

# Effect of Wax Burn-Out Heating Temperature on The Compressive Strength of Casting Dental Alloy Investment

**Lamia T Rejab**  
BDS, MSc (Lect)

**Department of Prosthetic Dentistry**  
College of Dentistry, University of Mosul

## ABSTRACT

**Aims:** To evaluate the effect of the burn-out heating on the compressive strength of investment materials. **Materials and Methods:** Three commercial investment materials were used in this study. Seventy two cylindrical shape specimens were prepared to evaluate the compressive strength of the investment materials at room temperature (cold strength) and at two different burn-out heating temperatures : 700 °C and 1000 °C (hot strength). Three groups were prepared according to tested investment materials, The specimens were then subdivided into three subgroups according to burn-out heating temperatures, eight specimens for each subgroup. The compressive strength (kg /cm<sup>2</sup>) was evaluated by using Instron testing machine. Mean values were compared statistically with one way analysis of variance (ANOVA) ,Duncan 's multiple range test and t-test to determine the significant difference among the tested groups at ( $p<0.05$ ) level of significance. **Results:** The results showed that there is a significant difference of the means value of the compressive strength among the three tested investment materials. The compressive strength value significantly decreased with increasing burn-out heating temperature. **Conclusion:** The result of this study showed that the increase of burn-out heating had a significant decrease the compressive strength of the investment materials, and cold compressive strength gives an indication of the hot strength .

**Key words :** investment, compressive strength, burn-out heating

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## INTRODUCTION

Investments used with the wax pattern in forming molds for casting dental alloys of various types consist of powdered refractory, a binder, and modifiers. The refractory base is usually some crystalline form of silica (SiO<sub>2</sub>) . The binder in these investments are either gypsum binder, or silica-binder or phosphate binder. The modifiers employed are boric acid and sodium and other chlorides, graphite, colloidal copper and others substances that would tend to produce a non-oxidizing atmospheric in the mold<sup>(1,2)</sup>. The nature of the binder characterizes the material. There are three main groups of investment material in common use. They are referred to as gypsum-bounded , silica-bounded and phosphate-bounded materials<sup>(3)</sup>.

Silica-based phosphate-bounded investments have been commonly used for casting high temperature melting noble and base metal alloys in dentistry<sup>(4)</sup>, they are now routinely employed for the preci-

sion casting of high-fusing dental alloys, to construct a variety of dental restorations ranging from removable partial dentures to multi-unit bridgework substructures<sup>(5-7)</sup>. The main criteria govern the selection of investment materials for casting dental alloys are the casting temperature of the alloy being cast, and the thermal expansion required from the investment to compensate for casting shrinkage of the alloy being cast to ensure a satisfactory fit<sup>(1,2,3,8)</sup>. Since casting is carried out at very high temperatures, often in excess of 1000°C, the investment mold should be capable of maintaining its shape and integrity at these elevated temperatures<sup>(1,6,7,9,10)</sup>.

The phosphate-bounded investments fulfill these requirements. These investments can be mixed with water or with a special liquid or with a combination. The special liquid is a form of silica sol in water. When mixed with the silica sol, the phosphate-bounded investments exhibit a higher setting expansion than when mixed with water<sup>(11)</sup>.

The burn-out operation serves three purposes: it drives off moisture in the investment mold, it vaporizes and thus eliminates the wax pattern, leaving a cavity in the mold to compensate for contraction of the metal on cooling<sup>(12)</sup>.

The aim of this study was to evaluate the effect of burn-out heating on the compressive strength of the investment materials, by evaluating the compressive strength of the three commercial phosphate-bonded investment materials (PBI) at room temperature and after heated at two different burnout temperatures 700 °C and 1000 °C.

### MATERIALS AND METHODS

Three commercial investment materials were tested in this study. Rema Exakt (DENTAURUM, Germany) investment for cobalt-chromium model casting Biosint-Supra (Degussa, Germany) special investment for the Co-Cr-Mo model casting technique, Deguvest soft (Degussa, Germany) precision investment for the complete range of precious metal casting technique. To evaluate the compressive strength values of the investment materials the specimens were prepared according to the ADA specification No. 2 for casting investment for dental alloy. The speci-

