The Relationship Between the Marginal Integrity, Surface Adaptation of Cast Base Metal Crown and Storage Time & Conditions of investing

Mostafa Gomaa* and Ali Fahmy**

* Lecturer of Fixed prosthodontics, Faculty of Dentistry Misr International University.
**Assistant professor of fixed prosthodontics, Faculty of Dentistry Misr International University.
Corresponding author: yeheaali60@hotmail.com

ABSTRACT: The conventional investing technique is used most commonly for casting. Conventional casting techniques require considerable time, typically one hour for bench set (generally judged as the time taken for the investment to reach its maximum exothermic setting reaction temperature) for the investment and 1 to 2 hours for the wax elimination. It has been traditional either to cast invested wax patterns immediately after the investment has set or to store the invested patterns in a humidor for casting later. Sometimes, due to unexpected conditions, the bench set may extend to many hours. **The purpose of this study** was to evaluate different storage conditions effect and time before wax elimination on the marginal fit & surface adaptation (cement space) of base metal alloy crowns invested in phosphate-bonded investment material. This study compared the marginal fit , surface adaptation (cement space) of base metal alloy crowns to parent dyes after 1 hour following the setting of the investment in air, storage in a humidor for 12, 24 and36 hours, and storage in air for the same period of time before wax elimination. **Material and Methods** : A total of 35wax patterns were made simulating the artificial crown from the master dye (for investigation of surface adaptation and marginal accuracy) ,divided into three groups ; Group A (control group ;n=5) 1hour bench set. Group B divided into 3 subgroups B1(n=5),B2(n=5) &B3(n=5) ,rings stored in a humidor for 12, 24 & 36 hours respectively.. Group C divided into 3 subgroup C1(n=5),C2 (n=5),C3 (n=5) rings stored in air for 12,24 &36 hours respectively. Wax burnout was carried out for all rings followed by casing using base metal alloy (Wiron Light) following the manufacturer instructions. Marginal discrepancy and surface adaptation of Groups A, B, and C were determined using measuring microscope .The obtained values of Groups A, B, and C were subjected to statistical analysis using student's "t" test. **Results:** The study showed that as regard to marginal discrepancy there were significant differences between the control group A and each of tested groups (at $P<0.05$) .But for surface adaptation, the only significant difference were observed between point 2 in group A 138.8(±13.8), and point 2 in subgroup B2, 226,3 (±8.7). Also significant difference was observed between all measuring points in group A and that in all measuring points in subgroup B3. **Conclusions:** Increasing storage time of the invested wax pattern in humidor or air, adversely affects the marginal integrity. Invested wax patterns that had been stored for 36 hours in a humidor were demonstrated remarkable changes in surface adaptation in comparison with the control group especially at occlusal area. Storing the wax patterns in air for different periods had no statistical difference from control group.

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Key words: Marginal discrepancy- Surface adaptation- Bench set- Humidor- Master dies- Counter die

1.Introduction

Casting is one of the extremely demanding processes in dentistry. Virtually all the castings are done using adaptation of lost wax technique the conventional/standard investing and casting procedures for dental restorations call for minimum 1 h bench set for investment, followed by one or two stage burnout procedure before casting [Anusavice (2003)]. The whole process requires 2–4 h for completion.The four mechanisms that play an important role are, setting expansion, hygroscopic expansion, wax pattern expansion and thermal expansion [Hasti and Patil (2010)].

To obtain a good cast restoration, care should be taken at each step of fabrication namely impression making, wax pattern fabrication, spruing and investing and casting. Investing the wax pattern and casting procedure is the most critical step where there are more chances for making an accurate casting. Therefore, it is essential to know about properties and behaviors of the materials used in investing procedures for a range of dental appliances and also the interaction that can occur with casting alloys, when cast into an appropriate mould [Dental Investments(2012)].

