Effects Of Setting Under Positive Pressure In Closed Pot And Atmospheric Pressure On Surface Roughness And Bubbles Of Dental Gypsum Bonded And Phosphate Bonded Investment Material- An In Vitro Study.

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**ARTICLE INFO**

**ABSTRACT**

**Aim:** The purpose of this study was to investigate the effect of air pressure on the pore numbers and surface roughness of the Specimens present than specimens set under atmospheric pressure.

**Material and Methods:** Four dental investments, 2 gypsum-bonded investment and 2 phosphate-bonded investments, were investigated. They were vacuum mixed according to the manufacturers’ recommendations, then poured into a ringless casting system. The prepared specimens were divided into 2 groups: 1 Setting under atmospheric pressure and the other placed under pressure pot at 1.72 bar. After 45 minutes of setting, the rings were removed and the investments were cut at a right angle to the long axis with a saw. Total 32 specimens were observed. The surfaces of the investments were steam cleaned, dried with an air spray, and observed with a stereomicroscope. A profilometer was used to evaluate the surface roughness (mm) of the castings. The number of surface pores was counted for 8 specimens from each group and the means and standard deviations were reported. Two-way ANOVA was used to compare the data.

**Results:** For both types of dental investment materials, the groups that set under atmospheric air (WOP) had a significantly higher number of pores or bubbles on their surfaces than specimens that set under air pressure (WP) (P<.05). The surface morphologies done by Stereomicroscope. For both types of dental investment materials, the groups that set under atmospheric air (WOP) had a significantly higher number of pores or bubbles on their surfaces than specimens that set under air pressure (WP) (P<.05).

**Conclusion:** Specimens set under positive air pressure in a pressure pot present fewer surface bubbles and surface roughness than specimens set under atmospheric pressure.
INTRODUCTION:

Surface roughness and irregularities are important properties of dental investment materials that can affect the fit of a restoration. Whether setting under air pressure affects the surface irregularities of gypsum-bonded and phosphate-bonded investment materials is unknown. Surface roughness and irregularities can affect the fit of a restoration. It is unknown whether different investment techniques have an effect on surface roughness and irregularities of gold palladium alloy castings. The purpose of the casting process is to accurately reproduce a wax pattern.

A defective casting results in a considerable loss of time and effort. Types of defects in castings have been classified into 4 broad categories:\(^1\):

1. Distortion,
2. Surface roughness and irregularities,
3. Porosities, and
4. Incomplete or missing castings.

Surface roughness and irregularities, though synonymously used, are not interchangeable terms. Surface roughness refers to finely spaced imperfections, of which the height, width, and direction establish the predominant surface pattern.\(^1\) Surface roughness can be lessened by abrading and polishing procedures, ensuring in this way a good tissue response to the alloy.\(^6-8\) A smooth surface not only prevents plaque and calculus accumulation, but it also improves the corrosion resistance of the alloy.\(^8\) Furthermore, surface roughness on the intaglio surface of the cast restoration affects the fit of the restoration.\(^9\) Therefore, the smaller these flaws are, the better the fit of a restoration to the surface of the prepared tooth.

There are a variety of factors that have an important role in controlling surface roughness and irregularities. These factors include the liquid-powder ratio of the investment, air bubbles in the investment, water films, rapid heating rates, under heating, prolonged heating, the temperature of the melted alloy, casting pressure, composition of the investment, investment technique, foreign bodies, impact of molten alloy, carbon inclusions, and mixing and melting different alloys together.\(^1,2\)

Casting should fit the preparation properly and that is free from bubbles and any irregularities. The investment of the wax pattern is one of the most important steps in the technique and the surface properties and roughness of the investment materials are important aspects. Studies have reported that roughness can be increased either by water clinging to the pattern and weakening the investment that forms the surface of the mold or by air trapped in the investment and forming bubbles that cling to the wax pattern during the investment process.

