***ISSN:* 1812–1217**

Evaluation of compressive strength for refractory casts made from different investment materials

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ABSTRACT

Aims: To compare the compressive strength of refractory casts made from investments for cobalt–chromium and investment for titanium and to study the effect of mixing fluid on compressive strength. **Materials and Methods:** Three types of investments were used, one for titanium and two for cobalt–chromium, each one is mixed with three types of mixing fluids; tap water, distilled water and special liquid, to produce refractory casts. Compressive strength test was carried out using compression testing machine. **Results:** Showed significant differences in compressive strength between the types of investments, with titanium investment mixed with special liquid showed the highest value. There were significant differences between subgroups of the same type by changing mixing fluid type. **Conclusions:** Refractory casts made from titanium investment showed significantly higher compressive strength than refractory casts made from Co–Cr investments, and there was a difference between the two special liquids used, and tap water in which it produced casts with higher compressive strength than distilled water in two out of the three investment materials tested.

Key words: refractory cast**,** compressive strength, investment

Al–Ali AA. Evaluation of compressive strength for refractory casts made from different investment materials. *Al–Rafidain Dent J*. 2007; 7(2): 166–172.

Received: 4/4/2006 ***Sent to Referees:*** 11/4/2006 ***Accepted for Publication:*** 29/6/2006

INTRODUCTION

Many years of dental application have made investments a familiar and versatile class of materials used in the laboratory. They are used in the construction of cobalt–chromium denture frameworks then their applications have been increased and they are now routinely employed for the precision casting of high–fusing dental alloys, to construct a variety of dental restorations ranging from removable partial denture to multi–unit bridgework substructures. Their use has been developed to include dies for the production of porcelain custom veneer facing and molds for castable ceramics. Investments are also being used with pressable ceramics for the production of all–ceramic crowns, inlays and onlays. [1]

The strength of the investment for a partial denture framework must be adequate to prevent fracture or chipping of the mold during heating and casting. Therefore, an investment should possess sufficient strength to withstand the impact of the molten alloy [2].

Papadopoulos and Caracatsanis [3] studied the influence of mixing and heating on the compressive strength of four dental investment materials and concluded that mechanical mixing increased the compressive strength and the compressive strength of phosphate–bonded investment increased at the highest temperature of the heating procedure.

Davis [4] determined the effect of wet and dry cellulose ring liners on compressive strength of a gypsum–bonded investment and found that the compressive strength of investment from dry liner group were greater tan those from the wet liner group.

Luk and Darvell[5] studied the effects of burnout temperature on the strength of phosphate–bonded investments and the contribution of metal casting temperature. They concluded that heat from the high–temperature casting metal decrease the strength of phosphate–bonded investments.

In a study made by Curtis[6], the stress–strain and thermal expansion characteristics of a phosphate–bonded investment material were measured to determine its suitability as a die material for superplastic forming of dental appliances. The conclusion was that the lowest initial W/P ratio should be used for highest hot strength.

Chew *et al.*,[7] evaluated and compared the compressive strength characteristics of selected investments and to determine whether if these changes as a function of time and temperature after mixing. The conclusion was that at room temperature, the phosphate–bonded investments were not significantly stronger than the gypsum–bonded investment material. However, they exhibited increased compressive strength as a function of time and temperature that was considerably higher than that exhibited by gypsum–bonded investments.

Taira *et al.*,[8] studied the effects of four mixing methods (hand, two conventional blade–driven mixers and a new mixing device) on setting expansion and compressive strength of six commercial phosphate–bonded silica investments and found that the compressive strength of all six investments varied by changing the mixing method.

Low and Swain[9] compared two different methods for measurement of the elastic modulus of investment materials, gypsum– and phosphate–bonded. Method 1 is a traditional three–point bending test. Method 2 is an ultra micro–indentation system. The conclusion was that both methods are practical ways of measuring the elastic modulus of investment materials.

Kaloyiannides *et al.*, [10] studied the effect of powder–liquid ratio and the mixing method on the surface hardness of phosphate–bonded investment materials. The study indicated that the surface hardness of the specimens increased after mechanical mixing and it was higher in 24 hours than in three hours. Also, as more water was included in the mixing liquid, as lower became the surface hardness of the materials.

