Measuring and comparing the surface roughness of nickel chromium alloy by using different types of air abrasive materials such as carborundum, aluminum oxide and glass beads.

قياس ومقارنة خشونة السطح لسبائك النيكل كروم باستخدام انواع مختلفة للمواد الكاشطة مثل المواد المفحمة، أكسيد الألومنيوم، الحبيبات الزجاجية.

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Abstract

Background: One of the important applications of the Abrasive blasting materials such as carborundum, aluminum oxide, glass beads are used to remove rust, impurities, and coatings (paint) from crown and bridges or removable partial denture (chromium cobalt) . Sandblasting techniques are used for cleaning metals, when the metal exposed to abrasive materials to cleaning industrial as well as They are the most important materials used in dental applications but is rarely used for non-metallic work pieces. Surface roughness of cast metal frameworks may lead to difficulties in finishing or polishing procedures and weaken the framework.

This study aims: Measuring and comparing the surface roughness of nickel chromium alloy by using different types of air abrasive materials such as carborundum, aluminum oxide, glass beads and evaluating the results of the surface roughness test of nickel chromium alloy after using different types of air abrasive.

Methods: Thirty samples from ni.cr. Alloy that exposed to air abrasive materials such as (carborundum, aluminum oxide, glass beads) and specimens were prepared as follow:

1- 10 samples for group A (aluminum oxide). 2- 10 samples for group B (carborundum).

3- 10 samples for group C (glass beads).

Results: Showed that significant differences among these groups. It appeared that the physical properties are: the carborundum material (higher surface roughness 2.22) and the glass beads (lower surface roughness 1.77).

Conclusion: the results revealed that the higher surface roughness is the carborundum materials that can be use for retention with ceramic while the lower surface roughness is the glass beads material can be use for cast crown or bridge or removable partial denture (chromium cobalt).

Keywords: nickel chromium, air abrasive materials (carborundum, aluminum oxide, glass beads).

الخلاصة

الخلفية: من اهم التطبيقات للمواد الكاشطة مثل المواد المفحمة وأكسيد الألومنيوم والحبيبات الزجاجية هي لإزالة الصدأ، الشوائب ، والطلاء (الدهان) من التيجان والجسور أو الطقوم الجزئية المتحركة (الكروم كوبلت). باستخدام تقنيات الرمي بالرمال لتنظيف المعادن، عندما المعدن يتعرض للمواد الكاشطة للتنظيف الصناعي، فضلا عن ذلك فهي تعتبرمن اهم المواد المستخدمة في تطبيقات طب الأسنان، ولكن نادراً ما يستخدم في العمل غير المعدنية. خشونة السطح للهياكل معدنية قد تؤدي إلى صعوبات في التشطيب أو التلميع وهذه الطريقة قد تؤدي الى إضعاف الهياكل المعدنية.

الهدف: قياس ومقارنة خشونة سطح سبائك النيكل الكروم باستخدام أنواع مختلفة من المواد الكاشطة مثل المواد المفحمة ، وأكسيد الألومنيوم ، الحبيبات الزجاجية. تقييم نتائج اختبار خشونة السطح من سبائك النيكل الكروم بعد استخدام أنواع مختلفة من المواد الكاشطة.

الطريقة: ثلاثين من ni.cr. سبيكة تم تعرضها للهواء المواد الكاشطة مثل و(مواد المفحمة ، وأكسيد الألومنيوم، الحبيبات الزجاجية) وعينات أعدت كالتالي :1 – (10) عينات للمجموعة A (أكسيد الألومنيوم).2 –(10) عينات للمجموعة B (مواد المفحمة).3- (10)عينات للمجموعة C (الحبيبات الزجاجية).

النتائج: وأظهرت النتائج أن فروق ذات دلالة إحصائية بين هذه المجموعات. ويبدو أن الخاصية الفيزيائية هي: المواد المفحمة (أعلى خشونة السطح) الحبيبات الزجاجية (أقل خشونة السطح).

المناقشة: نستخلص من هذه النتائج إلى أن أعلى خشونة السطح هو المواد المفحمة التي يمكن استخدامها للثباتية مع السيراميك في حين أن اقل خشونة السطح للمواد الحبيبات الزجاجية يمكن استخدامها في عمل التيجان والجسورالمعدنية او الطقوم الجزئية المتحركة (الكروم كوبلت).