Two methods have been suggested to overcome the surface irregularities of investment materials: Careful hand or mechanical spatulation of the mixture of water and investment to eliminate air bubbles and great care in applying the mixture to the pattern by brushing, painting, and mixing the investment in a vacuum. Mixing the investment in a vacuum gave a smooth mold surface almost free of air bubbles.

Great attention has been given to the mixing and application of investment to wax patterns, but no study has been done of the investment after pouring the casting ring. Study showed that specimens subjected to air pressure during the setting of the investment had fewer trapped air bubbles. Specimens that set under atmospheric pressure showed increased surface irregularity than those that set under positive pressure. The use of pressure could help produce castings with fewer surface irregularities. The influence of the handling technique on the strength of phosphate-bonded investments and found that setting under pressure significantly reduced the pore size of the set investment material, which led to increased mechanical strength.

The effect of different investment techniques using different investment materials and alloys on various properties of castings has been studied by several investigators. The fit of dental casting alloys, investments, and techniques to determine which were superior. Better fitting castings were made from
molds that had more available expansion. A phosphate-bonded, carbon containing investment (Ceramigold) and a high fusing gold alloy (Ceramco no.1) produced the best fitting castings.

Use of vacuum has been suggested as an effective technique to minimize air bubbles in castings, thereby lessening surface roughness and irregularities. Several manufacturers have developed investors that allow both mixing and investing to be performed under vacuum. Additionally, the use of pressure which is greater than the atmospheric pressure may also be an effective method to produce smooth castings. The rationale is that the pressure acts by reducing the size of the air bubbles present in the investment. Furthermore, pressure may help reproduce surface details by forcing the particles of the investment closer together. Previous studies[22-24] have also focused on the surface finish, marginal fit, and dimensional accuracy of dental alloys when cast with accelerated investing techniques and with the ringless system.

MATERIALS AND METHODS:
The present study was conducted in the department of prosthodontics, Crown & Bridge to evaluate the effect of pressure on surface roughness and porosity of gypsum bonded and phosphate bonded investment material.

The methodology is described under following headings:
1) Materials used.
2) Instruments used.
3) Grouping of specimens
4) Fabrication of specimens for testing surface roughness and porosity
5) Imaging under stereomicroscope.
6) Surface roughness testing of the specimens under profilometer.
7) Statistical analyses

1. MATERIALS USED:
   1. Investment material
      1) Phosphate bonded -(1) chromo Casting- A, Ruthinium group
         - (2) BC West,
      2) Gypsum bonded –(1) Satin Cast – 20
         (2) Kerr Cast -2000
      2) Expansion liquid for phosphate bonded investment material
      3) Distilled water

2. INSTRUMENTS USED:
   1. Rubber bowl
   2. Plaster spatula
   3. Water measuring jar
   4. Vacuum mixer (MESTRA IRIS 2, Evolution)
   5. Ring-less casting system
   6. Pressure pot (MESTRA, Precision Maxima 2kg.cm$^2$)
   7. Saw
   8. Lathe machine
   9. Stereomicroscope (Olympus DF PLAPO SZ X 7)
   10. Profilometer

3. GROUPING OF THE SPECIMENS:
Grouping of the specimens was done as follows:

Total specimens (n=32)

Setting under atmospheric pressure (WOP) (n=16) Setting under pressure pot(WP)(n=16)

SAWOP KEWOP RUWOP BCWOP SAWP KEWP RUWP BCWP
(n=4) (n=4) (n=4) (n=4) (n=4) (n=4) (n=4) (n=4)
(SA, Satin cast; KE, Kerr cast; RU, Ruthinium; BC, BC west; WOP, Bench setting; WP, Pressure pot)
4. FABRICATION OF SPECIMENS FOR TESTING SURFACE ROUGHNESS AND POROSITY:

For testing Surface roughness and porosity, specimens in each group were mixed for 20 seconds, 400 rpm according to manufacturer’s instructions in vacuum mixer (Figure 2). After vacuum mixing each specimen was invested in ringless casting system (Figure 3). Now from 32 specimens 16 specimens from 4 subgroups of bench test group were set under bench testing for 45 minutes, 72Kpa. 16 specimens from 4 subgroups of pressure group were set under pressure in pressure pot for 45 minutes, 72Kpa. (Figure 4)