Achieving a casting with accurate fitting and less surface roughness has been one of the most difficult tasks, which are the important criteria to render the casting fit. Marginal fit has always been of great importance. The fit of the casting is the direct accuracy indicator of the casting. Surface roughness can be external or internal. Internal surface roughness or even a small nodule can indirectly result in marginal gap width, and even can limit uniform space for luting cement [Hasti and Patil (2010)].

Most laboratories use phosphate bonded investment for all alloys—precious and non-precious. The main advantage of phosphate over gypsum investment is that it can withstand the much higher heating required for non-gold and low-gold alloys ,as well as, ceramics. Expansion can also be adjusted with the colloidal silica liquid. As a result, phosphate investments are compatible with many different alloys and ceramics[Boyd and Knopf(1998)].

A typical phosphate investment system consists of three key components: Binder, Refractory, and Liquid. The binder system is the most important component in a phosphate investment because it can have the greatest effect on the overall investment performance. It is even more important in the rapid burnout investments. The binder chemistry can affect all of the main properties that are considered important for an investment: Setting time, Setting expansion Strength, Thermal expansion, Pattern expansion, Cracking & spalling, and Casting size. [Hasti and Patil (2010)]

The investment is allowed to set for the recommended time (usually one-hour) then the crucible former is removed. If a metal sprue former is used, it is removed by heating over a flame to loosen it from the wax pattern. Any loose particles of investment should be blown off with compressed air. The ring should be placed in a humidor if stored overnight, [Krishnan(2011)]

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

Surface roughness and irregularities, though synonymously used, are no interchangeable terms. Surface roughness refers to finely spaced imperfections, of which the height, width, and direction establish the predominant surface pattern. [Phillips(2003); Powers and Sakaguchi(2006)]

Surface roughness can be lessened by abrading and polishing procedures, ensuring in this way a good tissue response to the alloy [Shafagh(1986)] .

A smooth surface not only prevents plaque and calculus accumulation, but it also improves the corrosion resistance of the alloy. Furthermore, surface roughness on the intaglio surface of the cast restoration affects the fit of the restoration, [White et al.,(1991)] .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, [Phillips (2003)]

The effect of different investment techniques using different investment materials and alloys on various properties of castings has been studied by several investigators [Custer and Desalvo (1968); Bedi et al.,(2008)] studied the accuracy of castings produced by various investments and casting techniques and stated that a technique is only a means to an end. It can be altered with a working knowledge of instruments and materials to produce the desired results.

While Lacy et al, (1985) studying axial setting expansion under various conditions, they described an anomalous event in which set gypsum-bonded investment apparently shrank in volume in 24 hours, eliminating all axial expansion.

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. [Takahashi et al.,(1999)].The traditional methods of handling invested wax patterns have been to heat the molds and cast after 45- to 60-minute bench set or to store the invested patterns in a humidor, purportedly to prevent cracking of the investment and aid in the elimination of wax from the mold by the creation of steam during heating.

The effect of the time between mixing and heating on the expansion of four phosphate bonded investments was investigated. Setting and thermal expansion of the same specimen was measured in a dilatometer. Unexpectedly large differences in setting expansion occurred between the investments. The combined setting and thermal expansion of one investment was affected by the time between mixing and heating [Stevens and DipEdTech (1986)].

Marginal fit and adaptation is crucial for the prognosis of restorations including metal-ceramic crowns. Any marginal discrepancy can lead to micro leakage, marginal discoloration, secondary caries and eventually failure of restoration [Aggarwal et al.,(2008)] .Various factors including ceramic firing effect, curvature of finish line and type of cement on the effect of the marginal adaptation of metal-ceramic crown restorations has been reported[Beschnidt and Strub(1999)] .Regarding finish lines, there are conflicting results in the literature. Majority of authors suggests that shoulder finish lines produce less marginal discrepancy as compared to chamfer finish lines. On the other hand, several investigators have reported that the finish line design has no effect on the marginal discrepancy of conventional full crowns [Syu et al.,(1993);Beschnidt and Strub(1999)].Dennis et al., (1991) mentioned that, because few published reports could be found to support the need for humidor storage, the purpose of his investigation was to study the effects of storage conditions of gypsum-bonded investment on the fit of MOD inlay castings. The authors identified no study that evaluated the surface roughness and cast accuracy of base metal alloys cast with phosphate-bonded investments by leaving the ring after investing to deferent periods of time before casting.