Luk and Darvell [11] investigated the variation of the strength of gypsum–bonded dental investments with burnout temperature and concluded that the use by manufacturers of room temperature strength data conveys no information about high temperature beha-vior. Investment properties should be optim-ized by reference to behavior under casting conditions.

The purposes of this study are to investigate and compare the compressive strength of refractory casts made from three investment materials, two of them were for cobalt–chromium, and the third one was for titanium; furthermore to access the influence of mixing fluid on the compressive strength

MATERIALS AND METHODS

Specimens were prepared by pouring investment material (Table 1, 2) into cylindeical, highly polished acrylic molds with a height of 40mm and a diameter of 20mm according to ADA specification and according to a study by Cany *et al.*[2] Manufacturer instructions were followed precisely in powder–liquid ratio and setting time (Table 3). Six specimens for each variable were made. Sensitive electronic balance was used to weight the powder and a graduated cylinder was used to measure the liquid. Each material was mixed with each mixing liquid. The mixture was vibrated into the molds, and a glass slab was placed over the mold to ensure flat and parallel ends. After set, the cylindrical specimens were removed from the molds and dried according to the manufacturer instructions (Table 3).

Compressive strength tests were carried out using compression testing machine (Model CN 472,USA) at a crosshead speed of 0.5mm/min.

Data were analyzed statistically using analysis of variance(ANOVA) coupled with Duncan multiple range test to show how the difference among groups is arranged at a significant level of $P<0.05$.

Table (1): Investment materials used in this study.

Trade name	Company
For cobalt–chromium investment materials	
Biosint Supra,	Degussa / Germany
Rema Exakt,	Dentaurum/ Germany
For titanium investment materials	
Rematitan Plus investment	Dentaurum/ Germany

Table (2): Mixing liquids used in this study

1. tap water
2. distilled water
3. special liquids A–special liquid from Degussa company, Germany: for Biosint Supra investment material. B–special liquid from DENTAURUM company, Germany: for Rema Exakt and Rematitan Plus investment materials.

Table (3):Materials and technical data

Material	P:L ratio	Set time	Drying time and temperature
Biosint Supra	73g:11ml	30min	20min at 90–95^{o}C followed by additional 20–25 min at a maximum of 170^{o}C
Rema Exakt	73g:11ml	30min	40min at 170^{o}C
Rematitan Plus	75g:12ml	40min	40min at 70^{0}C

P/L ratio: powder/ liquid ratio

RESULTS

Statistical analysis by ANOVA and Duncan multiple range test showed a significant difference between groups (P=0.000), with Rematitan Plus mixed with special liquid having the highest compressive strength (1751.8035 Kg/cm^2) (Table 4,5).

Within the group of Biosint Supra investment (Table 6,Figure 1), the specimens mixed with tap water showed significantly higher compressive strength (902.3647 Kg/cm^2) than specimens mixed with distilled water or special liquid. There was no significant difference between specimens mixed with distilled water and those mixed with special liquid.

In relation to Rema Exakt group (Table 7,Figure 2) there was no significant differrence in compressive strength between specimens mixed with tap water and those mixed with distilled water, but specimens mixed with special liquid showed significantly higher compressive strength than both of them (1076.9018 Kg/cm^2).

There was significant difference in compressive strength between subgroups of Rematitan Plus investment (Table 8) with specimens mixed with distilled water showed the lowest compressive strength (1035.1658 Kg/cm^2) and specimens mixed with special liquid having the highest compressive strength (1751.8035 Kg/cm^2) (Figure 3).

Table (4): Analysis of variance for all tested groups

Source of variance	Sum of squares	DF	Mean Square	F–value	P–value
Between Groups	3039513.742	8	379939.218	75.744	.000
Within Groups	45145.112	9	5016.124		
Total	3084658.853	17			

DF: degree of freedom.

Table (5): Duncan multiple range tests for all tested groups

Specimen	Compressive strength (Kg/cm^2)	Duncan's group
Biosint supra –tap water	902.3647	D
Biosint supra–distilled water	504.019	E
Biosint supra–special liquid	574.3978	E
Rema exakt–tap water	546.36	E
Rema exakt–distilled water	545.0825	E
Rema exakt–special liquid	1076.9018	C
Rematitan plus–tap water	1386.062	B
Rematitan plus–distilled water	1035.1658	C
Rematitan plus–special liquid	1751.8035	A

Means with different lketters is significant at 0.05 level.

