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Comparative study of heat release of various cement base materials during their setting

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SUMMARY

An ideal cement base material in order to protect the pulpal tissue from several external irritations (microbial, mechanical, thermal, galvanic and osmotic irritations) must present the following requirements: to attach or bond to the residual dentin, to be biocompatible, to present suitable physicomechanical, antimicrobial and optical properties, to be color stable, easy to use and rapid to set. Thermal phenomena developed during the mixing and setting are a factor influencing the biocompatibility properties of these materials. Cement base materials are used under various types of filling materials (amalgams, composite resins, gold and porcelain inlays) and are placed in contact with the dentin that contains exposed dentinal tubules. The purpose of this study was to investigate the possible exothermic reaction of these materials and to measure the developing temperatures for a time period from their mixing up to the completion of their setting. We studied the following types of cement base materials: a) Zinc oxide eugenol cement, b) Zinc phosphate cement, c) Zinc polycarboxylate cement and d) Glass ionomer cement both light and self curied. From the obtained results we observed that ZOE cements developed the lowest temperatures ranging from 32.8°C to 37°C, while Zinc phosphate cements developed the highest temperatures ranging from 44.4°C to 52°C. The other two types of materials Zinc polycarboxylate and Glass ionomer cements developed biocompatible temperatures ranging from 38°C to 40.8°C, which usually do not cause deteriorations and harms to the pulp.
We concluded that the ZOE cements presented the best thermal behaviour followed by Zinc polycarboxylate and Glass ionomer cements. Hence, these materials can be safely used without causing any pulpal response.

KEY WORDS:

Cement base materials, heat release.

RÉSUMÉ

Un cément de fond idéal en vue de protéger le tissu pulpaire de diverses irritations externes (irritations microbiennes, mécaniques, thermiques, galvaniques et osmotiques) doit présenter les propriétés suivantes: pouvoir s'attacher ou se lier à la dentine résiduelle, être biocompatible, présenter des propriétés physicomécaniques, antimicrobiennes et optiques, de conserver une teinte stable, d'être d'utilisation facile et

mise en place rapide. Le phénomène thermique qui se déroule au cours du mélange et de la mise en place est un facteur qui influence les propriétés de biocompatibilité de ces matériaux.
Les céments de fond sont utilisés sous différents types de matériaux de comblement (amalgame, résines composites, inlays en or et en porcelaine) et sont placés en contact avec de la dentine et des tubuli dentinaires ouverts.
Le but de cette étude a été d'investiguer la réaction exothermique possible de ces matériaux et de mesurer les températures développées pour la période de temps allant de leur mélange à la fin de leur mise en place.
Nous avons étudié les céments de fond suivants: Oxyde de Zinc Eugénol (OZE), le Phosphate de Zinc, le Polycarboxylate de Zinc et l'Ionomère de Verre. Les résultats obtenus nous ont permis de constater que OZE développent les températures les moins élevées entre 32.8° à 37°C, tandis que le phosphate de Zinc développe les températures les plus élevées entre 44.4° à 52°C. Les deux autres types de céments, le Polycarboxylate de Zinc et l'Ionomère de Verre développent des températures biocompatibles entre 38° et 40.8°C, qui habituellement ne provoquent pas de détériorations ou dommages à la pulpe.
Nous concluons que les céments OZE présentent le meilleur comportement thermique suivis par le Polycarboxylate de Zinc et l'Ionomère de Verre. Par conséquent, ces matériaux peuvent être utilisés en toute sécurité en n'étant responsables d'aucune réponse pulpaire.

MOTS CLÉS:
Cément de fond, libération de chaleur.

INTRODUCTION

It is well known that the dentin is perforated by dentinal tubules. In the process of removing the caries and preparing the cavity, during which the dentinal tubules are being cut and exposed, all external stimuli affect negatively the pulp. Despite today's improved application methods, there is always a small space left between the filling material and the dental tissues and as a result we have the phenomenon of penetration (Dijken, 1980).

According to Brannstrom (1986), penetration is the main factor for pulp irritation and secondary caries. The application of cement base materials is thus absolutely necessary for the protection of the pulp and this is the reason for the production and continuous improvement of various cement base materials.

In order to protect the pulp, an ideal cement base material must:
- be well attached to the dental tissues;
- be biocompatible;
- have good physicomechanical, antimicrobial and visual properties;
- have a good sublayer color;
- be easy to use and set rapidly.

The question is to what degree cement base materials are biocompatible. Thermal phenomena developed during the mixing and setting are a factor influencing the biocompatibility properties of these materials. In cases the cavities are deep, the heat produced and then transmitted through the open dentinal tubules affects negatively the pulp and, as a result, inflammations are caused which very often are irreversible.