After 45 minutes of setting, the rings were removed and the investments were sectioned at a right angle to the long axis (figure 5). The cross-section surfaces of the investments were steam cleaned (Triton SLA; Bego), air-dried, and each specimen sized 3×2×1 cm observed with a stereo microscope at 10 magnification (National Institute of Occupational Hazards, Civil) so final field view from stereomicroscope will be 19.6 mm according to specification of SZ×16 olympus stereomicroscope (Figure 5 and 7). The number of surface pores was counted for 16 specimens of each group. The surface roughness (µm) was counted 25 mm linear for 16 specimens from each group with profilometer (Gujarat Energy Research And Management Institute). (Figure 6)

The means and standard deviations were calculated. Two-way ANOVA (factors: material×pressure) was used to compare the data obtained at a significance level of α=0.05 by using software.

ARMAMENTARIUM (Figure 1)
1) Pressure Pot,
2) Vacuum Mixing Apparatus With Mixing Bowl,
3) Two Gypsum Bonded Investent Material,
4) Two Phosphate Bonded Investment Material,
5) Ringless Casting System

Figure 1

Figure 2
Surface morphology of each sample group under stereomicroscope (Figure 7)
Figure 14 A) & B: Photomicrographs Of Surfaces Of Different Materials
RESULTS

Surface roughness of specimens are measured in μm in 25 mm linear. according to data lowest surface roughness among all groups is in ruthenium specimens under pressure group(RUWP). The highest surface roughness among all group is in BC WEST without pressure group (BC WOP). Sample number is assigned to every specimen to identify specimen group. Number of surface pores.

Surface pores are counted under stereomicroscope under 10 X magnification of 19 mm area according to specification of stereomicroscope. lowest surface pores are measured in RUWP and BC WP. Highest surface pores are measured in BC WOP. Among the group comparison group 1,3,5 and 7 are under one group and 2,4,6 and 8 are under another group.

**Table 1.** of Means of WOP group as below, which shows highest mean of surface roughness seen in
BCWOP among intra group comparisons. Lowest mean of surface roughness is seen in SAWOP and in KR WOP groups. Data of surface roughness (µm)

Graph 1 and Graph 2 shows comparison charts within groups

**Graph: 1.** Means (µm) of samples which were set without pressure (atmospheric pressure)

Table 2 shows means of WP groups comparison, in which highest mean of surface roughness (µm) is seen in SAWP and lowest mean surface roughness is seen in RUWP. Surface roughness in ascending order, RUWP < BCWP < KRWP < SAWP

**Graph: 2.** Means (µm) of samples which were set with pressure

<table>
<thead>
<tr>
<th>material</th>
<th>Mean(µm)</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
<th>95% Confidence Interval</th>
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<tr>
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Graph 3 presents comparison of intergroup means with all groups, it shows significant difference with WP and WOP. Highest difference of surface roughness in RUWOP, RUWP and between BCWOP, BCWOP. There is also significant difference among SAWP, SAWOP and in KRWP, KRWOP.

### Means of Surface Roughness (µm)

![Means of Surface Roughness](image)

Pie Diagram Showing Comparison Of WP and WOP Groups, greater than 50% of pie is covered by WOP groups.

**Table 3** shows pairwise comparison of surface roughness with each group intergroup as well as intra group.

#### Pairwise Comparisons

<table>
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<tr>
<th>(I) material</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>P VALUE</th>
<th>95% Confidence Interval for Difference&lt;sup&gt;d&lt;/sup&gt;</th>
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<tr>
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<td></td>
<td></td>
<td>17.00</td>
<td>31.29</td>
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### Table 1

<p>| | | | | | |</p>
<table>
<thead>
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As small p value ≤ 0.05 indicates strong evidence against null hypothesis, every data has significant value (p value < 0.05) except comparison of SA WP, KR WP (0.460) and SAWOP, KRWOP (0.998). In which these groups comparison groups are intra group comparison (within same group).