Table (6): Analysis of variance for Biosint Supra investment

Source of variance	Sum of squares	DF	Mean Square	F–value	P–value
Between Groups	180796.502	2	90398.251	76.176	.003
Within Groups	3560.127	3	1186.709		
Total	184356.62	5			

DF: degree of freedom.

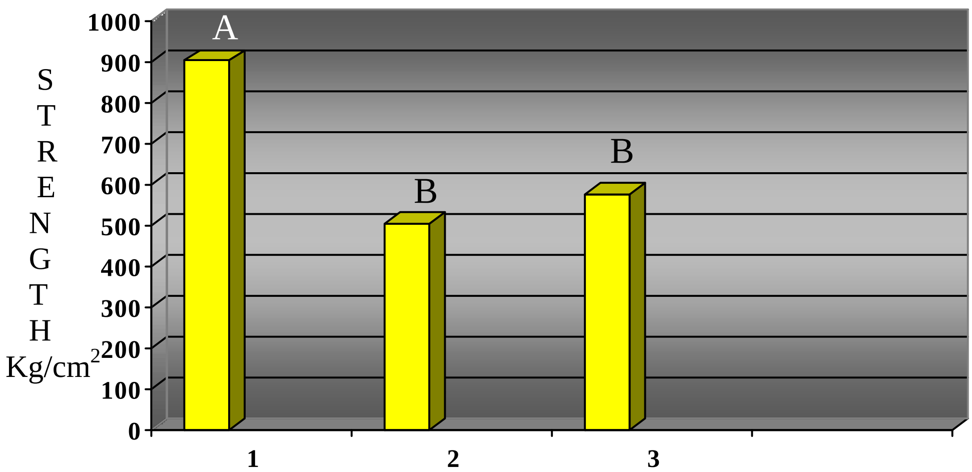

Figure (1): Duncan multiple range test for Biosint Supra Investment.
1 : Mixed with tap water; **2**: Mixed with distilled water; **3**: Mixed with special liquid.

Table (7): Analysis of variance for Rema Exakt investment

Source of variance	Sum of squares	DF	Mean Square	F–value	P–value
Between Groups	376205.456	2	188102.728	28.167	.011
Within Groups	20034.208	3	6678.069		
Total	396239.664	5			

DF: degree of freedom.

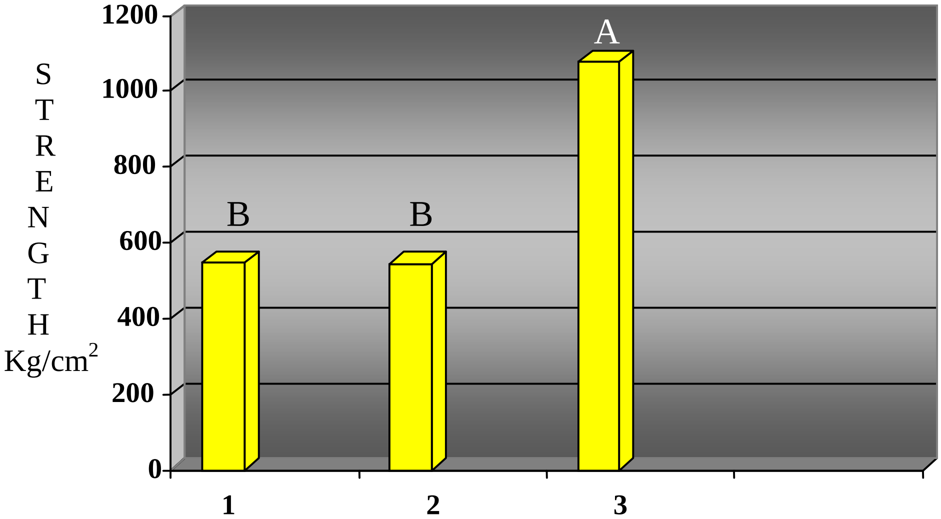

Figure (2): Duncan multiple range test for Rema Exakt Investment.
1 : Mixed with tap water; **2**: Mixed with distilled water; **3**: Mixed with special liquid.

Table (8): Analysis of variance for Rematitan plus investment

Source of variance	Sum of squares	DF	Mean Square	F–value	P–value
Between Groups	513643.023	2	256821.512	35.751	.008
Within Groups	21550.776	3	7183.592		
Total	535193.800	5			

DF: degree of freedom.