The purpose of this investigation was to measure the heat produced by various types of cement base materials from their mixing and application in the cavity up to the completion of their setting and hardening.

MATERIALS AND METHODS

In order to make our measurements an apparatus illustrated in figure 1 was used. It was a double-sided glass vessel (4.5 cm in internal diameter, 6.5 cm in external diameter and 8 cm height) through which water at a standard temperature of 37°C could circulate, with the help of a thermostat circulator (Lauda thermostat mgw, H. Jürgens & Co., Bremen, Germany) connected to the glass vessel. At the bottom of the vessel a cylindrical rubber mould, 8 mm in diameter and 2 mm in height, was attached. The cement base examined was placed into the mould and immediately a copper thermocouple (HT-1, Saddle Brook NJ 07013, Bailey, U.S.A.) was inserted into

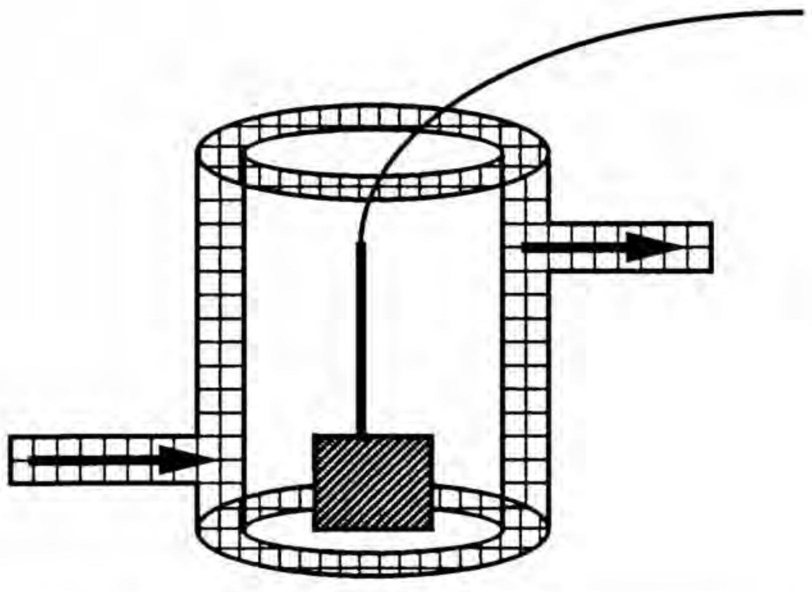


Fig. 1: Double-sided glass vessel using for the measurements.
Fig. 1: Vaisseau en verre double face utilisé pour les mesures.

the sample mass. The copper thermocouple was connected to an electronic digital thermometer (Saddle Brook NJ 07662, Bailey, U.S.A.) programmed to record the heat produced every 5 seconds for the period of 6 minutes from the moment of sample placing. The samples were prepared according to the manufacturer's instructions as for the mixing time and the powder/liquid ratio.

