Gutta-percha cones: properties for current endodontic practice

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ABSTRACT

Objective: The objective of this study was to identify the types of gutta-percha for obturation and their forms of presentation, as well as physical-chemical and biological characteristics of the material. **Materials and Methods:** Articles were selected from the PubMed and Science Direct databases, published between 1973 and 2016. Were used as descriptors: "gutta-percha and obturation"; "cones of gutta-percha" and "obturation cones and endodontic". **Review**: Gutta-percha is a material of organic origin, which can be found in two crystalline forms. It is usually found in the form of cones composed of gutta-percha associated with other substances. Gutta-percha is considered inert and biocompatible, because it causes little allergic reaction and slow biodegradation. It can suffer physical-chemical changes when used in thermo-obturation techniques, where the high temperatures accelerate its degradation, compromising its function. In addition, its early degradation is also affected by the presence or absence of periapical lesions. **Conclusion:** Gutta-percha Cones are still considered the most suitable and accessible material for root canal filling.

Keywords: Gutta-Percha. Root Canal Obturation. Endodontics.

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INTRODUCTION

After the chemical-mechanical preparation, the obturation aims the three-dimensional and hermetic sealing of the root canal system. The filling of all the space formerly occupied by the pulp tissue is intended to prevent microorganisms which may have survived the mechanical chemical preparation from being able perpetuate an infectious process. In addition, it prevents the remaining necrotic tissues and toxins from coming into contact with living tissue that may irritate the site.[1-5]

There are many kinds of materials proposed to perform the root canals obturation. The gold standard is to use gutta-percha cones associated with a sealer applied in many different techniques. Some studies have been developed with the aim of finding a material that presents better properties than gutta-percha. These materials must have greater adhesion on the walls of the canals, better antimicrobial activity and more stability and resistance to thermal and biological degradation.[6,7,8,9,10] Trying to overcome those characteristics there are some new materials being studied: the self-adhesive guta-percha,[9] the guta-core system, which uses a polyethylene core wrapped with gutta-percha[11] and resilon (synthetic thermoplastic polymer) containing bioactive glass, bismuth oxychloride and barium sulfate.[12] However, despite the efforts of the researches for finding a new material more biocompatible, a substitute that is capable of overcoming the physical-chemical qualities of gutta-percha as a sealing material has not yet been achieved.[3,13,14,15] The search for techniques and materials that results in three-dimensional, safe, effective, predictable and reversible obturation, is still a challenge.[3,16,17]

The obturation with a sealer and gutta-percha cones applied by lateral and vertical condensation techniques is widely used by clinicians. In the United States, 62% of dental surgeons use the technique of condensation obturation. Amount that 96% uses gutta-percha as obturation material.[18] Therefore, this work aims to produce a literature review on gutta-percha cones and its characteristics, verifying the compatibility of its properties with the different techniques of obturation currently proposed in daily clinical practice.

MATERIALS AND METHODS

Articles were selected from the PubMed and Science Direct databases, published between 1973 and 2018. Were used as descriptors "gutta-percha and obturation"; "cones of gutta-percha" and "obturation cones and endodontic". The inclusion criteria was articles that addressed the use of gutta-percha in the endodontic practice. The exclusion criteria was articles not involving endodontic area. The studies analyzed were case reports, review articles, research articles with endodontic materials and technique tested in laboratory, animals or humans.

REVIEW

The use of gutta-percha in dentistry began in 1847, when Hill used it as temporary restorative material. In 1867, Bowman was the first to use it as a root canal sealing material. Twenty years later, S.S. White was the pioneer in the market of gutta-percha cones. However, only in 1976, Ingle and Levine, proposed a standardization of the obturation materials, that are still used nowadays.[19]