mens prepared as cylindrical 25 mm in diameter and 50 mm high<sup>(1)</sup>. Special brass split mold was used, the mold was coated with a separating medium before pouring to facilitate the removal of the specimen, (Figure 1). Powder of the tested materials and distilled water were hand mixed according to the manufacturer's instruction. The dental casting investment should be porous enough to permit the air or other gases in the mold cavity to escape easily during the casting procedure<sup>(2)</sup>. The materials that are so closely packed and they are virtually porosity free, there is a danger of back pressure building up which will cause the mold to be incompletely filled or the casting to be porous<sup>(3)</sup>. The prepared mixed was poured down the side of the mold retained on glass plate. The mold was then vibrated gently while being filled using electrical vibrator (Qualy Dental, England) then a second glass plate placed on top of the over-filled mold and pressed flush with mold ends to ensure parallel ends. The cylinders specimens were removed from the mold as soon as they are hard enough to handle (25minutes), and stored in air at room temperature  $23 \pm 2$  °C at least for two hours before testing<sup>(1, 13)</sup>.

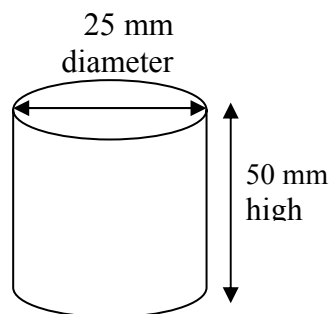


Figure (1): Special split mold for cylindrical shape specimen

Seventy two specimens were prepared. Three groups of specimens were prepared according to the tested investment material, twenty four specimens were prepared from each material, then each group subdivided into three subgroups (eight specimens for each subgroup) according to the temperature at which to be heated: one at room temperature and two at different

burn-out heating temperatures which were 700 °C and 1000 °C. For gold alloys burn-out at 700 °C. For Ni/Cr alloys a temperature in the range 700 °C-900 °C is normal, while for Co/Cr alloys a burn-out temperature of 1000 °C is typical<sup>(3,8,12,13)</sup>. So there was nine tested groups in this study: Group I (Rema Exakat at room temperature), Group II (Rema Exakt after heating

at 700 °C) Group III (Rema Exakt after heating at 1000 °C) , Group IV (Biosint-Supra at room temperature), Group V (Biosint-Supra after heating at 700 °C), Group VI (Biosint-Supra after heating at 1000 °C), Group VII (Deguvest soft at room temperature), Group VIII (Deguvest soft after heating at 700 °C), Group IX (Deguvest soft after heating at 1000 °C).

Burnout process started with a cold casting oven using type (Kavo, Leuykirch, Germany) to avoid heated too rapidly in the oven that may cause the investment to crack. Then the temperature of the oven increased slowly to a temperature of over period of 2 hours . This temperature then maintained for at least 30 minutes (heat-soaking) period to ensure uniform heat penetration<sup>(3,12)</sup>.

The specimens were crushed at a loading rate of 150 ± 30 kg /minute at different temperatures: when they are 2 hours old at room temperature (cold strength)<sup>(1)</sup> , and (hot strengths) after burn-out heated at 700 °C and 1000 °C. The compressive strength was evaluated by using Instron testing machine.

Statistically mean values and standard deviation were calculated. Mean values of the tested materials at room temperature were compared with one way analysis of

variance (ANOVA) followed by Duncan ' s multiple range test to determine the significant different at ( $p \leq 0.05$ ) level of significance. while t-test was carried out to determine the significant different between the tested groups at room temperature and at two different burn-out heating temperatures at ( $p < 0.05$ ).

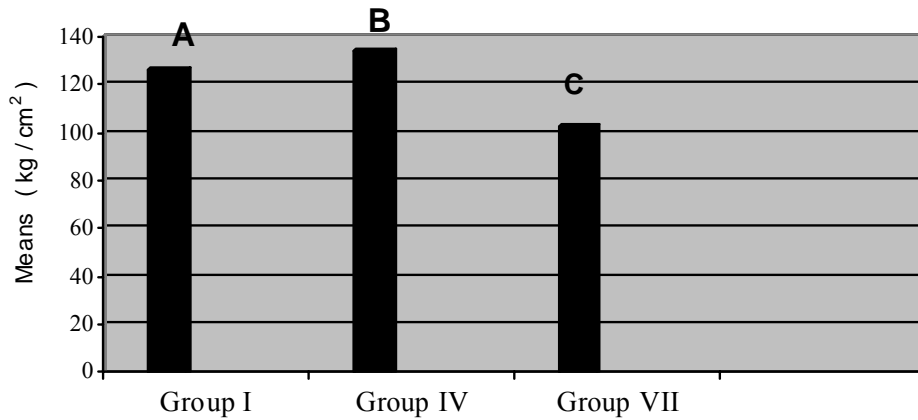
## RESULTS AND DISSCUSION

Means value of the compressive strength of the tested groups in this study are shown in Table (1), Figures (2 and 3). The results of ANOVA and Duncan ' s multiple range test in Tables (2 and 3) show there is a significant difference between the mean value of the compressive strength of the three tested investment materials at room temperature (Groups I, IV and VII). The difference in the compressive strength of the tested materials can be related to the several factors depending on chemical composition, refractory particles size and handling techniques<sup>(6,7,14,15)</sup>. As the tested investment materials are commercial and the exact chemical composition of them are unknown, the complexity of the present results suggest that several factors may be operating, so all of these possible factors can affect the strengths of the investment.