Introduction

Base metal alloys, such as cobalt-chromium (Co.Cr) and nickel-chromium (NiCr), have been widely used in the fabrication of fixed and removable partial denture frameworks since being introduced to dentistry in 1929.These alloys have increasingly replaced gold alloys owing to improved mechanical properties and decreased cost [1].

The primary physical-chemical properties of base metal alloys include a lower density than gold alloys, a particularly useful feature in fabricating bulky maxillary prostheses and a modulus of elasticity that is nearly twice that of gold alloys, providing fixed and removable partial dentures (FPD and RPD) with the advantage of maintaining rigidity with less bulk. These properties allow for improved esthetics and physiological contouring and the development of a suitable occlusion with less tooth structure reduction. However, technical short comings, such as the increased difficulty of grinding and polishing procedures with conventional chair side and laboratory instruments, restricted the use of base metal alloys in dental practice. More recently, improvement in alloy composition and development of new manufacturing techniques have optimized the use of these alloys [2].

The surface of the casting should be smooth and highly polished. Such surfaces limit the accumulation and retention of plaque and facilitate maintenance of health of the supporting periodontal tissues. Although conventional polishing kits reduced the surface roughness and adhesion, Ni. Cr alloy restorations are still showing a considerable amount of surface roughness with strep of coccus mutans adhesion, Schmalz and Garhammer [3].

During the last years several works were accomplished on the increase of the bond strength of resin to metals, mainly through surface treatment of metallic alloys [4].

There is several materials available for abrasing to metal because increase the bonding resin veneers .Aluminium oxide is an amphoteric oxide with the chemical formula Al_2O_3. It is commonly referred to as alumina (α-alumina), oxide, or corundum in its crystalline form, as well as many other names, reflecting its widespread occurrence in nature and industry. Its most significant use is in the production of aluminum metal, although it is also used as abrasive owing to its hardness and as a refractory material owing to its high melting point [3].

There is also a cubic γ-alumina with important technical applications.

Is a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite [5].

Silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics which are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide as light emitting diodes (LEDs) and detectors in early radios were first demonstrated around 1907 and today SiC is widely used in high-temperature/high-voltage semiconductor electronics. Large single crystals of silicon carbide can be grown by the Lely method; they can be cut into gems known as synthetic moissanite. Silicon carbide with high surface area can be produced from SiO_2 contained in plant material [6].

Glass Bead blasting can be used on a wide range of materials including metal, glass, plastic and rubber. The smaller the glass spheres, the smoother the surface; larger spheres produce a more textured finish [7].

In the present study, Measuring and comparing the surface roughness of nickel chromium alloy by using different type of air abrasive such as carborundum, aluminum oxide and glass beads.

Materials

The materials used in this study were:-

1. Modeling base plate wax (Hilfex, Lot No.300601, Exp.Date:7:2010, India).
2. Sprue wax (Dentaurum, Germany).
3. Ring liner (Kera-vlies, asbestos- free strips, Dentaurum, Germany). Surface tension reducing agent (nordenta, FINO SPANN-EX, Exp. Date: 2009, Germany).
4. Phosphate bounded investment (Free carbon, Gilvest, Batch No. 6134069775, Exp. Date: 4:2008, Germany).
5. Special liquid for mixing the investment (Gilvest liquid, Lot No. 6134069775, Exp. Date: 4:2008, Germany).
6. Ni-Cr alloy (Eisenbncher dental warn, kera, HD, Lot No.22674 Germany.fig(2)
7. Aluminum oxide powder ((polishing beads 50µm-110µm) Shera, Germany).fig(3)
8. Carborundum powder (polishing beads, Dentaurum, Germany). Fig(4)
9. Glass beads powder (polishing beads, Shera, Germany). Fig(5)
10. Sand paper (grit 220, China).
11. Distilled water (Iraq).
12. Separating medium (Iraq).
13. Soft tissue paper (Iraq).