Highest significance (<0.001) is seen in groups mentioned below:

SAWP-BCWOP
SAWOP-RUWP

**RUWP-RUWOP**
**RUWP-BCWOP**
**RUWP-KRWOP**
**RUWP-BCWP**
**BCWOP-KRWOP**

**Graph 4 and Graph 5** represents number of surface pores comparison of two groups (WP AND WOP) INTRA GROUP

**Graph 4** shows lowest number of surface pores is in RUWP group,
Graph 5 shows highest surface pores found in BCWOP group.

Graph 6
Comparison of mean between two groups of bubbles Data shows highest difference found in group BC WP, BCWOP. Each group has significant difference of numbers of surface pores. Which shows significantly lower number of surface pores in WP groups.
For both types of dental investment materials, the groups that set under atmospheric air (WOP) had a significantly higher number of pores or bubbles on their surfaces than specimens that set under air.
pressure (WP) (P<.05) as shown in Table 4. However, no significant difference was observed between the 2 different types of materials tested (P>.05).

The surface morphologies of SAWOP, SAWP, RUWOP, RUWP, BCWP, BCWOP, KRVP, and KRWOP are shown in Figure 2 done by Stereomicroscope. The descriptive statistics for the number of pores are presented in Table I. For both types of dental investment materials, the groups that set under atmospheric air (WOP) had a significantly higher number of pores or bubbles on their surfaces than specimens that set under air pressure (WP) (P<.05) as shown in graph 4, 5 and 6.

**DISCUSSION**

Successful casting procedures require meticulous attention to detail during the spruing and investing procedures to ensure production of an accurate mold. Proper choice of the properties of the investment and knowledge of the properties of the investment can aid in controlling the size of the final restoration. Proper sprue size, placement of the liner, position of the pattern in the ring, and cleanliness and neatness of equipment all aid in production of a clean, well-fitting final restoration.

Problems associated with spruing and investing the pattern do not usually become apparent until the casting is recovered from the mold and tried on the die. Problems with the fit of the casting, either too large or small, can usually be traced to failure to follow the investment manufacturer’s instructions. Alteration of water-powder ratio, and mixing rate can alter the size of the casting.

Lack of attention to neatness when spruing and investing the pattern can cause such problems as porosity, bubbles, incomplete margins, or rough surfaces. To prevent problems, it is important to develop and maintain a consistent investment technique. In our study consideration has been given to water powder ratio, spatulation techniques, ringless casting and setting of investment material under pressure. During investing of the pattern, the correct water powder ratio of the investment mix, a required number of spatulation turns, and a proper investing technique are essential to obtain acceptable casting results. In our study water-powder ratio was according to manufacturer’s instruction as study done by Takahashi J, Okazaki M, Taira M, Kubo F on Nonuniform vertical and horizontal setting expansion of a phosphate-bonded investment. It has been concluded that, the characteristics of investments depend on various factors such as the liquid-powder ratio, particle size and chemical composition of the powder, and mixing methods. The time between mixing and heating influences the setting behavior of the investment. Moreover, setting expansion may lead to distortion of the wax pattern. In 2000 Juszczyk et al. also found the influence of the handling technique on the strength of phosphate-bonded investments and found that setting under pressure significantly reduced the pore size of the set investment material, which led to increased mechanical strength.

