reduced cost, as it is an auxiliary material in the process of making dental prostheses. Furthermore, they

must set quickly, allowing time for handling, accurately reproduce the details of the impression negative, and have the appropriate strength for the jobs for which they are intended. Several variables influence the handling of plasters, such as setting time, water-to-plaster ratio, spatulation, and temperature, which will determine the strength of the final product and dimensional stability.

According to the American Dental Association (ADA), the classification of dental plasters are type I impression plaster, type II model plaster, type III stone plaster for all types of working models, type IV is characterized by its strength, low expansion and hardening, type V the newest, has high compressive strength.[4]

Considering that working models must be exact reproductions of oral structures for successful dental prosthetic restorations, every effort must be made to achieve the best dimensional accuracy with the material used. Therefore, the following research question is posed: Is there a difference in the dimensional accuracy of working models made under different handling variables?

The main reason for carrying out this research project is to establish, from a scientific and technical perspective, that the dimensional accuracy required for working models to replicate oral structures is of utmost importance and precision for the successful rehabilitation of oral medical devices (dental prostheses). When performing a dental prosthetic rehabilitation, it is necessary to make good use of impression materials, in this case irreversible hydrocolloids (alginates), these provide the negative of the prosthetic structures, also dental plasters, which provide the positive of the dental prosthetic structures, the latter are essential, on them the preliminary and definitive bases of the different oral medical devices are made.

The academic scope of this project is to raise awareness in the dental and laboratory sectors of the importance of following manufacturers' protocols and instructions when handling these materials. Therefore, this process should not be distorted, as it constitutes the scientific basis that guarantees the handling and quality of the final product.

The objective of this research is to evaluate the differences in dimensional accuracy between irreversible hydrocolloids and plasters that affect dental prosthetic rehabilitation. The project was funded and approved by the Central Research Committee of Visión de las Américas University Institution and was considered minimal-risk research. Acceptance code P211-2023.

Materials and methods

An in vitro, prospective, cross-sectional, comparative experimental study was conducted. Models similar to the oral cavity were used. Data were recorded as events occurred, and variables were studied simultaneously at a given time point, with a time interval. In addition, comparisons were made of the results obtained according to the variables studied.

The variables taken into account in this research were the following: Alginate with high and low dimensional stability, Alginate water-powder ratio, casting in type III plaster, plaster water-powder ratio, type of water and pH, imbibition, syneresis, plaster casting time, type of mixture.

The sample size to be worked was 40 models, similar to the oral cavity with their respective teeth. The master model was duplicated in alginate and then poured and set in type III plaster, according to each of the established variables. This procedure was performed first following an established protocol with the manufacturer's instructions and second working without following any protocol. Three identical pieces of the master model and the duplicate model were then measured with a digital caliper.

The data obtained were tabulated in Excel, and significant differences were determined for each model and variable of interest. After collecting all the observations of the variables measured during the process, the respective analysis of the study variables and their influence on dimensional changes in irreversible hydrocolloids (alginate) of high and low stability and casting in type III dental plasters was performed.

Results

Dimensional Change: The change is considered significant when there is a variation in the measurement of the parts of 500 microns.

In the duplicate models, there was a non-significant increase in the dimensional change of the pieces measured with each variable (Table 1 & 2).

Table 1 Results following a protocol established by the manufacturer

Alginates of high and low dimensional stability, cast in type III dental plaster		
Variables		**Observations**
Type of water	Normal	Creamy alginate mix, easy to handle, in the plaster the mix was creamy and had good consistency
	Distilled	The Alginate mix was drier and difficult to manipulate, while the plaster mix was creamy and easy to manipulate.
pH of the water	Normal	The pH measurement was always at 5
	Distilled	The pH measurement was always at 6
Imbibition		Negative bubbles in the alginate and adhesion to the tray
Syneresis		Alginate lost color and looked more opaque
Mixture Type		Manual mixing for 10 seconds followed by a vacuum mixer for 20 seconds

Table 2 Results without following a protocol established by the manufacturer

Alginates of high and low dimensional stability, cast in type III dental plaster		
Variables		**Observations**
Type of water	Normal	Creamy mixture of the Alginate and easy to handle and by not taking into account the water it could become very fluid, in the plaster the mixture was creamy and had good consistency
	Distilled	Creamy mixture of the Alginate and easy to handle and by not taking into account the water it could become very fluid, in the plaster the mixture was creamy and had good consistency
pH of the water	Normal	The pH measurement was always at 5
	Distilled	The pH measurement was always at 6
Imbibition		The copy model came out with negative bubbles
		The alginate tube adhered to the tray
Syneresis		Alginate lost color and looked more opaque
mixture type		Manual mixing for 10 seconds followed by a vacuum mixer for 20 seconds

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In the duplicate models, there was a greater non-significant increase in the dimensional change of the pieces measured with each variable in relation to when the protocol was followed.