Figure (1): Materials use of the study

Figure. (2): NI.CR. alloy

Figure (3): Aluminum oxide powder

Figure (4) Carborundum powder

Figure (5) Glass beads powder

Equipments:

The equipments which are used in this study, as shown Figure (6, 7, 8 and 9):-

1. Wax cutter, (hand made).
2. Metal casting ring (size 3X, Degussa, Germany).
3. Crucible former (Degussa, Germany).
4. Dental polishing bristle brush (Germany).
5. Cloth polishing brush (Degussa, Germany).
6. Hand piece engine (micromotor machine), (MF- Tectorque, W&H, Austria) Straight hand piece (W&H, Austria).
7. Carborundum Red Hi-speed disc, 100μm Aluminum oxide, Moores Co., USA).
8. Diamond disc (Meisinger, fine, Germany).
9. Stone burs (QD, England).
10. Vacuum- automixing device with vibrator (Bego, Germany).
11. Electrical furnace for wax burnout (200-1300C°, Derotor, QD, England).
12. Gas-Oxygen single orifice torch (Degussa, Germany).
13. Casting crucible (Degussa, Germany).
14. Manual driven broken arm centrifugal casting machine (TSI, Degussa, Germany).
15. Sandblast machine (Minipol, Degussa, Germany).
16. Profilometer (Pocket Surf.) machine (Mahr, FEDERAL, Germany).

Figure (6): Hand piece engine with Some abrasive instrument

Figure (7): Vacuum-auto mix device

Figure (8): Sandblast machine

Figure (9): profilomrter (Pocket Surf.)

Methods:

Samples grouping: thirty samples were divided into 3 groups according to the types of the air abrasive materials used, as Fig.10. Each group consisted of 10 specimens:

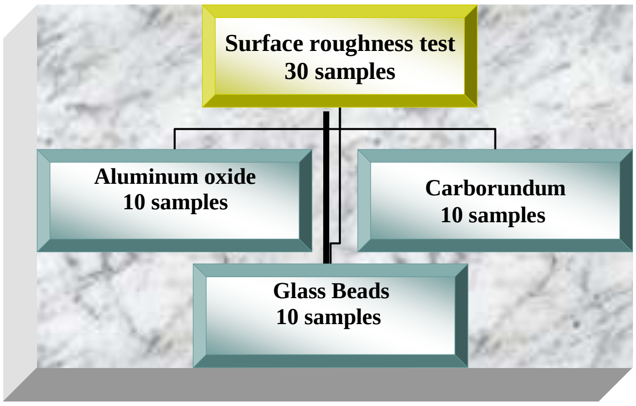

Figure (10) Samples grouping

Samples Preparation

Thirty square piece of modeling base plate wax [1(centimeter) cm in length, 1cm in width] [8, 9] were cut using wax cutter, as describes in Fig. 11.

Figure (11): Wax cutter used for preparing wax pattern.

Especially designed, wax cutter was used two saw discs (used for cutting the stone dies) mounted on aluminum plate handle (L-shape), 1cm apart to facilitate uniform cutting of wax without irregular borders, was should be stored in a refrigerator before using to avoid dimensional changes, then three points of each wax pattern could be measured by wax caliper device to check the uniform thickness (1.5mm) for each pattern. The spruing process was done, each six samples were sprued by sprue wax of (2.5mm thickness) attached to the running bar of (5mm in diameter) and the whole wax pattern was attached to the crucibl former to be away from the end of the ring in about (6mm), Fig. 12. [10]

The last four samples were sprued in the same manner and attached to the crucible former. Now, the samples were ready for investing procedure.

Figure (12) showed the spruing procedures.

Debubblizing agent (surface tension reducer) was sprayed on the upper and lower surface of wax pattern, and left for drying for (5 min.). [10]

A casting ring number 3X was used for investing with dry asbestos-free liner which was used to line the casting ring before its fixation on the crucible former, as appears in Fig. (12). A phosphate-bonded investment was mixed according to manufacturer instructions; each [100 (gram) gm] of powder was mixed with [24 (milliliter) ml] of its special liquid at room temperature (graduated glass measuring cylinder used to measure the amount of special liquid).

Both were mixed by hand spatulation for (15 sec.) then vacuum automixing device was used for (45sec.) under a pressure of (8 bars) to minimize the chance for air babbles that could be attached to the patterns during investing. [10]

The homogenous mixture was poured into the casting ring during its vibration to minimize the chances of air bubbles formation on the surface of the wax pattern then the mixture was left for setting for about [1hour (hr)]. [11]

The casting ring was kept in the electrical furnace at room temperature with the crucible former opening directed down word to allow the molten wax to escape out of the mold. [12]

The casting ring was heated according to manufacturer instructions [(200°C) for (30 min.) then to (950°C) for (1(hour) hr)]. Before (10 min.) of ending the burn-out, the ring was inverted so that the gases could escape outside the mold.

