Introduction

The ultimate goal for obturation is to achieve a fluid-tight seal throughout the root canal system. Endodontic sealers are considered an integral part in the obturation phase. Sealers help prevent leakage, which reduces the possibility of residual bacteria from the canal to invade the periapical tissues. An ideal root canal sealer should provide an excellent seal when set, exhibit dimensional stability, and a slow setting time to ensure sufficient working time. Insolubility to tissue fluids, adequate adhesion with canal walls, acceptable flow and biocompatibility are indispensible properties for root canal sealers.

Dimensional stability and flow are essential physicochemical properties of a root canal filling material. Shrinkage of endodontic sealers might cause gaps along the sealer/dentin or sealer/gutta-percha interface which will be harboured by microorganisms. Adequate flow of sealers ensures the filling of residual unfilled spaces within the root canal system.

The sealing ability is affected by the adhesive qualities of root canal sealers to the dentin walls and to gutta-percha. This is an important property for maintaining the integrity of the canal seal which in turn reduces apical microleakage.

During endodontic therapy the apical limit of the filling and the nature of the sealing material used are of fundamental importance for an ideal biological response. At the end of endodontic treatment the repair process starts. It is characterized by cell proliferation and formation of an organic matrix resulting in root apex sealing when the process is not interrupted. During this initial phase the irritant potential of the sealer may retard or even prevent repair. Thus, a biocompatible sealer that is not harmful to the periapical tissues should be used.

Nowadays, various kinds of endodontic sealers are available, including sealers based on glass ionomer, zinc oxide–eugenol, resin, calcium hydroxide.

Recently, bioceramic-based materials containing calcium silicate and/or calcium phosphate have attracted considerable attention. Bioceramic based sealers exhibit physical and biological properties such as alkaline pH, chemical stability within the biological environment, and lack of shrinkage. They are also nontoxic and biocompatible. It has been reported that a recently introduced premixed bioceramic endodontic sealer (Endosequence BC) showed favorable properties. It is composed of zirconium oxide and calcium silicate, and utilizes moisture within the canal to complete its setting reaction.

Therefore conducting a study to evaluate the sealing properties and biocompatibility of the recently introduced bioceramic BC root canal sealer was thought to be of value.

Review of literature

I- Physical Properties of root canal sealers:

A-Dimensional changes and Flow:

Dimensional stability for root canal sealers is a prime requirement. Neither shrinkage nor expansion is desirable. Shrinkage produces slits and passageways for bacteria and their products; expansion may create forces threatening to cause infractions and fractures in dentin. The flow of endodontic sealers may determine how effectively they obturate the accessory canals and voids between the filling core and dentine wall. Whereas adequate flow ability allows for the filling of irregularities. On the other hand, high flow may result in apical extrusion, leading to injury of the periapical tissues because of the cytotoxicity of the sealers.

Ørstavik etal [(1)] evaluated a method proposed for measuring dimensional changes of endodontic sealers, and to assess the dimensional changes of 11 commercial sealers after prolonged storage in water.

The method for linear dimensional change described in the draft standard for endodontic sealers was applied to 11 different types of endodontic sealers. The sealers showed markedly different dimensional properties. For most materials, the greatest dimensional changes took place within the first 4 weeks. Zinc-oxide-eugenol based sealers generally showed shrinkage ranging from 0.3 to 1%, while one product (Proco-Sol) exhibited expansion exceeding 6% after prolonged storage. The epoxy-based materials, AH 26 and AH 26 silverfree, exhibited a large, initial expansion of 4-5%. AH Plus expanded from 0.4% after 4 weeks up to 0.9%. Apexit, a Ca(OH)2-based material, showed only minor variation round baseline value, -0.14 to +0.19%. Roeko-Seal expanded to 0.2% within 4 weeks, but was stable thereafter.

Based on the results the author concluded that theoretical approaches to the consequences of expansion by materials of low bulk strength question the necessity of a strict requirement against expansion, whereas bacterial penetration may be a real threat from sealers shrinking as little as 1%.