Significant differences were found in the measurements of the duplicate model parts, such as the imbibition and use of distilled water.

After creating the plaster models under conditions that followed a protocol established by the manufacturers and without following a protocol, the research group proceeded to develop the following technical protocol for taking alginate impressions and casting them in type III dental plaster. This was done to achieve more accurate prosthetic restorations.

Impression taking and plaster casting protocol type III

Preparing the impression material

Alginate

1) Measure the water with a graduated cylinder and the powder with a scale, following the manufacturer's instructions.
2) If there are no indications, consult specialized literature.

Mixing the Alginate

1) Carefully and gradually add the powder to the water.
2) Mix with a flexible metal or plastic spatula, adapting it well to the sides of the cup.
3) Make figure-8 movements and gently rub or tap the cup to prevent the incorporation of bubbles.
4) Respect the mixing time recommended by the manufacturer, generally **45 to 60 seconds.**
5) The result should be a smooth, creamy mixture that does not drip when you lift the spatula.

Equipment

1) Use separate cups to mix Alginate and plaster.
2) Weigh the powder with a scale, avoiding measuring by volume with spoons.

Impression taking

Selecting the buckets

1) Prefer perforated metal buckets.
2) If using plastic buckets, apply a thin layer of bucket adhesive.

Time in the mouth for impression

1) Leave the impression in your mouth for at least **3 minutes after gelation**.
2) Avoid longer times to prevent significant distortions.

Preparation of the plaster

Dosage

1) Measure the water with a graduated cylinder and the powder with a scale, following the manufacturer's instructions.
2) In the absence of indications, use the ratio recommended in the literature: **100 g of powder per 30 ml of water**.
3) Do not rely on volume measurements due to uneven packing of powder.

Mixing the plaster

1) First, place the water in the cup and then add the powder carefully to avoid lumps.
2) Mix manually for **15 seconds** and then **20-30 seconds under vacuum** to avoid incorporating bubbles.

Equipment

1) Use a smooth, abrasion-resistant parabolic cup.
2) Use a stiff spatula with a comfortable handle.

Pouring the plaster

Supply of plaster

1) Place the bucket against a vibrator, keeping the surface free of excess water.
2) Use a small spatula to fill cavities with smooth movements.
3) Increase the amount of plaster once the cavities are completely filled.

Setting time

1) Allow the plaster to set for **45 to 60 minutes** before handling.

A protocol is carried out according to the literature on dental biomaterials.

Discussion

The poor handling of irreversible hydrocolloids or alginates and dental plasters by dentists, dental practices, and dental laboratories results in dimensional accuracy discrepancies that affect dental prosthetic rehabilitation.

In alginates, the water-to-powder ratio and mixing time significantly affect the tear resistance and elasticity of the irreversible gel. It is essential to measure the alginate powder and water and mix according to the proportion indicated by the manufacturer on the product box or bag. Different proportions of powder and water could not guarantee the maintenance of the physical-chemical characteristics declared by the manufacturer.[5] Dental alginate is presented as a powder to be mixed with water in proportions that have been provided by the manufacturers. Certain measures, such as a scoop for the powder and a graduated beaker for the water, are provided with each commercial product to facilitate handling. The powder/water ratio varies between different companies, resulting in a variation in the viscosity of the mixture produced, being thick and with high viscosity in some products, while others have a lower viscosity.[6] In addition, it is necessary to know the type of mixture; this can be manual, semi-automatic, and automatic. The latter is the most advanced and significantly reduces the number of bubbles that form within the mixture, reducing defects in the impression and plaster models, and resulting in more precise prostheses.