A manual driven broken arm centrifuge was prepared for casting. It was turned for three turns and then the fresh casting metal (Ni- Cr) was used for casting by using oxygen-gas single orifice torch to get the reducing zone (which was the hottest zone), the metal started to melt, the casting ring was removed from the electrical hot furnace and placed in its position in the centrifuge and adjusted well to receive the melted metal. The pin of the centrifuge was removed and torch was kept away and the metal was injected into the mold and left for bench cooling. [13]

Table (1) shows the physical properties and composition of supper bond (Ni-Cr) alloy (according to manufacturer instructions). [13]

Color	White
Coefficient of thermal expansion	25-500°C 14.1x 10^{-6} K^{-1}
Density	8.3g/cm^3
Melting range	1301-1364°C
Casting temperature	1450°C
Muffle temperature	850°C
0.2%yeild strength after firing	261 Mpa
Tensile strength after firing	316 Mpa
Elongation	3%
Type	4
Melting crucible	Ceramic
Investment	Phosphate-bound
Ni	61%
Cr	25%
Mo	10.5%
Si	1.5

The metal pieces were devested and investment residues were cleaned by sandblasting machine using (110µm) aluminum oxide powder fig (8), The sprues would be sectioned by the carborundum disc mounted on a laboratory hand piece leaving about (5 mm) as a handle. [5, 14]

Finishing will be done using stone bur mounted on a straight hand piece at(35000 rpm) revolution per minute to remove any sharp edges or bubbles on the surface of the metal samples. [15]

The standardization of a flat metal surface, to each sample was sandpapered (220 grit) manually at (1cycle/sec.) for (50sec.). Fig. (13). [16]

Figure (13) Sandpapering the metal samples.

Finally, each sample was rechecked using micrometer metal caliper device at three points (one in the middle and two in the periphery) for its thickness which was about (1.5mm.), Fig. (14). any samples less than the required thickness was discarded and the rest of samples were cleaned ultrasonically with distilled water to remove any debris and residues of abrasive materials. [17]

Figure (14) Micrometer metal caliper device used for checking the metal samples.

Polishing was accomplished using bristle brush and Cloth brush with pumice using dental lathe polishing machine (low speed, 1500 rpm) till glossy surface was obtained.

After finishing and polishing, the metal sample were exposed sandblasting machine (10 samples) using aluminum oxide powder and (10 samples) by carborundum powder and (10 samples) by glass beads powder. Show that Fig. (10).

Each sample was fixed by a holder (place inside the sandblasting machine) at a distance (5cm) away from the nozzle.

opening of the sandblasting machine and the distance was adjusted by using a plastic ruler fixed inside the machine, then the samples were exposed to sandblasting process for (5 sec.) under (5 bars) pressure.[18]

The surface roughness was expressed as a roughness average (Ra); this is calculated by first setting up a center line so the sum of the surface profile areas above the line is equal to those below, as appeared in Fig. (15).

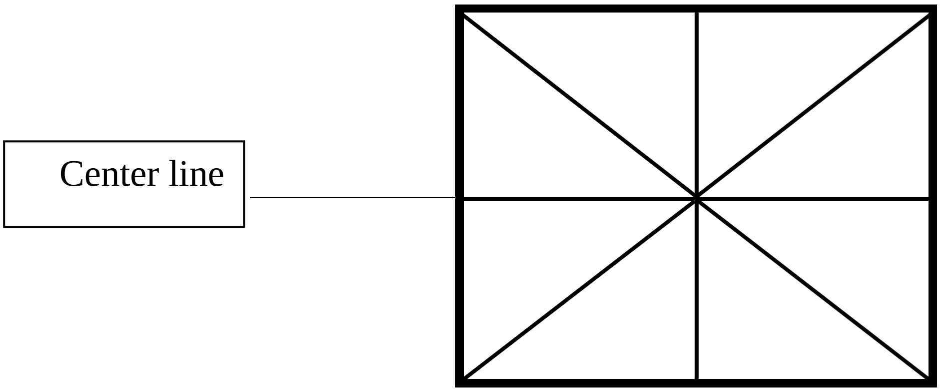

Figure (15) the lines draw above the center
Line equal to those below

The (Ra) value of the surface is the average height of profile above and below the center line along a given length. The (Ra) values for all specimens have been recorded using profilometer (pocket surf.)Fig. (9).