Gutta-Percha

Origin

Gutta-percha (GP) is obtained by the coagulation of latex, extracted from *Palanquium* or *Payena* trees, a genus of the *Sapotaceae* family native from Southeast Asia. Another type of similar material is gutta-balata or Suriname gutta-percha. This type of GP can be obtained by the tree *Mimusops globsa*, found in South America. It has a larger amount of resin than the true GP. These two types of gutta are considered essentially identical by the similarity of the physical and chemical characteristics. There are others, less used, substitutes extracted from *Sheabutter tree* (West Africa), *Dyera costulata* (Malay), *Maytenus phyllanthoides* (Mexico), *Calatropis giganlea* (India) and *Manilkara species* (Balata lower type in South America).[19]

Composition

GP is an organic polymer of methylbutadiene or isoprene. It is formed by a chain of atoms joined by covalent bonds. The chains are long, and range in molecular weight from 10^4 to 10^6 $g.mol^{-1}$.[20] The size and arrangement of the molecules in the chain are determined by the forces of attraction between them, known as the Van der Waals force. These interactions modify the characteristics of the polymers, creating specificities for each type of chain.[21] In its natural state gutta-percha has a white shade and is rigid and solid at 25° C. It has a melting point around 100° C.

Rubber and GP are considered isomers because they have the same molecular formula, but their structures are different. The difference in the arrangement of the atoms is responsible for the change in the mechanical and thermal properties of the polymers. Rubber is considered a 1.4-cis-polyisoprene and has CH_2 groups on the same side as the double bonds. GP is a 1.4 trans-polyisoprene and has the CH_2 groups on opposite sides of the double bonds.[7,19,21,22,23]

The "cis" rubber chain is a more undulated chain, which gives it the peculiarities attributed to the elastomers. The "trans" type of GP is more linear and crystallizes more rapidly, which makes it more rigid, friable and less elastic than rubber, and behaves similarly to crystalline polymers.[22]

The temperature affects the physical state and the arrangement of linear chains polymers. Above 30° C, it becomes malleable and at sufficiently high temperatures (around 60° C) the GP becomes melted and the molecules can be seen as serpentines, changing orientation, as a result from thermal excitation.[7,19,22,23]

Crystalline Form

In 1942, C. W. Bunn, found that GP has two crystalline forms: alpha and beta. The two forms differ only by the bond configuration and by the repeating distance of the molecule CH_2-CH_2 in the chain.[21] The forms, orthorhombic beta and monoclinic alpha, can be visualized in the following Figure 1.[8]

The crystalline form of alpha GP is the most stable, and therefore, it is found directly in nature. If heated until around 65° C it becomes an amorphous and softened substance. When cooled slowly, by less than 0.5° C per minute, it recrystallizes in the alpha form.[23] It is important to be careful in the thermoplastic filling techniques to avoid temperatures above 65° C (Fig 2), preventing the transformation of GP alpha into an amorphous substance and without adequate sealing characteristics.[25,26]

In dentistry the beta GP form is the most used. It is found in the traditional obturation cones fabricated according to ISO standardization and commercialized by Tanari (Brazil), Dentsply (EUA), VDW (Germany), among others. This form of GP is the most commercialized because of its advantages on flexibility and stability, that allows the material to have a more standardized quality, but the alpha form has better properties for thermal filling techniques.[24]

Gutta-Percha Cones

Composition

GP cones are produced by mixing organic (15.7 to 26.7%) and inorganic (54.3 to 84.3%) substances, which gives them unique characteristics, according to the ratio established by the manufacturer.[23,24,27,28,29]

The organic part consists GP, waxes and resins. The inorganic part is composed by zinc oxide, which acts as a bactericide, and as a radiopacifier along with barium sulphate.[8] Some cones also add dyes and antibacterial substances such as calcium hydroxide, chlorhexidine and iodoform. The higher the amount of zinc oxide present in the cone, the more rigid and brittle it becomes.[22]

