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PREPARATION OF DENTAL PHOSPHATE-BONDED INVESTMENT TO CAST NICKEL:CHROMIUM ALLOYS AND THE EVALUATION OF ITS MECHANICAL AND PHYSICAL PROPERTIES

Najdat H. Abdul-Razzak[1], Saadi M. D. Al-Nuzal[2*], Mohammed A. Mustafa[1], Flaih H. Ali[1], and Bushra A. Lafta[1]

[1]Ministry of Science and Technology, P.O 765, Al-Jadiryia, Baghdad, Iraq.
[2]Environmental Research Center, The University of Technology, Baghdad, Iraq.

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***Correspondence for Author**
Dr. Saadi M. D. Al-Nuzal
Environmental Research Center, the University of Technology, Baghdad, Iraq.

ABSTRACT

An investment composition is described for use in dental investment casting (also called lost wax casting), from Iraqi locally available raw materials. The major composition is a phosphate bonded material that contains synthesized mono-ammonium phosphate (MAP) as binder, and silica filler (quartz, cristobalite, or a mixture thereof) as refractory materials. The procedure included many steps among them chemical syntheses, and thermal treatments at high temperature (~1100ºC), followed by chemical analysis for quality control. The high purity investment was successfully, used to cast Nickel: Chromium alloys for dental use. The evaluation of the mechanical and physical properties of the prepared investment were carefully checked according to the required specification of the ISO No. 9694/1996, which was adapted for preparing chemical, physical, and mechanical properties of the prepared dental materials. The chemical analysis of this formulation showed to be in good agreement with many imported investments.

INTRODUCTION

Dental investments are refectory compositions suitable for forming mold into which molten metal may be cast. The cavity is formed in the mold by melting out an expandable wax pattern, which has been imbedded in the mold. Phosphate bonded investments are one type of investment material, which is extensively discussed [1]. Most Palladium and base metal alloys used for partial dentures and porcelain-fused-to metal restoration have high melting temperature and this alloy is cast into molds at 850° to 1100°C. Although these investments are some what more difficult to remove from casting than gypsum investment. They are more stable at (high casting metal) ceramic alloys [2]. Investment materials for casting alloys must meet exacting requirements: easy manipulation and handling, no chemical reactions with alloy at casting temperature, able to provide adequate expansion to compensate for casting shrinkage.

Many studies were performed to investigate the thermal behavior of $MgNH_4PO_4.6H_2O$, phosphate-bonded investment at elevated temperature, and their deterioration at various conditions. The rapid growth in use of metal ceramic restorations boost the use of phosphate or silicate bonded investments. One of the important requirements of an investment material to be used for a casting mould is that it should expand on setting and heating to compensate for the cooling of the cast metal as it returns to room temperature. The investment material should be of a suitable consistency for adaptation to the wax model and have a reasonable setting time. To withstand the temperatures required for the casting process there should be no distortion; no decomposition; should not fragment or disintegrate under the impact of the molten metal; the material should be porous to allow the escape of air and gases and the investment should be easily removed from the casting after cooling [3-8].

This type of investment usually has less than 20 % binder, and remainder of the investment is quartz or another form of silica (cristobalite). Each forms of silica expands when heated, with an expansion varies from one type to another. Pure cristobalite expands to 1.6 at 400°C, quartz 1.54 % at 600° C, and tridym less than 1% at 600° C. In case of cristobalite, the expansion is somewhat uniform to at 200° C, where its expansion increases sharply from 0.5 % to 1.2 %. These investments can be mixed with water or with other aqueous liquid. The special liquid in a form of silica solution in water, phosphate-bonded possess higher setting expansion when they are mixed with the silica solution than when they are mixed with water. With a mix containing silica solution, the investment mass in is capable of expanding hygroscopically, whereas if the mix is only water the hygroscopic expansion of such an investment is negligible. Using silica solution instead of water with phosphate-bonded investment also increases its strength considerably [9-11]. The purpose of this work is to establish a phosphate-bonded investment formula that fit the requirement of the ISO specification No. 9694/1996 [12], and has the capability to be produced locally.

MATERIAL AND METHOD

1. The Phosphate-Bonded Investment Preparation

The phosphate-bonded investment was prepared from two main groups of ingredients, fillers and binders. Fillers are usually quartz, cristobalite or a mixture of the two within the range of approximately 80 %. The function of the filler is to provide high-temperature thermal shock resistance, high thermal expansion, and both play small role in the chemistry of the investment during setting. The binders are essentially (MgO) and $NH_4H_2PO_4$. A typical formula for prepared phosphate bonded investment is prepared according to table 1.