The dimensional stability of the alginates was another variable taken into account in this study. Those with high dimensional stability have high elasticity and great resistance to breakage, a more homogeneous consistency and a more faithful reproduction of details.[7] We worked with alginates of high and low dimensional stability; when the manufacturer's instructions were followed, in the duplicate models there was a non-significant increase in the dimensional change of the pieces measured with each of the variables. However, when a

protocol was not followed, significant differences were present in the measurements of the pieces of the duplicate models, as was the case with imbibition and the use of distilled water.

The type of water used in the mix was another variable studied; both normal and distilled water were used. Normal water contains metallic ions of calcium and magnesium, which give it hardness. If this water has a high hardness, it can accelerate the setting of the alginate. Sodium alginate is difficult to dissolve in hard water because it contains calcium ions. Therefore, it is recommended to use distilled water; it does not contain metallic anions or cations, is free of impurities, and the absence of minerals contributes to a neutral pH and does not alter the gelation reaction. In this study it was observed that when Alginate was mixed with distilled water in the process where a protocol of measured quantities was followed, the Alginate mixture was drier and difficult to handle, while when the proportions of water were not respected the mixture was more fluid and easier to handle because the amount of water was controlled according to the fluidity of the paste.

The pH of the water was another variable under consideration in this study, the water used both normal and distilled had a slight acidity, Acidic pH levels cause molecular depolymerization of the gel and a loss of its strength. However, low temperatures slow down the setting process;[8] in this case, pH had no impact on the consistency of the alginate mixtures.

In the case of dental plasters, the setting time varies depending on factors such as the water/powder ratio, the speed of the spatula, the temperature of the water used in the mixture, and the humidity.

Type III plaster of Paris is preferred for models used in the making of dental prostheses, as it has sufficient strength, is also porous and the higher the water/powder ratio, the greater the porosity and the lower the compressive strength of the set material, because there are fewer dihydrate crystals available per unit volume.[1] It is essential to obtain a strong, accurate and hard model to provide resistance against breakage, avoid deformations and abrasion of the model surface during manufacturing, handling and its articulation.[3]

It is also recommended to store the plaster powder by sealing the material in a moisture-proof metal container, the material absorbs moisture from the air and would prolong the setting time.

A study found that the water-plaster ratio and troweling are operator-dependent factors. In the water-plaster ratio, the greater the amount of water, the lower the number of crystallization nuclei, and therefore, the longer the setting time. In spatulation, the greater the amount of spatulation, the greater the number of crystallization nuclei and the shorter the setting time, because the first nuclei formed break and divide into two. If setting time is to be shortened, this is changed, not the water-plaster ratio. It is essential to understand the correct handling of the proportions and manipulation of the plaster to avoid changes in its physical and mechanical properties. It was found that the proportions indicated by the manufacturer provide a balance with respect to the properties analyzed in the research.[9]

Multiple studies have shown that the properties of dental plaster depend on the variables mentioned above. However, it is known that dentists, dental laboratory technicians, and students do not always take these factors into account when handling plaster. **Students** surveyed in one study reported having little knowledge of recycling, handling, and the characteristics of plaster at the time of use, as well as potential health conditions associated with its use.[10]

The plaster can be mixed with water manually or using a mechanical vacuum mixer, according to the manufacturer's instructions. Vacuum mixing enhances the strength and hardness of the plaster. In this study, manual mixing for 10 seconds followed by a vacuum mixer for 20 seconds resulted in more precise, bubble-free models.

When the imbibition variable was taken into account, due to the amount of water absorbed, the duplicate models showed adherence to the tray and the plaster models came out with negative bubbles.

In this study, when a protocol established by the manufacturers of both products was followed, the duplicate models had a non-significant increase in the dimensional change of the pieces measured with each of the variables studied.

It is recommended to take measurements of the duplicate models with a scanner to have a more accurate value of the measurements obtained.

Conclusions

The dimensional stability of plaster models is key to producing well-fitting, functional, and aesthetic dental prostheses.

In the present study, it was determined that there are no significant differences in the results obtained on the dimensional accuracy of the master models and the duplicate models in alginates of high and low dimensional stability cast in type III plaster, when the protocols established by the manufacturers were followed.

Manufacturers' recommendations should always be followed when handling irreversible hydrocolloids and plasters. Failure to do so can result in significant differences in the measurements of duplicate casts, which can affect prosthetic rehabilitation.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

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