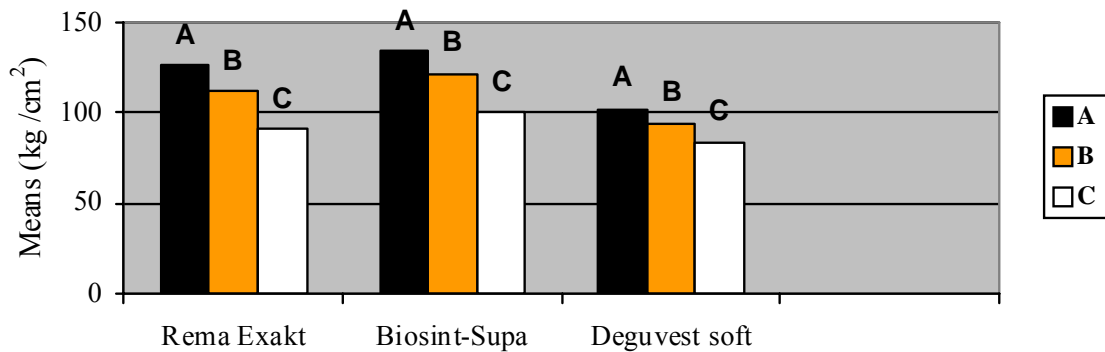
Table (1): Means of the compressive strength (kg /cm<sup>2</sup>) of tested groups of the investment materials before and after burn-out heating at two different temperatures

| Tested groups            | Group I | Group II | Group III | Group IV | Group V | Group VI | Group VII | Group VIII | Group IX |
|--------------------------|---------|----------|-----------|----------|---------|----------|-----------|------------|----------|
| No                       | 8       | 8        | 8         | 8        | 8       | 8        | 8         | 8          | 8        |
| Mean Kg /cm <sup>2</sup> | 126.07  | 112.18   | 90.77     | 133.80   | 121.27  | 99.83    | 102.28    | 94.41      | 84.05    |

Group I: Rema Exakt at room temperature, Group II: Rema Exakt after heating at 700 °C, Group III: Rema Exakt after heating at 1000 °C, Group IV: Biosint-Supra at room temperature, Group V: Biosint-Supra after heating at 700 °C, Group VI: Biosint-Supra after heating at 1000 °C, Group VII: Deguvest soft at room temperature, Group VIII: Deguvest soft after heating at 700 °C, Group IX: Deguvest soft after heating at 1000 °C. No : Samples number



Figure(2):Means of the compressive strength of the tested investment materials at room temperature.Group I: Rema Exakt at room temperature, Group VI: Biosint-Supra after heating at1000 °C, Group VII: Deguvest soft at room temperature



Figure(3):Means of the compressive strength of the tested investment materials at different heating temperature  
**A:** Means of the compressive strength at room temperature; **B:** Means of the compressive strength at 700 °C heating temperature; **C:** Means of the compressive strength at 1000 °C heating temperature; Means with different color are highly significant different at  $P \leq 0.01$

Table ( 2 ): ANOVA for the means of the compressive strength (kg /cm<sup>2</sup>) of tested groups of investment materials at room temperature

| Source of variation  | DF | Tested groups of investment materials |         |          |
|----------------------|----|---------------------------------------|---------|----------|
|                      |    | Mean square                           | F-value | P- value |
| <b>Tested groups</b> | 2  | 2158.4                                | 7.33    | 0.000    |
| <b>Error</b>         | 21 | 29.8                                  |         |          |
| <b>Total</b>         | 23 |                                       |         |          |

DF : Degree of freedom .