Table 1: Composition of Typical Phosphate-Bonded Investment.

Ingredients	Weight %
Large cristobalite	38-42
Fine cristobalite	19-21
Quartz	19-21
MAP	8-12
MgO	7-9
Boric acid	1-3

Table 2: Recommended Mechanical Properties of Phosphate Investment [12].

Mixing Ratio	100 g: 25 ml
Working Time	4.5 min
Setting time	25 min
Compressive strength	9-11 M Pa
Total Expansion	3.35 %
Thermal Expansion	1.35 %
Particle size	Ranging from size 425-45 micrometer

2. Mechanical Properties

Typical chemical, physical, and mechanical properties which was adapted for preparing of the prepared dental materials of the phosphate-bonded investments according to the ISO specification No. 9694/1996 [12] was listed in table 2, A-Setting time (working time): Shall be not less than 4 min from the moment of first contact of investment and water to measure setting time, stainless steel rings, with an internal diameter of 10 mm. and a thickness of 2 mm. The investment was manipulated and placed in metallic ring, after 120±10 s from the beginning of spatulation; the apparatus was placed over a grate inside a hermetically sealed plastic container after 150±10 s from the beginning of spatulation a 100 g, 2 mm active point Gillmor needle was positioned vertically on the surface of the material. This test was repeated every 60s until the needle did not mark the surface of the investment. The setting time was considered as the average of 5 measurements.

3. Expansion

All the phosphate-bonded investments currently available casting high-melting alloys have thermal expansion for setting expansion and hygroscopic expansion. The total dimensional change is a very important property of casting investments that occurs if the investment is in contact with water from any source during the setting process after investing the wax pattern. The mixed investment, when tested 2h after the first contact of investment and water, shall exhibit a total expansion (covering air setting, hygroscopic and thermal) of not less than 1.7 % if intended for use with base metal alloys. Table 2 shows the results of phosphate-bonded investment expansion.

4. Compressive Strength

Low temperature: The transverse strength of the set investment test pieces 2h after the commencement of mixing at a temperature of 23±2ºC shall be not less than 5 MPa. High temperature determined at the maximum mold temperature shall be not less than 5 M Pa. Table 2 shows the T.C.S of the investments.

5. Particle Size Test

Grain size particle in weight percentage for 100 g of phosphate-bonded investment ranging from size 425-45 micrometer.

RESULTS AND DISCUSSION

The required properties of an investment should have the following:

It should be easily manipulated. Not only should it be possible to mix and manipulate the mass readily and to paint the max pattern easily, but the investment also should harden within a relatively short time. Its mold have sufficient strength at room temperature to permit ease in handling, and enough strength temperature to withstand the impact force of the molten metal the inner surface of the mold should not break down at a high temperature.

1. On being heated to higher temperatures, the investment must not decompose to give off gasses that could damage the surface of the alloy. It should have enough expansion to compensate for shrinkage of the wax pattern and the metal that taken place during the casting procedure.

2. Casting temperature should not be critical preferably the thermal expansion versus temperature curve should have a plateau of the thermal expansion over a range of casting

temperature. A dental casting investment should be porous enough to permit the air or to other gases in the mold cavity to escape easily during the casting procedure. It should produce a smooth surface and fine dental and margins on the casting.

3. After the casting is completed, the investment should break away readily from the surface of the metal and should not have reached chemically with it. Because the mold is always destroyed in the casting process, the investment material must be comparative inexpensive.

There are three specifications on which the evaluation could be done for the investment, ISO No.9694 (Imitational organization for standardization), Geneve 1996, was applied for phosphate-bonded investments according to the following specification. Phosphate-bonded investment is composed mainly of refractory, binder and other additives many experimental and a large number of mixes had been done using the standard materials (Particularly the binder) until the best formula was obtained using the above ISO specification to evaluate every mix.

The phosphate-bonded investments for alloys having a solidus temperature above 1080°C. Initial setting time must not differ by more than 30 % from the time stated by the manufacture the compressive strength at room temperature is less than 15 % from the line stated by the manufacture. Certain phosphate compound, such as ammonium diacid phosphate ($NH_4H_2PO_4$), has been found to provide room temperature strength to the increase the strength of the investment at casting temperature.