The purpose of this study was to evaluate the effect different storage conditions and times before wax elimination on the marginal fit & surface adaptation (cement space) of base metal alloy crowns invested in phosphate-bonded investment material.

2.MATERIALS AND METHODS:

2.1.Materials:

2.1 .1. Investments:

-Phosphate-bonded investment, Bellvest (Bego, Bermen, Germany).

-Nickel-Chromium base metal alloy, Wiron Light (Bego, Bermen, Germany).

Master die was fabricated with a die and a former i.e. counterpart, it was divided into 3 parts (Fig. 1).

Table (1):Stainless die, splitted counter die and circular brass ring.

2.1.2. Master die and wax pattern of the crown;

Stainless steel master dies representing the prepared molars with 8mm base diameter, 8mm height, with 5º convergence angle and 0.3 mm chamfer finishing line. The die was fabricated with a root like portion in the form of cylinder, 20 mm height, and 10 mm diameter. One groove was made on the axial wall cervical to the finishing line for proper repositioning of the casting on its corresponding die. The Stainless Steel master die was duplicated with polyether impression material (Impregum-F, ESPE, and Germany) using custom made trays and these were poured with type IV improved stone (Ultra rock, India). A total number of 25 dies were prepared.

In order to standardize the construction of the wax pattern a one slatted bras counter die was machined in form of ring with internal diameter of 9.1 mm and 14 mm height (8 mm from the plane top was converge 5º while the remaining of 6 mm was parallel walls to guarantee the centralization of the master die inside the counter die).This centralization allowed 1mm space for the wax pattern.

A single circular brass ring with 2mm thickness and height and with 13.1mm internal diameter was machined for stabilizing the slatted counter die during working (fig 2).

Figure2::Stainless steel master die with crown and sectioned die and crown

The bras counter die was assembled and stabilized with the ring, and filled with molten blue inlay wax. The die was lubricated with separating medium and inserted into the bras counter die and stabilized in position by stable finger pressure during hardening of the wax pattern. The counter die was separated from the master die and the wax pattern was adapted and carved against the die .A reference groove was made on the axial wall of the wax pattern extending with the reference groove of the master die by the aid of a sharp probe for proper repositioning of the casting on its corresponding die.

Each crown pattern was placed on its corresponding die and examined carefully, if margins were satisfactory, the wax pattern was sprued and invested using Bellavest (Bego) investment material following the manufacturer instructions.

2.2.Methods:

2.2.1.Storage and casting of the invested rings;

-Invested wax patterns crown were cast after storage under one of three conditions.

***Group** rings were cast after a 1 -hour set in air (control group)

***Group B** rings stored in a humidor (plastic tube with water-saturated paper on the bottom and a tightly fitting lid) .This group were divided into three subgroups, B1 (n=5) stored for 12 hours, B2 (n=5) stored for 24 hours and B3 (n=5) stored for 36 hours before casting

***Group C**. rings stored in air and divided into three subgroups, C1 (n=5) stored for 12 hours, C2 (n=5) stored for 24 hours and C3 stored for 36 hours before casting.

Burnout of the wax patterns were carried out, then the specimens were cast using induction casting machine (Fornex, Bego,Germany) following the manufacturer instructions. The castings were divesting, sand blasted, all sprues were removed with thin carborundum disk.

All the 35 crown castings were obtained. The internal surface of crown castings were inspected with the magnifying glass and relieved of visible nodules with round carbide bur. Castings were cleaned with distilled water in an Ultrasonic Cleaner for 12 min, sprayed with an air water syringe and then dried.