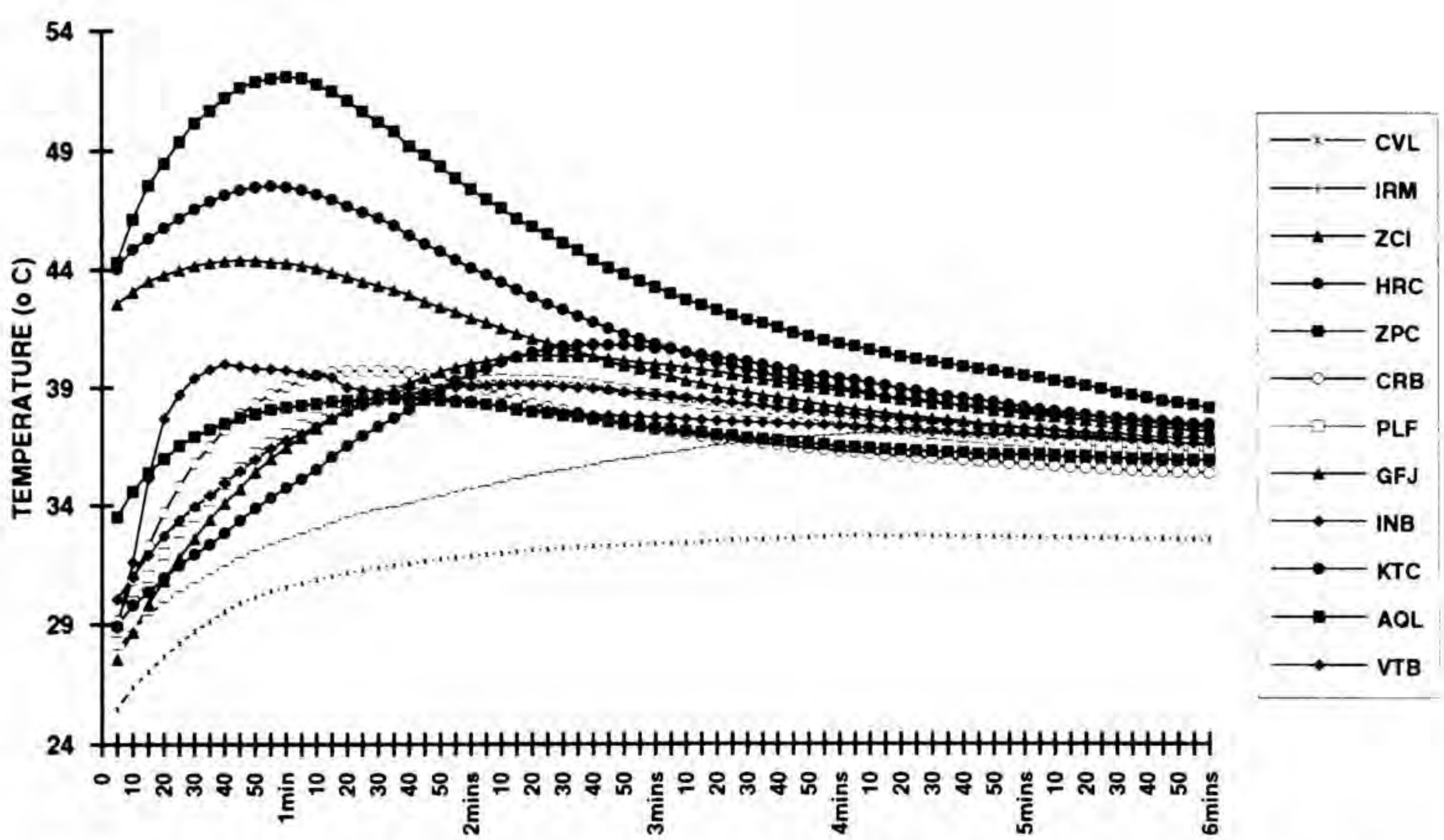
The materials examined were:

1. *Zinc Oxide Eugenol cements:*
- Cavity Lining, S.S. White, Pennwalt, Harrow Middx., England (CVL);
- IRM, Dentsply, De Trey, Weybridge, Surrey, England (IRM).

2. *Zinc Phosphate cements:*
- Zinc cement Improved Type I, Class II, S.S. White, Castelini-Siproda/Argenteuil, England (ZCI);
- Harvard cement, Richter & Hoffman Harvard Dental GmbH, Wilmersdorf, Germany (HRC);
- Zinc phosphate cement, Cavex Holland bv. Keur & Sneltjes Dental mfg, Co., Holland (ZPC).

3. *Zinc Polycarboxylate cements:*
- Poly-F-plus, Dentsply, De Trey, Weybridge, Surrey, England (PLF);
- Carbchem Aquaset, PSP Dental Co., Ltd., Belvedere, U.K. (CRB).

4. *Glass Ionomer cements:*
- Ketac Cem, Espe GmbH, Seefeld/Oberbay, Germany (KTC);
- GC Fuji II, GC Dental Ind., Co., Tokyo, Japan (GFJ);



Graph. 1: The amount of heat released during the setting of various cement base materials.

Graph. 1: Quantité de chaleur libérée au cours de la mise en place des différents céments de fond.

- Ionobond, Voco Chemie, Cuxhaven, Germany (INB);
- Aqualin, S.S. White, Siproda E.M.B., England (AQL);
- Vitrebond, 3M Dental Products Division, St. Paul, U.S.A. (VTB).

RESULTS

The results are illustrated in graph. 1. The amount of heat produced during the hardening of the cement base materials tested, seems to depend up on their composition. This assumption is based on the fact that we observed a grouping in the amount of the heat produced, according to the category of cements.

The maximum temperatures observed ranged from 32.7°C to 52°C. The lowest temperatures, 32.7°C to 37°C, were developed by the Zinc Oxide Eugenol cements in 4 mins from their application in the cavity. On the contrary the highest temperatures, 44.4°C to 52°C, were developed by the Zinc Phosphate cements in 45 sec to 1 min from their application.

The Zinc Polycarboxylate cements and Glass Ionomer cements both light and self curied developed similar temperatures ranging from 38°C to 40.8°C in 1.5 to 2.5 mins from their application into the cavity. The only exception was the light curied glass ionomer cement, which developed its maximum temperature in 40 secs from its application.

DISCUSSION

The protection of the pulp by the enamel and dentin is not always strong enough to protect it from many external stimuli. The changes in temperature into the mouth during food intake have a direct effect on the physiopathology of the pulpal tissue, especially when ever there is an effect of other harmful factors (Fazekas, 1973). Pathogenic microorganisms, physical variables, chemical substances, fierce mechanical lesions and radiation are inflammatory factors for the pulpal tissue.