Spatulation of the investment material can be done manually as well as mechanical (vacuum) mixing. The use of vacuum mixing has been proposed by many researchers because of its advantages like, minimize air bubbles in castings, thereby lessening surface roughness and irregularities. It was first advocated in The study on relative merits of vacuum investing of small castings as compared to conventional methods' by Ralph W. Phillips in 1947 who concluded that, Vacuum investing produces a denser mass of investment, as measured by an air flow meter, which results in slightly greater crushing strength of investment. The increased density of the investment in turn produces a denser gold surface. In 1948 Hollenback also suggested Use of vacuum is an effective technique to minimize air bubbles in castings, thereby lessening surface roughness and irregularities. The study conducted by H. W. Lyon, I. C. Schoonover 1953 on Effectiveness of vacuum investing in the elimination of surface defects in gold castings and concluded that The vacuum investing technics used in this investigation produced a much higher percentage of nodule-free castings than did the atmospheric pressure technic use. In 1986 Scrabeck JG, Eames WB, Hicks MJ suggested Two methods to overcome the surface irregularities of investment materials, careful hand or mechanical spatulation of the mixture of water and investment to eliminate air bubbles and great care in applying the mixture to the pattern Spatulation methods and porosities in investment and impression materials. In 1991 Hero H,
Waarli M. [36] studied Effect of vacuum and super temperature on mold filling during casting and conclude that roughness can be increased either by water clinging to the pattern and weakening the investment that forms the surface of the mold or by air trapped in the investment and forming bubbles that cling to the wax pattern during the investment process.

There are two methods of investing the wax pattern: hand investing and vacuum investing. In both cases, the proper amount of investment powder and water should be used, following the manufacturer's instructions exactly. The water is added first, followed by the slow addition of the powder to encourage the removal of air from the powder. The powder and liquid are mixed briefly with a plaster spatula until all the powder is wetted.

For that in our present study, for testing Surface roughness and porosity, specimens in each group were mixed for 20 seconds, 400 rpm according to manufacturer’s instructions in vacuum mixer.

The investment technique used is a matter of clinician or technician preference. However, the pressure chamber used in this study was a useful tool in producing castings with fewer surface irregularities and should be used during investing procedures. This is important, since surface irregularities can interfere with the complete seating of the casting. Although removal of these irregularities is often feasible, their presence may sometimes necessitate remaking of the restoration, especially if the irregularities are located near the margins of the casting. This situation can be frustrating for the patient, clinician, and technician.

The use of pressure in close pot has many advantages on surface roughness and surface pores as In 1973 Chandler HT, Fisher WT, Brudwik JS, Bottiger G. [17] studied on Vacuum-air pressure investing advocated the use of pressure for investment and reported that this method has been successfully used by the authors for casting over 20,000 units. In our study final result of two groups was like with pressure (WP) and without pressure (WOP). According to final result TABLE 1, lowest surface roughness among all groups is in ruthenium specimens under pressure group (RUWP). The highest surface roughness among all group is in BC WEST without pressure group (BC WOP). The means of all subgroups can be presented in ascending orders as RUWP<BCWP<KRWP<SAWP<SAWOP<KERRW OP<RUWOP<BCWOP. According to these data, there is less surface roughness in under pressure group than without pressure. Surface pores according to Graph: 6 shows Comparison of mean between two groups of bubbles Data shows highest difference found in group BC WP, BCWOP. The descriptive statistics for the number of pores are presented in Table 1. For both types of dental investment materials, the groups that set under atmospheric air (WOP) had a significantly higher number of pores or bubbles on their surfaces than specimens that set under air pressure (WP) (P<.05) as shown in Table 4.