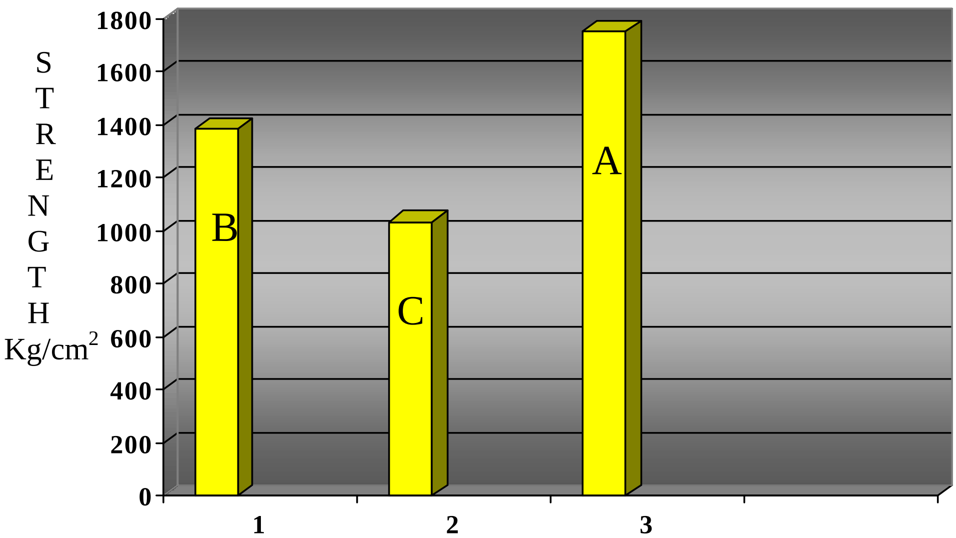

Figure (1): Duncan multiple range test for Rematitan Plus Investment.
1 : Mixed with tap water; **2**: Mixed with distilled water; **3**: Mixed with special liquid.

DISCUSSION

The strength of investment must be adequate to prevent fracture or chipping of the mold during heating and casting of the alloy. It is theorized that the compressive strength of the investment mold can be a primary factor to be considered, in addition to the expansion when evaluating the dimensional accuracy of dental castings. The strength of an investment is usually measured under compressive stress.[12]

Commercially pure titanium and titanium alloys require specially formulated investments to minimize the interaction of the molten metal with the investment. [12] The results of the current study showed that investment for titanium and titanium alloys having significantly higher compressive strength than investments for cobalt–chromium alloy and this is agree with Hsu *et al.*, [13] who evaluated different investments for titanium casting.

Some phosphate–bonded investments are made to be used with water for the casting of many alloys. In time, colloidal silica suspensions became available for use with the phosphate investments in place of water. [12] In this study, when investment was mixed with special liquid from Dentaurum company, the compressive strength of refractory casts significantly increase, and this is in agreement with Luk and Darvell [14]who measured the effect of special liquid on strength under actual casting condition and found that the use of special liquid increase substantially the strength of four phosphate–bonded investment tested. The results, also, agreed with Li *et al.*,[15] who compared the compressive strength of three phosphate–bonded investments and found significant difference between groups and compressive strength of (X–20 chrome) investment mixed with special liquid was the highest.

In this study, investment mixed with special liquid from Degussa company produced refractory casts with significantly lower compressive strength than investment mixed with water and this disagree with some studies [14,15]. This may be explained by the fact that special liquid for investment is a colloidal silica suspension, and the disadvantage of an investment that contain sufficient silica to prevent any contraction during heating is that the weakening effect of the silica in such quantities is likely to be too great. The addition of small amounts of sodium, potassium, or lithium chlorides to the investments eliminates the contraction caused by the gypsum and increase the expansion without the presence of an excessive amount of silica [12], and this may be the difference between the two special liquids used in the study.

The effect of chemical modifiers is, also, obvious in a study made by Meng *et al.*,[16] who evaluated the effect of different additive content on room temperature– and burnout–compressive strength of the investtment. The compressive strength of some investments decrease with the increase of the additive contents and the burnout strength of other investments significantly increase while the room temperature strength remained unchanged. The results also agree with Nakai[17]who investigated the setting time and the compressive strength.