2.2.2. Measuring of marginal discrepancy:

Each casting was seated on the Stainless steel master die and repositioned on its reference groove. Then the casting was exposed to a static load of 5 KG to obtain a maximum seating of the casting on the die. The marginal discrepancy between the margin of the casting and the steel die finishing line was measured under measuring microscope through 4 measurements at 90º a part around the circumference of the casting, then the average of the measurements and standard deviation of the marginal fit was calculated. student's "t" test was used to compare the mean values in all groups.

2.2.3. Measuring of surface adaptation:

The castings were luted under a 5-kg load using Dyract Cem (Caulk/ Dentsply) a dual-cure acid resin modified cement .The cement was used only to prevent the castings from shifting during measuring procedures and sectioning with a diamond saw. The castings were sectioned mesiodistally and the arbitrarily designated facial half was finished through consecutively finer grits to 30-fim diamond grit. All finishing was done away from the dies as much as possible, except for the diamond finishing, which was done with a rotary motion. Measurements of cement spaces between the castings and the dies were made at five sites (Fig 3) using a measuring microscope. The measurement sites were marked on the stone surfaces of the arbitrarily designated facial halves of the mesiodistal sections using a sharp metal scribe ,a metal millimeter rule and was established by measuring all sites on all sections and then repeating the measurements on each section.

2.2.4. Statistical Analysis:

Measurements at each site between the groups were compared using student's "t" test.

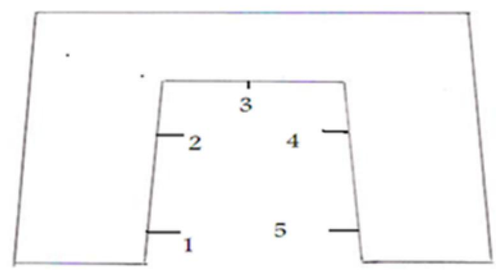

Fig 3 Schematic drawing of the sites at which cement spaces were measured

3.RESULTS

The collected data was tabulated and illustrated graphically according to the mean marginal and axial discrepancy (μm) of the casting obtained from casting the ring after storage the investment ring for:

1- Group A one hour bench set before casting
2- Group B stored in humidor and divided into three subgroups, B^1, B^2 and B^3 for 12, 24 and 36 hours respectively.
3- Group C stored in air and divided into three subgroups, C^1, C^2 and C^3 for 12, 24 and 36 hours respectively.

The results were analyzed statistically using student's "t" test paired. The level of significance was taken at P value <0.05.

3.1.Effect of investment storage time in marginal discrepancy:

As shown in table (1) and figure (4) ,the lowest mean marginal discrepancy (122± 14.3) with recorded after one hour bench set while the highest mean marginal discrepancy (143± 13.2) with recorded after 48 hours storage in humidor. Statistically by using student's "t" test paired, there were significant differences between the control group A and each of tested groups at P<0.05

Table 1- Mean of marginal discrepancy & Standard deviation in all groups

Groups	A	B			C		
		B^1	B^2	B^3	C^1	C^2	C^3
Average	122	128	135	143	126	130	136
S D	±14.3	±15.4	± 15.7	± 13.2	± 15.5	± 13.6	± 16.3
Student's T test, paired		A & B^1 , A& B^2 , A& B^3 [Significant]			A & C^1 , A& C^2 , A& C^3 [significant]		