Table (3): Duncan Multiple Range test for the compressive strength (kg /cm<sup>2</sup>) of tested groups of investment materials at room temperature

| *Tested groups   | No | **Mean ± SD   | Grouping |
|------------------|----|---------------|----------|
| <b>Group IV</b>  | 8  | 133.80 ± 4.36 | <b>A</b> |
| <b>Group I</b>   | 8  | 126.07 ± 4.21 | <b>B</b> |
| <b>Group VII</b> | 8  | 102.28 ± 7.26 | <b>C</b> |

Group I: Rema Exakt at room temperature, Group IV: Biosint-Supra at room temperature, Group VII: Deguvest soft at room temperature, No : Samples number SD : Standard deviation

The results of t-test in Tables (4,6,8) appeared that there is a highly significant difference between the mean value of the compressive strength of the three tested investment materials at room temperature (Groups I, IV and VII) and after burn-out heating at 700 °C (Groups II, V and VIII). The result showed that there is decrease in the value of the compressive strength of the three tested investment after burn-out heating at 700 °C. This result indicated that the compressive strength of the investment materials is affected by heating and the strength at room temperature (cold strength) it is not the same hot strength, or it not represent that at high temperature. When the investment is heated, silica reduce the compressive strength<sup>(11)</sup>. This result come in agreement with the finding of Juszczyka *etal*<sup>(7)</sup> in that the high temperature strengths are markedly lower than those reported for the same materials at room temperature, Also this result come in agreement with the finding of Luk *etal* and other<sup>(15,16)</sup> they found that the high-

temperature compressive strength was greatly decreased by thermal transformation of crystallization of silica and thermal decomposition of the binder Silica transformation explained in that quartz and cristabolite are the two allotropic form of silica that are commonly employed for the formation of dental investments. There is an  $\alpha$ - to  $\beta$ -phase transformation for cristabolite and quartz from 220 to 270 °C and at 573 °C respectively and those lead to volumetric expansion on heating, such expansion has been utilized to compensate for much of the alloy thermal contraction, but it must lead to a slightly less dense mass which may therefore weaken it and also during the burn-out process, crack occur in the heating of variation in the expansion on heating between components as well as effect due to decomposition reaction. The progressive change in strength with temperature due to the development of liquid phase or breakdown of bonding<sup>(15,17)</sup>.

Table (4) : T- test for the difference in the means of the compressive strength (kg /cm<sup>2</sup>) of Rema Exakt investment material at room temperature and burn-out heating at 700 °C

| Tested material | No | **Tested groups<br>(Mean ± SD) |               | DF | T-value | P- value |
|-----------------|----|--------------------------------|---------------|----|---------|----------|
|                 |    | Croup I                        | Croup II      |    |         |          |
| Rema Exakt      | 8  | 126.07 ± 4.21                  | 112.18 ± 4.36 | 13 | 6.48    | 0.0000   |

No: samples number for each group; DF: degree of freedom ; Tested groups: Group I: Rema Exakt at room temperature; Group II: Rema Exakt after heating at 700 °C.

Table (6) : T- test for the difference in the means of the compressive strength (kg /cm<sup>2</sup>) of Biosint-Supra investment material at room temperature and burn-out heating at 700 °C

| Tested material | *No | **Tested groups<br>(Mean ± SD) |               | DF | T-value | P- value |
|-----------------|-----|--------------------------------|---------------|----|---------|----------|
|                 |     | Croup IV                       | Croup V       |    |         |          |
| Biosint-Supra   | 8   | 133.80 ± 4.36                  | 121.27 ± 2.74 | 11 | 6.88    | 0.0000   |

No: samples number for each group; DF: degree of freedom; Group IV: Biosint-Supra at room temperature; Group V: Biosint-Supra after heating at 700 °C.

Table (8) : T- test for the difference in the means of the compressive strength (kg /cm<sup>2</sup>) of Deguvest soft investment material at room temperature and burn-out heating at 700 °C

| Tested material | No | Tested groups<br>(Mean ± SD) |              | DF | T-value | P- value |
|-----------------|----|------------------------------|--------------|----|---------|----------|
|                 |    | Croup VII                    | Croup VIII   |    |         |          |
| Deguvest soft   | 8  | 102.28 ± 7.26                | 94.41 ± 4.19 | 11 | 2.65    | 0.022    |

No: samples number for each group; DF: degree of freedom; goup VII: Deguvest soft at room temperature; Group VIII: Deguvest soft after heating at 700 °C

The results of t-test in Tables(5,7,9) appeared that there is a highly significant difference between the mean value of the compressive strength of the three tested investment materials after burn-out heating at the two different temperatures 700 °C (Groups II, V and VIII) and 1000 °C (Groups III, VI and IX). This result come in agreement with the finding of Luck *et al* <sup>(18)</sup> They found that higher casting temperature could effectively reduce the

strength of PBI by raising the investment temperature This result can be explained in that the melting temperature of sodium salts are normally low, example sodium sulfate melting point 884 °C, sodium chloride melting point 801 °C and sodium disilicate melting point 874 °C <sup>(19)</sup>, so these melting points of sodium salts which are lower than the burn-out temperature 1000 °C could be the possible event that can reduce the strengths of the investment.