The effect of chemicals is also appeared when the investment materials mixed with tap water; they showed higher compressive strength than when mixed with distilled water. Tap water may contain some minerals like hydrogenated calcium carbonate or hydrogenated magnesium carbonate that are dissolved in water and can be easily removed by heating. These chemicals may be responsible for the increased compressive strength in two of the tested investment materials.

The use of chemical modifier aids in increasing the strength because more of the binder can be used without a marked reduction in the thermal expansion. [12] This does not mean that the researcher suggest using tap water instead of distilled water because as Anusavice said " although a certain minimum strength is necessary to prevent fracture of the investment mold during casting, surprisingly it has been postulated that the compressive strength should not be unduly high". [12]

CONCLUSIONS

Refractory (investment) cast for titanium showed significantly higher compressive strength than refractory (investment) cast for Co–Cr.

Special liquid from Dentaurum Company significantly increase the compressive strength of refractory (investment) cast but special liquid from Degussa Company does not.

Mixing with tap water give refractory (investment) cast with significantly higher compressive strength than mixing with distilled water in two out of the three investments tested.

REFERENCES

1. Juszczyk AS, Radford DR, Curtis RV. The influence of handling technique on the strength of phosphate –bonded investments. *Dent Mater*. 2000; 16: 26–32.
2. Canay S, Hersek N, Ciftci Y, Akca K. Comparison of diametrical tensile strength of microwave and oven–dried investment materials. *J Prosthet Dent*. 1999; 82: 286–290.
3. Papadopoulos T, Caracatsanis M. The influence of mixing and heating on the compressive strength of investment materials. *Odontostomatol Proodos*. 1989; 43: 339–346.
4. Davis DR. Effect of wet and dry cellulose ring liner on setting expansion and compressive strength of a gypsum–bonded investment. *J Prosthet Dent*. 1996; 76: 519–523.
5. Luk HW, Darvell BW. Effect of burnout temperatures on strength of phosphate –bonded investment–Part II: Effect of metal temperature. *J Dent*. 1997; 25: 423–430.
6. Curtis RV. Stress–strain and thermal expansion characteristics of a phosphate –bonded investment mould material for dental superplastic forming. *J Dent*. 1998; 26: 251–258.
7. Chew CL, Land MF, Thoma CC, Norman RD. Investment strength as a function of time and temperature. *J Dent*. 1999; 27: 297–302.
8. Taira M, Okazaki M, Takahashi J, Kubo F. Effects of four mixing methods on setting expansion and compressive strength of six commercial phosphate–bonded silica investments. *J Oral Rehabil*. 2000; 27: 306–311.
9. Low D, Swain MV. Mechanical properties of dental investment materials. *J Mater Sci Mater Med*. 2000; 11: 399–405.
10. Kaloyiannides A, Diakoyianni I, Pentheroudaki M. The effect of powder–liquid ratio and the mixing method on the surface hardness of phosphate–bonded investment materials. *Bull Group Int Rech Sci Stomatol Odontol*. 2001; 43: 14–18.
11. Luk WK, Darvell BW. Effect of burnout temperature on strength of gypsum–bonded investments. *Dent Mater*. 2003; 19: 552–557.
12. Anusavice KJ. Phillips science of dental materials. 10^{th} ed. W.B.Saunders Co. 1996; Pp: 281–285.
13. Hsu HC, Kikuchi H, Yen SK, Nishyama M. Evaluation of different bonded investments for dental titanium casting. *J Mater Sci Mater Med*. 2005; 16: 821–825.
14. Luk HW, Darvell BW. Strength of phosphate–bonded investments at high temperature. *Dent Mater*. 1991; 7: 99–102.
15. Li Z, Hao F, Xiong Y. The study of compressive strength of phosphate–bonded investment materials. *Hua Xi Kou Qiang Yi Xue Za Zhi*. 2003; 21: 284–286.
16. Meng Y, Nakai A, Ogura H. Development of casting investment preventing blackening of noble metal alloy part 3.Effect of reducing agent addition on the strength and expansion of the investments. *Dent Mater J*. 2004; 23: 129–135.
17. Nakai A. Study of resin bonded calcia investment: Part I: setting time and compressive strength. *Dent Mater J*. 2000; 19: 283–293.