Each group has significant difference of numbers of surface pores. Which shows significantly lower number of surface pores in WP groups In 1994, Johnson and Winstanley [18] also showed that specimens subjected to air pressure during the setting of the investment had fewer trapped air bubbles. The study on Wiropress SL: A Multipurpose Dental Pressure Vessel with Transparent Chamber By Nels Ewoldsen and Sreeniuas Koka [35] in 1998 evaluated Pneumatic vessels used in dentistry provide a pressurized environment to enhance the outcome of many laboratory procedures. A pressurized environment directs volume loss associated with polymerization shrinkage, minimizes air inclusions in powder/liquid mixtures, raises the boiling point of liquids, and facilitates flow of impression and replication materials, improving surface detail. The following report illustrates the usefulness of a reliable pneumatic vessel during denture base repair resin processing and replication of pattern details. These both studies prominently suggest the effect of positive pressure on surface properties detail which is supporting our study results. Another important significance of positive pressure has been evaluated by Bedi [31] et al in 2008 and Anita et al [40] who reported that specimens that set under atmospheric pressure showed increased surface irregularity than those that set under positive pressure. They concluded that the use of pressure could help produce castings with fewer surface irregularities.
The use of ringless casting has many advantages over metal ring. Use of it in our study is due to many evident studies which advocates the use of ringless casting. In 1980, Dern WM, Hinman RW, Hesby RA, Pelleu GB Jr. \cite{22} studied Effect of a two-step ringless investment technique on alloy castability and conclude The possible usefulness of a ringless system attached to the vacuum mixer and investor for investing purposes is an issue that should be addressed. The ringless system was used with phosphate bonded investments originally for the fabrication of removable partial denture frameworks, and recently for the fabrication of fixed partial dentures. In 1985, Dern WM, Hinman RW, Hesby RA, Pelleu GB Jr. \cite{22} had studied Effect of two-step ringless investment technique on alloy castability, The use of the casting ring was challenged with the introduction of a ringless technique initially for phosphate-bonded investments for removable partial denture frameworks and, recently, for conventional fixed restorations and even experimentally for implant-connected frameworks. The high strength of the material makes it possible to abandon the use of the casting ring. The ringless techniques are easier, less expensive, and give clinically acceptable castings. This study had compared 2 casting techniques for fixed restorations. In 1992, Morey EF, Earnshaw R. \cite{37} The fit of gold-alloy full-crown castings made with pre-wetted casting ring liners., The ringless technique for investing and casting has been in use for many years for the fabrication of frameworks for removable partial dentures. It was introduced in fixed prosthodontics technology. With the use of a ringless technique, the restriction of thermal expansion that is associated with the presence of the metal ring is avoided. In this study, the margin discrepancy of castings produced with the ringless technique and the conventional technique using the metal ring were compared.

The study conducted on Dimensional accuracy of castings produced with ringless and metal ring investment systems by Pelopidas Lombardas, Andres Carbunaru, Mona E. McAlarney and R. W. Toothaker, 2000 \cite{23} had concluded that

1. The vertical margin discrepancy of the ringless group for the buccal, the lingual, and the distal sites were significantly less than that of the 2 ring groups (P<.001).
2. There was no significant difference of the vertical margin discrepancy between the 2 metal ring groups.
3. There was no significant difference in the vertical margin discrepancy at the buccal, lingual, mesial, and distal surfaces within the same group.
4. The ringless technique was clinically acceptable and can be used for the fabrication of fixed prosthodontics restorations. Further investigation should be conducted to be determined whether it can be used for the fabrication of implant-supported prostheses.

In our study, slight differences were observed in the number of surface bubbles in phosphate bonded and gypsum-bonded investment materials, which might be attributed to a different surface chemistry or laboratory errors.

**SUMMARY**

In 21st century, though availability of CAD-CAM casting, the conventional casting method is still choice of method because of its cost effectiveness and simple procedure. So improvements in conventional casting have been topic of interest. The ultimate goal of casting process is to accurately reproduce a wax pattern. Different factors like investing technique which includes correct water powder ratio, use of vacuum investing; use of ringless casting system and use of air pressure for setting altogether affects surface roughness and number of surface pores of the casting investment.

Optimal use of all techniques leads to optimal casting and fitting of restoration. Use of closed pot to set casting under pressure has been proposed. In present study use of optimal water powder ratio, ringless casting system, vacuum investing, and closed pot to set investment under pressure. Measurement of surface roughness and surface pores has been done with use of Profilometer and stereomicroscope. The results show decrease in surface roughness and surface pore numbers. As surface roughness and surface pores decrease, it leads to smoother surface which ensures good tissue response to the alloy as well increased corrosion resistance of the alloy. These all lead to increase in quality of the final prosthesis.
Within the limitations of the current study, the following conclusions are drawn:

1. Specimens set under positive air pressure in a pressure pot present fewer surface bubbles than specimens set under atmospheric pressure.
2. The surface roughness of the Specimens set under positive air pressure in a pressure pot is significantly lower than specimens set under atmospheric pressure.

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