Schäfer and Zandbiglari [(2)] compared the weight loss of eight different root-canal sealers in water and in artificial saliva with different pH values. For standardized samples (*n* = 12 per group), ring moulds were filled with epoxy resin (AH 26, AH Plus)-, silicone (RSA RoekoSeal)-, calcium hydroxide (Apexit, Sealapex)-, zinc oxide–eugenol (Aptal-Harz)-, glass-ionomer (Ketac Endo)- and polyketone (Diaket)-based sealers. These samples were immersed in double-distilled water and artificial saliva with different pH values 7.0, 5.7 and 4.5 for 30 s, 1 min, 2 min, 5 min, 10 min, 20 min, 1 h, 2 h, 10 h, 24 h, 48 h, 72 h, 14 days and 28 days. Results showed that most sealers were of low solubility, although Sealapex, Aptal-Harz and Ketac Endo showed a marked weight loss in all liquids. Even after 28 days of storage in water, AH 26, AH Plus, RSA RoekoSeal, and Diaket showed less than 3% weight loss. At exposure times greater than 14 days, Sealapex showed the significantly greatest weight loss of all sealers tested . Aptal-Harz and Ketac Endo were significantly more soluble in saliva (pH 4.5) than in water. AH Plus showed the least weight loss of all sealers tested, independent of the solubility medium used.

Versiani etal [(3)] evaluated the setting time, solubility and disintegration, flow, film thickness, and dimensional change following setting in a dual-cured resin root canal sealer Epiphany compared with an epoxy-resin-based sealer AH Plus.

The experiments were performed according to ANSI/ADA Specification 57 which tests the physicochemical properties of endodontic sealing materials. Five samples of each material were tested for each of the properties. In addition, deionized distilled water from the solubility test of Epiphany was submitted for analysis of the cations Fe, Ni, Ca, Mg, Zn, Na, and K in an atomic absorption spectrometer.

Results showed that setting time, flow, and film thickness tests for both cements conformed to ANSI/ADA standards. Dimensional alteration test for both cements were greater than values considered acceptable by ANSI/ADA. Epiphany values regarding solubility were also greater than values considered acceptable by ANSI/ADA.

Carvalho-Junior et al [(4)] studied the solubility and dimensional change that occur after setting of two different root canal sealers (Endofill and AH plus) on the basis of American National Standard Institute/American Dental Association (ANSI/ADA) Specification No. 57. The volume, mass and density of the test samples were determined. For the solubility test, samples were weighted, stored in distilled and dionized water for 24 hours, dried, and weighed again. Solubility was calculated by using samples' weight loss (%). For dimensional change analysis, the samples' heights were measured before and after immersion in dionized water for 30 days. Results showed that Endofill sealer presented higher solubility values than AH Plus. The Endofill sealer presented 0.56% of shrinkage and AH Plus 0.62% expansion. Smaller dimensions for test samples used in solubility and dimensional change tests are a viable alternative, decreasing the amount of filling material necessary for executing these tests.

Marciano et al [(5)] evaluated the radiopacity, solubility, flow, film thickness, setting time, and adaptation to the root canal walls of 3 epoxy resin–based sealers: AH Plus, Acroseal, and Adseal. Physical tests were performed following American National Standards Institute/American Dental Association's requirements. For interfacial adaptation analysis, 30 maxillary canines were shaped by using ProTaper instruments. The specimens were divided into 3 groups (n = 10): group 1, AH Plus; group 2, Acroseal; and group 3, Adseal. The sealers were mixed with rhodamine B dye, and the canals were filled by using the lateral compaction technique. The percentage of gaps and voids area was calculated at 2, 4, and 6 mm levels from the apex. Results showed that , for the setting time, there were statistical differences among all the studied sealers. AH Plus, Acroseal, and Adseal presented similar root canal adaptation, solubility, flow, and film thickness with no statistical difference.