A small amount of magnesium oxide that was used at room temperature ammonium diacid phosphate reacts with magnesium oxide to give the investment green strength, or room-temperature strength according to the chemical reaction. The chemical reaction for the binder system that causes the investment to set and harden generally written as follows:

$$NH_4H_2PO_4 + MgO + 5H_2O \longrightarrow NH_4MgPO_4.6H_2O$$

However, phosphate are quite complex, and the reaction is not as simple as indicated by the above equation [1, 8, 10-11]. The ammonium diacid phosphate is used in a greater amount than necessary for this reaction so that the remainder can react with silica at an elevated temperature. The higher temperature probably causes a superficial reaction between P_2O_5 and

SiO_2 to form silicophosphate, which increases the strength of the investment at higher temperature. The water produced by this reaction lower the viscosity of the mix as spatulation continuous. The investments can be mixed with water or with a special liquid. The special liquid is a form of silica sol. In water, phosphate-bounds investments posses higher setting expansion when they are mixed with the silica sol. Than when they are mixed with water, with a mixed with water, with a mix containing silica sol, the investment mass capable of expanding hygroscopic, whereas if the mix is only water, the hygroscopic expansion of such an investment is negligible using silica sol. Instead of water with phosphate-bonded investment also increases its strength considerably.

CONCLUSION

An investment composition is described for use in dental investment casting (also called lost wax casting), from Iraqi locally available raw materials. The major composition is a phosphate bonded material that contains synthesized mono-ammonium phosphate (MAP) as binder, and silica filler (quartz, cristobalite, or a mixture thereof) as refractory materials. The high purity investment was successfully, used to cast Nickel:Chromium alloys for dental use. The chemical analysis of this formulation showed to be in good agreement with many imported investments.

REFERENCE

1. Ralph, W. Phillips, *"Skinner's Science of Dental Materials."*, 8th ed., pp. 406-410, W. B Sander's Co., Philadelphia, 1982.
2. Wang, C., Millstein, P. L., Nathanson, D., "Effects of cement, cement space, marginal design, seating aid materials, and seating force on crown cementation.", *J. Prosthet. Dent*, 1992; 67: 786-790.
3. Asaoka, K., Bae, J. Y., Lee, H. H., "Porosity of dental gypsum-bonded investments in setting and heating process.", *Dent. Mater. J*, 2012; 31: 120-124.
4. Higuchi, H., Matsuya, S., Yamane, M., "Thermal behavior of phosphate-bonded investment. Part 1. Thermal behavior of $MgNH_4PO_4.6H_2O$.", *J. J. Dent. Mater.* 1982; 23: 1-5.
5. Habu, N., Takahashi, H., Min, Y., Motomura, K., Nakamura, H., Nishimura, F., "Properties of a phosphate-bonded dental investment for quick heating.", J. J. Dent Mater. 1995; 14: 681-690.

6. Juszczyk, A. S., Radford, D. R., Curtis, R. V., "Deformation of phosphate-bonded investment materials at elevated temperatures.", *Dental Mater*, 2007; 23: 579-585.
7. Raya M. Jawad Al- Ghabban, "The Effect of Different Concentrations of Gilvest with Water on the Setting Time of Phosphate-bonded investment.", *Iraqi Sci. J. Nursing*, 2010; 23(2).
8. Miyaji, T., Utsumi, K., Suzuki, E., Shimizu, Y., "Deterioration of phosphate-bonded investment on exposure to 100 % relative humidity atomosphere.", *Bull. Tokoyo Med. Dent. Univ*, 1982; 29: 53.
9. Ayad M. F., Rosenstiel, S. F., Salama, M., "Influence of tooth surface roughness and type of cement on retention of complete cast crowns.", *J. Prosthet. Dent*, 1997; 77:116-121.
10. Schnell, R. J. Mumford, G., Philips, R. W., "An evaluation of phosphate bonded investment used with a high fusing gold alloy.", *J. Prasthet. Dent*, 1963; 13: 324.
11. Craig, R. G., O'brien, W. J., Powers, J. M., *"Dental Materials"*, 6th Edt, Mosby, 1996.
12. ISO 9694:1996 Dental phosphate-bonded casting investments. *International Standards Organization*, Geneva.