For each specimen four readings were recorded and the mean was calculated. The surface profiles of the specimen that represent the means of scores for all groups were recorded. The roughness average (Ra) is the arithmetic mean of all values of the roughness profile within the measuring length (Lm). [16]

Results

Descriptive and inferential statistics of some physical properties such as (surface roughness) of nickel chromium alloy by using different types of air abrasive materials such as carborundum, aluminum oxide, glass beads and a comparison between the results of them where done.

Mean values, standard deviation (SD), standard error (SE), minimum and Maximum are presented in (table 2) and figure (16) for surface roughness test.

The values of surface roughness varied according to air abrasive materials that are used. The highest mean surface roughness value was obtained from carborundum materials group (B) is (2.22um). While the lowest mean surface roughness value was obtained from glass beads materials group(C) is (1.77um).

Table (2): Descriptive statistics for surface roughness (um) according to the studied groups.

groups	N	Mean (um)	Std. Deviation	Std. Error	Range		Sum	Variance
					Minimum	Maximum		
Aluminum oxide (Group A)	10	2.000	.3621	.1145	1.3	2.4	20.0	.131
Carborundum (Group B)	10	2.220	.5673	.1794	1.5	3.2	22.2	.322
Glass Beads (Group C)	10	1.770	.2627	.0831	1.4	2.2	17.7	.069
Total	30							

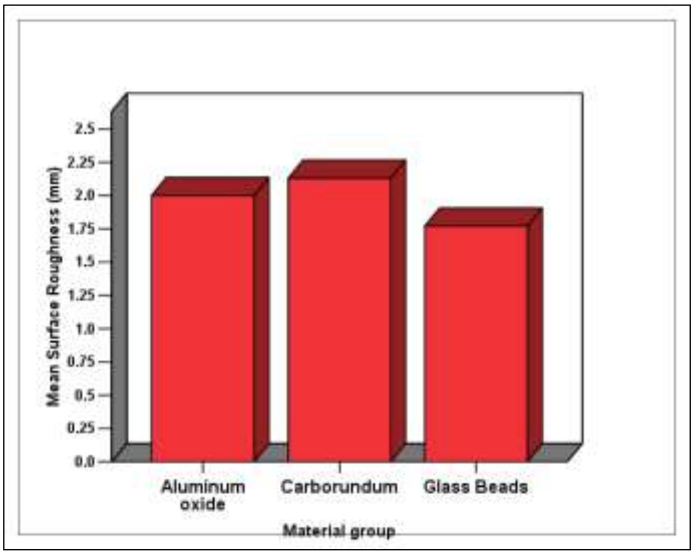

Figure (16): Bar chart show mean values for surface roughness (um) Air abrasive materials groups.

In table (3) shows that the inferential statistics. Onaway ANOVA of surface roughness test. The results have shown that there was significant difference ($P<0.05$) among the groups of the air abrasive materials (aluminum oxide, carborundum, glass beads).

Table (3): Inferential statistic ANOVA for surface roughness.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.013	2	.506	2.911	Sig.
Within Groups	4.697	27	.174		
Total	5.710	29			

In table (4) shows that the inferential statistics. Dependent variable of surface roughness (LSD) of multiple comparison tests, the results have shown that, there was significant difference ($P<0.05$) between the groups (A, B) and groups (B, C). While it's not significant difference ($P>0.05$) between the groups (A, C).

Table (4): LSD least significant difference for surface roughness test for air abrasive Materials.

(I) Sample	(J) Groups	Mean Difference (I-J)	Std. Error	Sig t-test	95% Confidence Interval	
					Lower Bound	Upper Bound
A dimension3	B	-.2200	.1865	Sig.	-.603	.163
	C	.2300	.1865	Not Sig.	-.153	.613
B imension3	A	.2200	.1865	Sig.	-.163	.603
	C	.4500*	.1865	Sig.	.067	.833
C dimension3	A	-.2300	.1865	Not Sig.	-.613	.153
	B	-.4500*	.1865	Sig.	-.833	-.067

Discussion

Abrasive blasting materials are often used for cleaning metal surfaces to remove rust and to prepare a surface before the application of a coating. The pre-blast and post-blast (spent) abrasive materials contain traces of heavy metal constituents such as Cr, Ni, Pb Fe, and Ba. Hence.
In the present study, there are used different types of air abrasive materials such as carborundum, aluminum oxide, glass beads on the surface roughness of nickel chromium alloy.