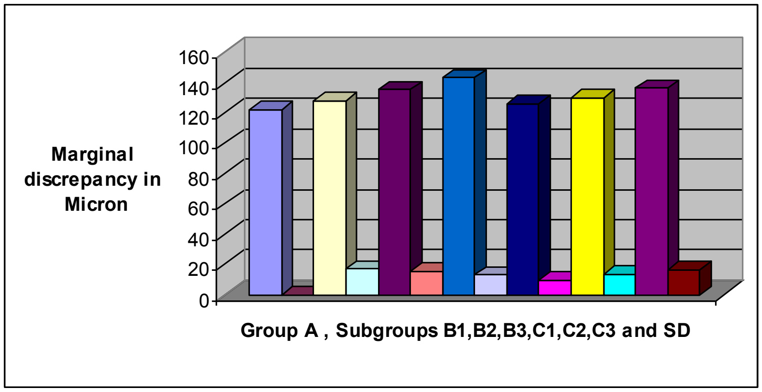

Figure 4- Mean of marginal discrepancy & Standard deviation in all groups

3.2.Effect of investment storage time in surface adaptation:

The mean (SD) of surface adaptation(cement space) in all groups were presented in table 2 and Figures 5&6.the results showing a slight difference in surface adaptation in most readings but the maximum decrease in cement space were observed in subgroup B2 at measuring point 3 (226,3 ±8.7) and subgroup B3 at all measuring points 151.2 (±12.8), 124 (±11.7), 210 (±10.8), 127.6 (±9.5) and 147.6 (±11.5).

Statistically by using student's "t" test paired , (table 3) the only significant deference were observed between point 2 in group A 138.8(±13.8), and point 2 in subgroup B2, 226,3 (±8.7). Also significant deference were observed between all measuring points in group A and that in all measuring points in subgroup B3

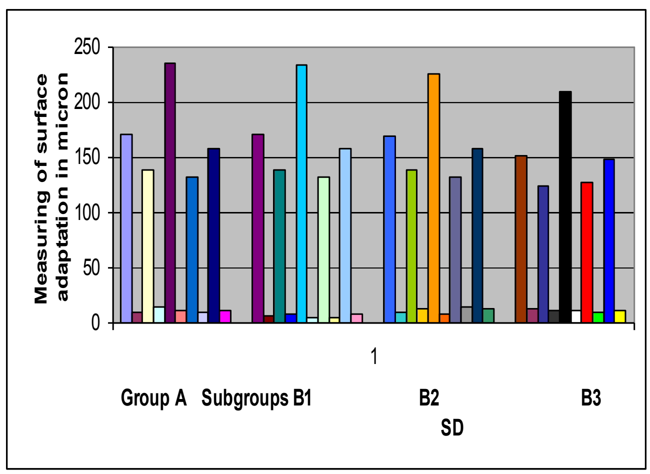

Figure 5: Comparison between cement space mean and standard deviation of group A and group

Table 2- Mean and S D. of surface adaptation in all groups

Groups & Sub-groups		Point 1	point 2	point 3	point4	point5
		Mean and S D. of surface adaptation at each measuring point				
A		170.6 (±10.4)	138.8(±13.8)	235 (±11.5)	132.8 (±9.3)	158.8 (±10.6)
B	B¹	170.3 (±6.4)	138.7 (±8.3)	234.8 (±5.6)	132.6 (5.5)	158.2 (±7.3)
	B²	169.6 (±9.5)	138.4 (±12.4)	226,3 (±8.7)	132.5(±14.5)	158.3 (±13.2)
	B³	151.2 (±12.8)	124 (±11.7)	210 (±10.8)	127.6 (±9.5)	147.6 (±11.5)
C	C¹	169.8 (±9.7)	138.5 (±11.3)	234.7 (10.6)	132.5 (±12.4)	158.7 (±13.5)
	C²	170 (±11.3)	137.9(±9.7)	234.5(±14.8)	131.6(±12.5)	158.4 (±9.5)
	C³	170.2 (±8.2)	137.6 (±8.5)	234 (±16.6)	132 (±8.9)	157.9 (±16.5)