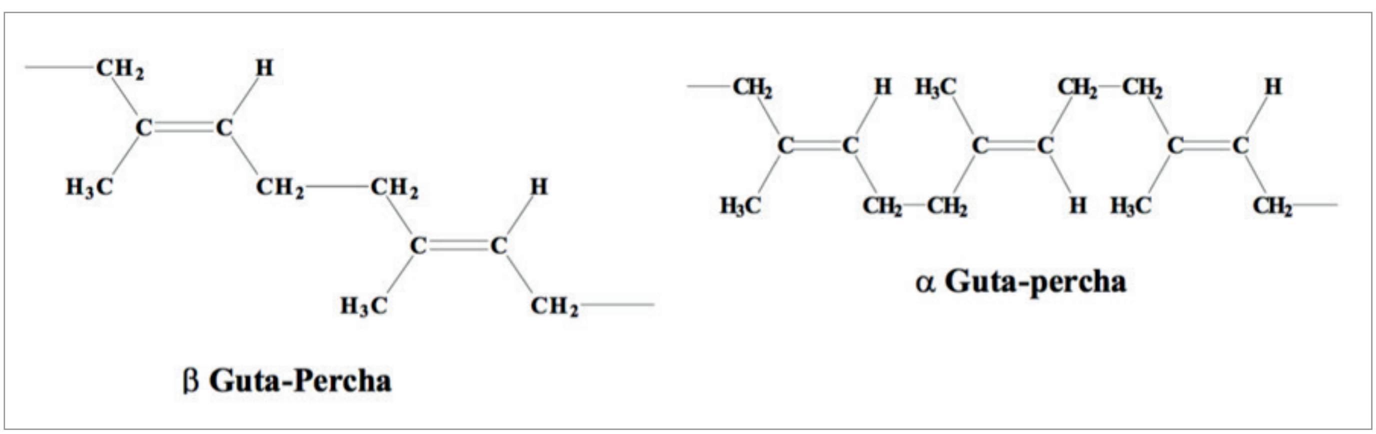

Figure 1. Crystalline Form of Alfa and Betha of Gutta-Percha.

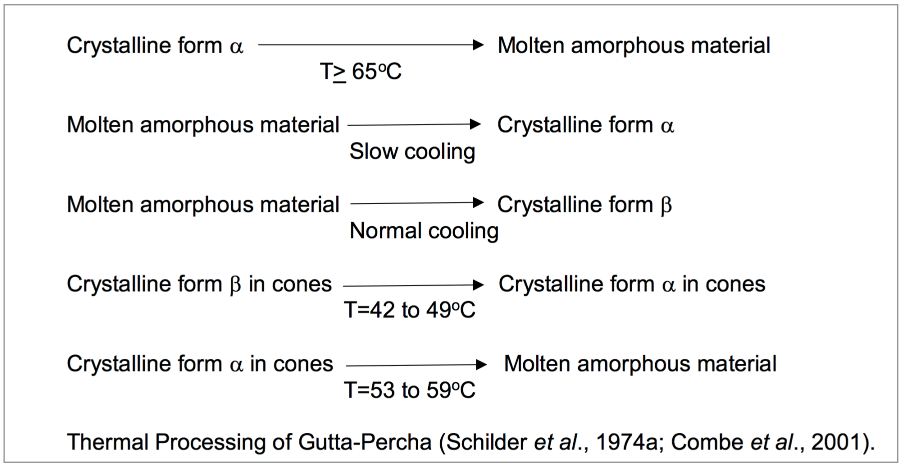

Figure 2. Thermal transformation of Gutta-Percha.

Thermal characteristics

The temperature variation required to transform the crystalline alpha form into beta, and vice versa, can cause volume changes in the GP cones, which is sometimes irreversible. This temperature can be altered by molecular weight, purity, composition, mechanical and thermal history and degrees of crystallization.[21] Cones containing other substances besides GP have different temperatures in the transformation of the alpha and beta phases compared to gutta-percha alone, which may alter the clinical protocol chosen by the dental practice.[20,21] Different sealing techniques can be used: vertical compaction, thermal condensation with condenser, thermal with electric condenser, thermoinjectable seal and etc. These techniques should be chosen according to their efficiency in the obturation of root canals and causes no alteration of the physical-chemical properties of gutta-percha.[3]

The cones with GP in beta form were produced to achieve clinical needs focused on cold filling techniques, such as lateral condensation, because they have low compressive strength. When compressed these cones deform easily, filling the internal voids of the root canals, without diminishing the intermolecular distances of the polymer. The GP will remain stable, without returning to its initial form when the compression stress disappears.[16,21,22,25] A cold filling technique is valid for endodontic filling because it is effective and accessible, and it is still the most commonly used obturation technique in dental practice.[18]