The profilometer appeared to be the ideal instrument for studying surface roughness of restorative materials, since this instrument give quantitative measurements that can be calculated and compared statistically (Zakaria and Al-Na'ami, 2002).

Many researchers used this instrument in conducting their studies. In this study, the surface roughness has been measured by profilometer.

The result in table (2), figure (16), tested samples of air abrasive materials such as (carborundum, aluminum oxide and glass beads). Showed that, the highest mean value of surface roughness is obtained from carborundum material group (B). This could be related to that Carborundum has a crystal structure like that of diamond and is almost as hard. It is used as an abrasive for cutting, grinding, and polishing, as an antislip additive, and as a refractory. So it is used to the retention between the metal and ceramic. This is results agreement with (Zakaria and Al-Na'ami, 2002; Rizkalla and Jones, 2004). While tested samples of glass beads abrasive materials (group C). Showed that lowered mean values of the surface roughness when compared with those samples of other groups, table (2), and figure (16).

Similar results were obtained by (Zalkind et al., 1996) who investigated the physical properties of glass beads is lower surface roughness. That could be glass bead blasting does not compromise the metal, sand blasting, similar to sand paper, has the capability of shaping and smoothing the underlying material. Additionally, blasting with glass beads is a slower process than sand blasting but is much gentler on the material and effectively strips it without causing damage to the material itself. This explanation supported with (Zakaria and Al-Na'ami, 2002, Al-Hadithy, 2004). While disagreement this result within (; Rizkalla and Jones, 2004).

The inferential statistics ANOVA of the surface roughness test of abrasive blasting materials (aluminum oxide, carborundum, glass beads). It appears that, it is significant different between groups as shown Table (3). This may be related to that Ni.cr. alloy when exposed the aluminum oxide or carborundum is give high rough surface was thought to be produced by the irregular particles and large grain size which were probably brought about by the removal of superficial grains during grinding. While the glass beads are low rough surface which related to the brittle and glass grain size that give the smoother surface. This explanation agreed with Shillingburg et al., 1997; Rosenstiel, 2001, results who found that the applied abrasive blasting lead to seal microscopic pitting present on the NI. CR. alloy surface that produce a satisfactory surface for restorations.

In the table (4) showed that, the inferential statistics are dependent variable of surface roughness (LSD) of multiple comparison tests, the results have shown that, there was significant difference ($P<0.05$) between the groups (carborundum, aluminum oxide, glass beads).

This is investigated by Keith Hudson et, al in 2002, they are studied the physical properties of the abrasive blasting and obtain to the higher surface roughness of the carborundum and aluminum oxide and lower surface roughness of the glass beads. This is result could be the carborundum and aluminum oxide is similar the composition and structure of atom and the larger particular and large grain size. This is supported with Al – Juboori 2006.

On other hand, show that in the table (4), it is not significant different between aluminum oxide (group A) and glass beads (group C). This is may be due to, the oxide is an abrasive as well and used for its trusted strength and hardness. Widely used abrasive, it is also in use as a lesser expensive substitute of industrial diamond. A huge number of sandpapers are also known to use the crystals of the oxide. The oxide also retains heat as well as low specific kind of heat that makes it to be used highly in grinding processes in cutoff tools particularly. While glass bead blasting a surface in order to clean or strip it, tiny glass beads are forced on to material under lower air pressure than sand blasting. Additionally, blasting with glass beads is a slower process than sand blasting but is much gently on the material and effectively strips it without causing damage to the material itself. This leads to a fresh, shiny and more polished appearance. Also the composition of the aluminum oxide (Al_2O_3) and glass beads are (SiO_2, Na_2O and CaO) in it, contain the oxide and this is lead to no significant difference between them. This is results agreement with Zakaria and Al-Na'ami, 2002, AL-Alawi, 2005, Al – Juboori 2006.

Conclusion:

Within the limitations of this study, the following conclusion could be with drawn:

1. The comparison between the air abrasive materials such as carborundum and aluminum oxide and glass beads on the surface roughness is higher of (carborundum) and lower of (glass beads).
2. The measuring of the surface roughness of nickel chromium alloy by using different types of air abrasive materials are significant different between carborundum and aluminum oxide and glass beads.
3. The conclude that the higher surface roughness is the (carborundum, aluminum oxide) materials that can be use for retention with ceramic while the lower surface roughness for the (glass beads) material can be use for cast crown or bridge.

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