These factors appear during the restorative process of carious teeth when, apart from the preexistence of inflammations due to the caries and the daily changes in temperature due to food intake (Fazekas, 1973), there are certain iatrogenic factors such as the high-speed cavity preparation, the insufficient spraying with water, the drying of the dentinal tubules (Proctor *et al.*, 1979).

It is well known (Langeland and Langeland, 1970) that the first histological deteriorations, hyperemia, start with an increase in the temperature by 5°C to 7°C inside the pulpal cavity, and are reversible (Pohto and Scheinin, 1958; Zach and Cohen, 1965). However, when endopulpal temperature exceeds 46°C an acute generalized inflammation is caused, with tissue changes which can either be restored or not and most of the times this results in the necrosis of the pulp (Tziafas, 1983).

The degree of inflammation caused in the pulpal tissue depends both up on the increase of the endopulpal temperature and its duration (Hamilton and Cramer, 1967; Loyd *et al.*, 1978; Zach and Cohen, 1965). It is evident that in order to have an increase in the endopulpal temperature, the temperature on the dentinal surface must also be increased substantially (Brown *et al.*, 1970). It is reported by Jarby (1958) that the temperature at the bottom of a prepared cavity after the application of heated guttapercha was 32°C. In case the dentin layer between the guttapercha and the pulpal tissue is thin, the increase in temperature constitutes a serious harmful factor (Carson *et al.*, 1979; Proctor *et al.*, 1979). Therefore, in deeply carious cavities where a very thin layer of dentin remains between the pulpal tissue and the cement base, the increase in temperature beyond a certain degree during the exothermal reaction of the hardening of the cement layer also constitutes a serious harmful factor (Plant *et al.*, 1974).

From the results, the zinc phosphate cements presented the highest temperatures during their hardening, due to the strong exothermal reaction that is caused. If we take into account their distinct disadvantages such as pulp irritation due to the phosphate acid (after the mixing the pH is 3 to 3.5 and in 48 hours it becomes 6), lack of antibacterial action, brittleness, lack of adhesion (which causes penetration) and solubility in oral fluids (Greener *et al.*, 1972; O'Brien *et al.*, 1978; Anderson, 1987), we realize that the thermal irritation mentioned above leads to the exclusion of these materials from clinical practice – despite their strength – since they contribute to pulpal damage. Nevertheless, they may be used in combination with ZOE cements.

On the contrary ZOE cements presented the lowest temperatures during their hardening. This fact, combined with their sedative effect on the pulp, their capability to seal the exposed dentinal tubules and thus protect the pulp from chemical irritations that may penetrate through the odontoblastic processes, their capability to stimulate the odontoblastis for secondary dentin production and their good adhesion to the dental tissues (Craig *et al.*, 1987; Greener *et al.*, 1972; McCabe, 1990; O'Brien and Ryge, 1978; O'Brien, 1989), makes the ZOE cements necessary in clinical practice. However, these materials cannot be used neither in very deep cavities, because of their low strength and abrasion resistance, nor under composite resins, since eugenol does not allow their polymerization.

Polycarboxylate and glass ionomer cements, presented biocompatible temperatures during their setting. The main advantages of these materials are the low irritancy, thermal insulative efficency (Paroussis *et al.*, 1990), adhesion to tooth structure, easy manipulation, strength and film thickness properties comparable to those of zinc phosphate cements. Similarly the advantages of the glass ionomer cements include easy mixing, thermal insulative efficency (Paroussis *et al.*, 1990), high strength and stiffness, potentially adhesive characteristics and translucency, leachable fluoride and good resistance to acid dissolution (Anderson, 1977; Craig *et al.*, 1987; Greener *et al.*, 1972; McCabe, 1990; O'Brien and Ryge, 1978; O'Brien, 1989). By leaching fluoride which is taken up by enamel, the ionomer cements strengthen the dental tissues and promote the anticariogenic action. However, although these materials have many advantages, they are sensitive to moisture (Wilson and McLean, 1988). In order to overcome this disadvantage, light curied glass ionomer cements have been developed.

By comparison, it is obvious that both polycarboxylate and glass ionomer cements may almost be considered ideal cement base materials and can be safely used without causing any pulpal response.

CONCLUSION

The following conclusions were drawn from this investigation:

- All cement base materials examined, with the exception of the zinc phosphate cements, developed biocompatible to the pulpal tissue temperatures from their application up to their setting. Hence these materials can be safely used without causing any pulpal response.
- On the contrary, the zinc phosphate cements developed high temperatures and the damage which may be caused depends up on the thickness of the dentin remain after the cavity preparation.
- The selection of the most appropriate cement base material depents up on the magnitude of the temperature developed as well as on the rest of its properties.

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