With the advent of thermal obturation techniques, the companies began to produce cones with GP in the alpha form, which becomes sticky and viscous when heated.[25] They are commercialized as cones for thermoplasticity by VDW or Dentsply brands, or in systems such as Thermafil. However, to have stability and flexibility, components are added to the cone, that alter its thermal behavior when compared to pure GP alpha.[25] Another form of presentation of the GP alpha is in sticks, which are most commonly used for temporary obturation techniques.

In thermal obturation techniques GP cones, in the alpha or beta form, when heated, expand and contract as they cool down.[30] Since the cones have high thermal expansion, after being heated, they must be compacted and maintained under pressure to compensate the volumetric variations. If that doesn't occur it can result in a lack of sealing of the root canal. The compacting shortly after heating, as well as removal of the material in the coronary area, assists in the hermetic sealing of the canals.[3,22,30] The cones plastification occurs only at a distance of 3 to 5 mm from the distance of the heat source.[31,32] However, a more recent study[33] with infrared thermography showed that the GP cones carry the heat irregularly and, in order to be effective in plastification, the heat source must be 1 to 2 mm of the desired area.

This interferes with the methodology of the obturation techniques currently applied, such as the techniques of continuous waves and other techniques that use as basis the thermo-obturation. The temperature variation required to transform one crystalline form into the other can cause changes in volume, which is sometimes irreversible. The change from beta form to alpha determines the plastification characteristics of the obturation material.[30,31,33] As GP is a thermal isolator, the cone turns into a poor conductor of heat. This feature allows the periapical tissues not to be damaged, but also does not allow the cone plastification in places of difficult access.[22,33]

In thermoinjectable obturation techniques, there is considerable contraction of gutta-percha after cooling (0.96 to 2.31%), which can be partially compensated by the sealer and the compression after injection.[30] However, the gutta-percha can take up to 10 minutes to cool completely, allowing volume variation of the material. In addition, the authors concluded that thermal conductivity is directly related to contraction after cooling, because, the results where gutta-percha reached the highest temperature also had the highest percentage of material contraction.[30]

Besides this study, it has been found that GP cones in contact with sealers based on zinc oxide and eugenol expand. And the expansion is due to the presence of eugenol in the composition. Using a sealer with a proportion of one part zinc oxide to three parts of eugenol after one month, the GP cone volume increased up to 20%. Therefore, it is important to verify the relation of the GP cones with the sealer, due to its influence on the sealing effectiveness of the root canals.[34]

Biocompability and alergic reactions

In addition to presenting physic-chemical characteristics suitable for use as a sealing material, GP cones are biocompatible and are not reabsorbed.[22] Although they are considered inert, there are some cases of allergic reaction to Hevea latex protein, that belongs in the composition of GP. In one study the presence of levels below 40 ng/g of this protein in synthetic trans-polyisoprene GP cones (Dentsply, Diadent, VDW) was present, which represents a minimal risk for patients with sensitivity to Hevea latex IgE. Regarding the cones with gutta balata extracts (Odous de Deus), the same authors verified that they contained levels of proteins that were reactive to the specific allergen of the Hevea latex IgE antibody, which could produce an allergic reaction.[35] In contrast, another study performed in vitro with gutta-percha and gutta-balata resulted in the unlikely occurrence of any allergic reaction due to the use of cones in patients reactive to latex protein.[36] Althought the GP cone stays inside the root canal, there is a comunication with the periapical tissues.