Marin-bauza [(6)] assessed the setting time (ST), flow (FL), radiopacity (RD), solubility (SB) and dimensional change following setting (DC) of different sealers (AH Plus, Polifil, Apexit Plus, Sealapex, Endométhasone and Endofill according to

American National Standards Institute/American Dental Association (ANSI/ADA) Specification 57.

Five samples of each material were used for each test. For ST, cast rings were filled with sealers and tested with a Gilmore needle. For FL, the sealer was placed on a glass plate. After 180 s, another plate with 20 g and a load of 100 g were applied on the material, and the diameters of the discs formed were measured. In RD, circular molds were filled with the sealers, radiographed and analyzed using Digora software. For SB, circular molds were filled with the sealers, a nylon thread was placed inside the material and another glass plate was positioned on the set, pressed and stored at 37ºC. Samples were weighed, placed in water, dried and reweighed. The water used for SB was analyzed by atomic absorption spectrometry. For DC, circular molds were filled with the sealers, covered by glass plates and stored at 37ºC. Samples were measured and stored in water for 30 days. After this period, they were dried and measured again. The results demonstrated that except for DC, all other physicochemical properties of the tested sealers conformed to ANSI/ADA requirements.

Zuolo etal [(7)] evaluated the physicochemical properties of the epoxy-resin based root canal cement Sealer 26 enhanced with different amounts of iodoform. The properties of setting time, radiopacity, flow, solubility and dimensional stability were measured according to ANSI/ADA Specification 57 for sealing materials. The samples were divided into five groups: (S) Sealer(SI5) Sealer+ 5% iodoform; (SI7) Sealer+7% iodoform; (SI10) Sealer+10% iodoform; (SI30) Sealer+30% iodoform. Five samples were prepared from each group, for each test. The results showed that the values for setting time, solubility and dimensional stability did not meet the standards demanded by ADA Specification 57. The addition of iodoform to the Sealer 26endodontic cement did not alter the property for radiopacity. However, it decreases the solubility and increases the values for setting time, flow, and dimensional stability

Yigita and Gencoglua [(8)] evaluated the physical properties of EndoRez, Diaket, Epiphany, Roekoseal, Fibrefill, GuttaFlow, AHPlus, AH26 to that of a traditional zinc oxide based Kerr PCS sealers. Ten samples of each material were evaluated for flow, radiopacity, solubility and dimensional change tests according to ISO standards 2001- 6876. Results showed that the radiopacity and solubility of all sealers were in accordance with ISO standards 6876, except dimensional stability. However, all sealers had expansion values above the ISO requirements. Epiphany sealer showed the greatest expansion and the most flow rates under the given condition. According to the result of this study, all root canal sealers showed acceptable properties due to ISO standards except dimensional stability. Hydrophilic methacrylate resin-based sealer Epiphany showed the greatest dimensional change with 8 % expansion.

Candeiro etal [9] evaluated the physicochemical properties of the bioceramic root canal sealer, Endosequence BC Sealer. Radiopacity, pH, release of calcium ions (Ca(2+)), and flow were analyzed, and the results were compared with AH Plus cement.

Flow was evaluated according to ISO 6876/2001 standards. The flow test was performed with 0.05 mL of cement placed on a glass plate. A 120-g weight was carefully placed over the cement. The largest and smallest diameters of the disks formed were measured by using a digital caliper. The flow test revealed that BC Sealer and AH Plus presented flow of 26.96 mm and 21.17 mm, respectively , with no statistically significant difference. Furthermore, the Endosequence BC Sealer showed flow results in accordance to ISO 6876/2001 recommendations. The other physicochemical properties analyzed demonstrated favorable values for a root canal sealer.

Tyagi etal [10] reviewed different endodontic sealers and found that AH Plus has a film thickness of 26 mm, which is clearly below the value of less than 50 mm required by the ISO standard for root canal sealing materials. AH Plus has been designed to be slightly thixotropic. A flow of 36 mm also perfectly meets the requirements of the ISO standard (>25 mm).

AH Plus has better penetration into the micro-irregularities because of its creep capacity and long setting time, which increases the mechanical interlocking between sealer and root dentin and the sealer has good cohesion .