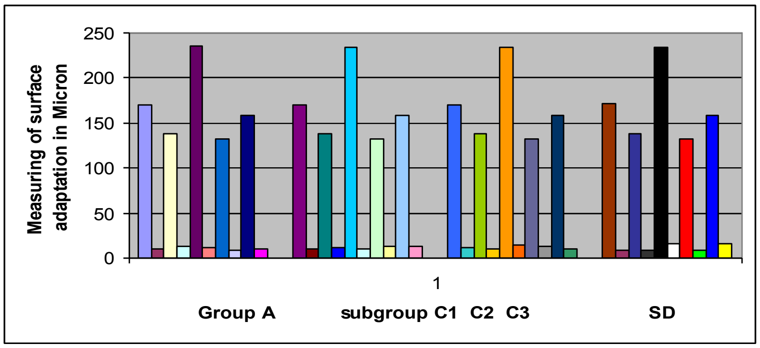

Figure 6- Comparison between cement space mean and standard deviation of group A and group C

Table 3 - Statistical analysis between Group A And all Subgroups

Subgroups		B1	B2	B3	C1	C2	C3
Group		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
A	1	NS	NS	S	NS	NS	NS
	2	NS	NS	S	NS	NS	NS
	3	NS	S	S	NS	NS	NS
	4	NS	NS	S	NS	NS	NS
	5	Ns	NS	S	NS	NS	NS

4.DISCUSSION

In this study one of the aim was focused on the investigating the differences in marginal fit and surface adaptation of cast crowns made after different period and conditions of investment storage before casting. Fit was determined on the master die to standardized the volumetric size not on stone die to minimize several factors other than casting procedures such as the impression materials used and their techniques and process for making a working die.

From this study, significant difference was found in marginal adaptation (fit) between Group A (control) and each of the subgroups B¹, B², B³, C¹, and C² & C³ respectively.

For surface adaptation (cement thicknesses), it was clear that subgroup B³ (storage for 36 hours in a humidor) showing remarkable decrease in cement thickness at all measuring points in comparison with the control group with lowest values at point 2 ,this results were in accordance with results obtained by Dennis et al.,(1991) who mentioned that, to meaningfully decrease the space between the dies and the castings seen in the humidor-stored group, the investment within the wax patterns would have to decrease in diameter. A decrease in diameter could occur from a rearrangement of gypsum crystals or from deformation of the investment. Because radial expansion is restricted by the walls of the casting rings, further investment movement after the 1-hour set could only proceed axially to preferential path of least resistance. If such a deformation occurred casting from humidor-stored investment would expected to be longer axially than those cast after setting or after drying in air.

While the absolute physicochemical causes of the dimensional changes in the molds are unknown, there are interesting physical and chemical properties of gypsum investments that could be responsible for such behavior. Using x-ray diffraction, Hascoust and Lautenschlager(1970) demonstrated that unreacted calcium sulfate hemihydrate remained after the material had reached its final set according to either Vicar or Gillmore tests or clinical judgment. Thus, it is possible that maintaining a most environment helps the reaction to continue beyond the first hour set and cause the mold to deform.

Maintenance of a moist environment may also allow reorganization of the crystalline matrix by a mechanism similar to the dissolution and precipitation equilibrium of gypsum in an aqueous medium .Careful examination of the set investment surface adjacent to the axio-gingival junction of the wax pattern before burnout suggests that a reorganization of crystals may have occurred, producing a surface with definite pores and large crystals [Dennis et al.,(1991)].

Another result of storage of set investment in a humid environment could increase hydration of silica, forming silanol groups (SiOH) on the surface of the silica particles [Dennis et al.,(1991)].If the hydration were enough to cause the particles to increase in diameter , distortion of the investment could occur if the damp gypsum crystal matrix were deformable under those conditions.

Conclusions

Under the limitation of the present study it was concluded that;

1- Increasing storage time of the invested wax pattern in humidor or air, adversely affect the marginal integrity.
2- Invested wax patterns that had been stored for 36 hours in a humidor were demonstrated remarkable changes in surface adaptation in comparison with the control group especially at occlusal area.
3- Storage the wax patterns in air for the different period had no statistical difference from control group .

For the investment used in this study the results suggested that an invested wax pattern should not be stored in a humidor for 36 hours before casting.

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