Cones Degradation

The oxidation of GP is a relevant reaction to be considered in the clinical procedure of the root canals obturation. It can occur in physical form, by solar radiation, air and temperature, or by chemical reactions, when in contact with water, acids, oxygen and others. Early oxidation can occur when in contact with the action of biological agents, such as fungi and bacteria.[8]

Degradation may occur due to contact with body fluids. Even though there is no coronary infiltration or caries associated with endodontic treated teeth, GP is in contact with body fluids through the periodontal ligament, where occurs the aging process of the cones over time.[37]

In addition, some studies are suggesting that there are bacterial species associated with degradation of the obturation material. Species such as *Pseudomonas aeruginosa* have been found to use cis-polyisoprene as a substrate[38] as well as the species *Streptomyces, Actinoplanes* and *Methylibium*, gram-negative bacterias, which degrade cis-polyisoprene.[39] Both studies were performed with the cis-1,4 form, polysoprene, natural rubber. In one study it was found that the species *Actinobacteria* (*corynebacterium, mycobacterium* and *nocardia*) were able to degrade GP (trans-polyisoprene). The authors concluded that there are species that degrade natural rubber (cis-polyisoprene) but do not have the same action on GP. However, they observed that all species that can degrade GP also degrade natural rubber.[40]

Periapical lesions induce early onset and potentiate the oxidation process by providing an environment where there is a large flow of body fluids, composed by bacteria, enzymes, cells and microorganisms, because of the infection. Besides the degradation of the rubber (trans-1,4-polyisoprene), the ZnO dissolves when in contact with blood and tissue fluids.[8,41] The reduction of the zinc oxide and GP mass allows the formation of voids that may allow reinfection of the root canal, and failure of endodontic treatment.[42]

An in vivo study showed that there was a considerable loss of mass in teeth with endodontic treatment, without periapical lesion after 15 years, and a more pronounced degradation in teeth associated with periapical lesions, where there was a significant degradation after only 5 years.[17]

Gutta-Percha Cones Standartization

In order for GP cones to be sold, there are rules that companies must follow. Standards are dictated by the ISO (International Organization for Standardization) and by the American Dental Association (ADA).[43,44]

The cones must be at least 28 mm long, and their tip must have diameters in accordance with the standard established by ISO. According to the ISO 6877/2006, the tip diameters should vary from 10 to 140, which are equivalent to 0.10 to 1.40 mm in diameter at the tip, following the tip gauge of the endodontic files.[42] The accessory cones doesn't have a diameter or taper pre-defined by the standard, these must be established by the manufacturer, but must follow the maximum variation of the diameter size. For GP cones the tolerance for the variation of the measured diameters should be a maximum of ± 0.05 mm for tips of 10 to 25 and of ± 0.07 mm for tips of 30 a 140.[43] One problem is that the tolerance diameters variations defined by the standardization is different from what is required for the tolerance of the file diameters (+- 0.02 mm) and gutta-percha cones (± 0.07 mm). For a cone size 30, the size variation between the cone and the file can reach +- 0.09 mm, that is, a variation of up to two ISO files, interfering in the adaptation of the cone in the root canal.[45,46]

In order for standardization measures (ISO 6877/2006) to be respected, cones must pass quality tests. Ten cones are chosen randomly by the manufacturer and the test is performed according to the standardization methodology, where all 10 cones must be approved. If only eight reach the standards, the product is not accepted, if 9 are suitable, 5 more cones are selected, and all of them must be correct. Cones shall be measured in an apparatus having an accuracy of at least 0.005 mm.[43]

Just like the files, the cones are standardized in three series (15-40, 45-80, 90-140), and they follow the same colors of the instruments (white, yellow, red, blue, green and black).[43] Another important feature is the taper of GP cones. Taper refers to the increasing of the diameter every 1 mm far from the tip. According to the ISO standard, the taper should increase 0.02 mm every millimeter (taper = 2%), being uniform up to the 16 mm length of the cone. If the taper is determined by the manufacturer, which is very common in current rotary systems, the cones receive distinct colors defined by the manufacturer.[43]

Conclusion

In clinical practice it is very important that we know the physical-chemical properties of the materials used in routine procedures. This knowledge is important so that decisions are made in order to obtain excellence and longevity of the endodontic treatment. Gutta-percha is a material with important properties for root canal obturation and is still considered gold standard in this area. In order of that, the acknowledge of its properties is essential to choose the best suitable obturation technique in the endodontic practice.

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