Table (5) : T- test for the difference in the means of the compressive strength (kg /cm<sup>2</sup>) of Rema Exakt investment material at burn-out heating 700 °C and burn-out heating 1000 °C

| Tested material | No | Tested groups<br>(Mean ± SD) |              | DF | T-value | P- value |
|-----------------|----|------------------------------|--------------|----|---------|----------|
|                 |    | Croup II                     | Croup III    |    |         |          |
| Rema Exakt      | 8  | 112.18 ± 4.36                | 90.77 ± 2.95 | 12 | 11.50   | 0.0000   |
|                 |    |                              |              |    |         |          |

No: samples number for each group; DF: degree of freedom; Group II: Rema Exakt after heating at 700 °C; Group III: Rema Exakt after heating at 1000 °C.

Table (7) : T- test for the difference in the means of the compressive strength (kg /cm<sup>2</sup>) of Biosint-Supra investment material at burn-out heating 700 °C and burn-out heating 1000 °C

| Tested material | No | Tested groups<br>(Mean ± SD) |              | DF | T-value | P- value |
|-----------------|----|------------------------------|--------------|----|---------|----------|
|                 |    | Croup V                      | Croup VI     |    |         |          |
| Biosint-Supra   | 8  | 121.27 ± 2.74                | 99.83 ± 3.23 | 13 | 14.31   | 0.0000   |
|                 |    |                              |              |    |         |          |

No: samples number for each group; DF: degree of freedom; Group V: Biosint-Supra after heating at 700 °C; Group VI: Biosint-Supra after heating at 1000 °C

Table (9) : T- test for the difference in the means of the compressive strength (kg /cm<sup>2</sup>) of Deguvest soft investment material at burn-out heating 700 °C and burn-out heating 1000 °C

| Tested material | No | Tested groups<br>(Mean ± SD) |              | DF | T-value | P- value |
|-----------------|----|------------------------------|--------------|----|---------|----------|
|                 |    | Croup VIII                   | Croup IX     |    |         |          |
| Deguvest soft   | 8  | 94.41 ± 4.19                 | 84.05 ± 6.02 | 12 | 4.00    | 0.0018   |
|                 |    |                              |              |    |         |          |

No: samples number for each group; DF: degree of freedom; Group VIII: Deguvest soft after heating at 700 °C; Group IX: Deguvest soft after heating at 1000 °C.

The results in Table (1) showed that for cold ( room temperature) strength the order of strength of the tested materials was, Biosint-Supra material (Group IV) has the higher value (133.8 kg /cm<sup>2</sup>) followed by Rema Exakt (Group I) which was (126.07 kg /cm<sup>2</sup>), while Deguvest soft( Group VII) material has the least value (102.28 kg /cm<sup>2</sup>), and for hot strength the order is

the same for the tested materials at the two burn-out heating temperatures 700 °C (Groups V, II and VIII) and 1000 °C (Groups VI, III and IX) . This result indicated that the order of the value of the compressive strength of the compared tested material investment materials at room temperature (cold strength) are the same after burn-out heating (hot strength). This result come in

agreement with the finding of Jon<sup>(17)</sup> suggested that comparison of room temperature strengths of pre-fired specimens with hot strengths may give a good indication of spalling tendency of these materials. However Luk *etal*<sup>(20)</sup> conclusion that no indication of high temperature strength can be gained from low temperature measurement. The strength at casting temperature may be quite different from that of a 2 hours old specimens measure, in accordance with the specification, at room temperature. The effect of the temperature depend on the additives<sup>(1)</sup>.

So test at working temperature provide the most important information about the strength of these materials. A method of testing which applied a force at casting temperature and at a rate similar to dental casting would provide a more realistic assessment of the strength of PBI<sup>(17)</sup>.

### CONCLUSION

The results appeared there is a significant difference of the mean value of the compressive strength of the tested investment materials, Biosint-Supra material has the higher value and Rema Exakt has lower value while Deguvest soft has the least value, and the compressive strength of the three tested investment material at burn-out heating temperatures (700 °C and 1000 °C) was markedly reduce from that at room temperature in the same order that indicated that the cold strength of the tested investment materials gives an indication of the high burn-out heating temperatures strength.

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