Due to its excellent properties, such as low solubility, small expansion, adhesion to dentin, and very good sealing ability, AH Plus is considered as a benchmark "Gold Standard."

Zhou etal [(11)] evaluated the pH change,flow, solubility,and dimensional stability of 2 novel root canal sealers (MTA Fillapex and Endosequence BC) in comparison with 2 epoxy resin-based sealers (AH Plus and ThermaSeal), a silicone-based sealer (GuttaFlow), and a zinc oxide-eugenol–based sealer (Pulp Canal Sealer). Results demonstrated that the flow, dimensional change, solubility, and film thickness of all the tested sealers were in agreement with ISO 6876/2001 recommendations. The MTA Fillapex sealer exhibited a higher flow than the Endosequence BC sealer. The MTA Fillapex and Endosequence BC sealers showed the highest film thicknesses among the tested samples. The Endosequence BC sealer exhibited the highest value of solubility, which was in accordance with 3% mass fraction recommended by the ISO 6876/2001, and showed an acceptable dimensional change. The MTA Fillapex and Endosequence BC sealers presented an alkaline pH at all times. The viscosity of the tested sealers increased with the decreased injection rates. The tested sealers were pseudoplastic according to their viscosities as determined in this study. The MTA Fillapex and Endosequence BC sealers each possessed comparable flow and dimensional stability but higher film thickness and solubility than the other sealers tested.

Tanomaru-Filho etal [(12)] evaluated the flow of different endodontic sealers: AH Plus, Endo CPM, MTA Fillapex, Sealapex, Epiphany, and Epiphany SE. To measure the flow rate sealers were placed between 2 glass slabs under a weight of 120 g. The diameters of the formed discs were measured with a digital paquimeter. The test was repeated 5 times for each sealer. MTA Fillapex, AH Plus, Epiphany, and Epiphany SE had similar values with MTA to be the best while Endo CPM and Sealapex presented the lowest flow values. All sealers presented flow values according to ISO and ANSI/ADA recommendations.

Garrido et al [(13)] compared a new root canal sealer based on Copaifera multijuga oil-resin (Biosealer) with three other sealers (Sealer 26 , Endofill and AH plus) in terms of their physicochemical properties. The study was carried out according to the requirements of Specification Number 57 of the American Dental Association (ADA) dimensional stability, solubility/disintegration. Regarding the solubility and disintegration, only Endofill did not meet the ADA's specifications and presented the worst results of all materials. Sealer 26 presented the greatest dimensional changes and differed significantly from all other sealers.

Bernardes etal [14] evaluated the flow rate of 3 endodontic sealers: Sealer 26, AH Plus, and MTA Obtura. According to the method proposed by the American Dental Association (ADA specification no. 57), the sealers were placed between 2 glass slabs under a weight of 120 g. The diameters of the formed discs were measured with a digital paquimeter. The test was repeated 5 times for each sealer. AH Plus showed significantly superior flow rate compared with Sealer 26 and MTA Obtura. There was no statistically significant difference between flow rates presented by Sealer 26 and MTA Obtura. Within the limitations of this in vitro study, it was concluded that all of the endodontic sealers tested presented greater flow than the minimum recommended in the ADA 57 specification.

De Faria-Júnior etal [15] evaluated the flow rate of AH Plus, Acroseal, Endomethasone N, Sealapex, and ActiV GP according to the standards of the ISO specification 6876/2001. A volume of 0.05 mL of the cement mixed according to the manufacturer's recommendations was placed on a glass plate. At 180±5 s after the commencement of mixing, the second glass plate was placed on top of the sealer, followed by the weight of mass approximately 100 g to make a total mass on the plate of 120±2 g. Ten min after the start of mixing, the weight was removed and the value of the diameter of the compressed disc of sealer was measured. Only the Endomethasone N did not conform to ISO Specification that requires that a sealer would have a diameter of not less than 20 mm. The Sealapex achieved the greatest flow, but it did not differ from Activ GP and AH Plus.