The effect of metal alloys and surface treatment on the retention of cast post: An in vitro study

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ABSTRACT

The main objectives of this study were to determine the effect of different metal alloy posts with different surface treatments cemented within their prepared post canal spaces with two luting agents on the tensile strength of cast posts.

Ninety sound upper permanent canines were collected; the anatomical crown were removed about (1) mm above the Cemento-Enamel Junction. Preparation of post space was made by using slow speed straight hand piece fixed onto swiveled arm of the surveyor direct acrylic pattern is made and undergoes a casting procedure immediately. The samples were divided into (3) groups thirty in each; first group was casted with MAX-white A alloy, second group with CB Blando (72) alloy and the third group with Palliag M alloy. Three surface treatment procedures for each group were done. Ten samples in each, first group was sandblasted with (100) µm aluminum oxide and second one was sandblasted with (50) µm aluminum oxide and the third one receive no surface treatment and considered as a control group. Then each of these three groups were further subdivided randomly into two subgroups, (5) samples for each according to the type of luting agent used for cementation of the posts. First subgroup was cemented with zinc phosphate cement, the second subgroup was cemented by adhesive resin luting cement (Aureocem). A tensile strength tester was used to test the tensile strength.

The results showed that there was no significant difference in the mean tensile strength among different alloys used and surface treatment with (100) µm aluminum oxide procedure, produced the highest tensile strength when it is used in combination with resin cement.

Examination of the type of failure after tensile test showed that most of the samples cemented with resin cement failed adhesively at resin-dentin interface. While for samples that were cemented with zinc phosphate most of failure were cohesive within the cement followed by failure at the metal cement interface.

Key words: Retention, cast, post, resin.

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الخلاصة

الهدف الرئيسي من هذه الدراسة هو دراسة تأثير نوع المعدن المستخدم في صب الأوتاد المثبتة في قناة الجذر باستعمال طرق مختلفة لمعالجة سطح الوتد مع استعمال مواد لاصقة مختلفة ودراسة تأثير هذه العوامل الثلاثة على قوة سحب الوتد من قناة الجذر .

جمع (٩٠) ناب علوي خالي من التسوس وقطع التاج عرضياً بحوالي (١) ملم تاجياً لمنطقة اتصال التاج مع الجذر وبعدها تم حشو قناة الجذر باستعمال مادة الغوتابيركا. بعد ذلك صب الجذر المحشو لبياً بقالب بلاستيكي دائري باستعمال قبضة اليد المستقيمة وأداة موسعة للقناة كان تحضير القناة الخاصة بالوتد بقطر (١,٨) ملم وبعمق (٨) ملم. ومن ثم حضر الشكل الاكريليكي للوتد بشكل مباشر وادخل في عملية الصب مباشرة.

قسمت النماذج إلى ثلاث مجاميع (٣٠) نموذج لكل مجموعة حسب السبائك المستعملة للصب وكما يأتي:

المجموعة الأولى: صبت باستعمال سبيكة الـ ماكس وايت أي والمصنوعة من مادتي الكروم والنيكل.

المجموعة الثانية: صبت باستعمال سبيكة إلى سي بي بلاند و ٧٢ والمصنوعة أيضا من مادتي الكروم

المجموعة الثالثة: صبت باستعمال سبيكة ال بالك إم المصنوعة من مادتي الفضة والبلاديوم كمواد أساسية والتي تعتبر من السبائك النبيلة.

ثلاث طرق لمعالجة السطوح تم إجراءها لكل مجموعة من المجاميع السابقة (١٠) نماذج لكل طريقة:

المجموعة الأولى : تم معالجتها باستعمال اكاسيد الألمنيوم حجم (١٠٠) مايكرون .

المجموعة الثانية : تم معالجتها باستعمال اكاسيد الألمنيوم حجم (٥٠) مايكرون .

المجموعة الثالثة : لم يتم معالجة سطوحها واعتبرت مجموعة ضابطة .

بعدها كل من هذه المجاميع الثلاثة تم تقسيمها إلى مجموعتين فرعيتين بشكل عشوائي (٥)نماذج لكل مجموعة وحسب نوع المادة اللاصقة المستعملة لتثبيت الوتد داخل قناته المحضرة مسبقاً

المجموعة الفرعية الأولى : تم تثبيتها باستعمال سمنت الزنك الفوسفاتي .

المجموعة الفرعية الثانية : تم لصقها باستعمال مادة الراتنج الرابط وهي من نوع All-Bond2 مع المادة اللاصقة الراتنجية من نوع Aureocem.

بعدها تمت عملية فحص قوة السحب للأوتاد وكذلك دراسة نوع الفشل الحاصل بعد عملية السحب .

لقد تبين من هذه الداسة إن قوة السحب لأوتاد الصب لا تعتمد على نوع السبيكة المعدنية المستخدمة كذلك تبين إن معالجة سطح الوتد بواسطة اكاسيد الألمنيوم حجم (١٠٠) مايكرون حصل على أعلى قوة سحب عندما استعمل مع مادة الراتنج اللاصقة . تبين بعد عملية السحب إن معظم النماذج فشلت تلاصقيا بين الراتنج وعاج السن ثم تلت بعدها فشل تلاصقي بين المعدن والراتنج والأقل حدوثاً هو حصول فشل مركب للحالتين السابقتين.أما بالنسبة للنماذج التي ثبتت بواسطة سمنت الزنك الفوسفاتي فان معظم النماذج فشلت تماسكيا داخل المادة الأسمنتية نفسها تلتها فشل بين المعدن والمادة الأسمنتية .

INTRODUCTION

Coronoradicular stabilization in a severely compromised endodontically treated tooth provide adequate retention and resistance form for a definite cast restoration [1].

There are two basic reasons for the use of a post, first, to retain the restoration and second to protect the remaining tooth structure. The retention function of the post is necessary when insufficient tooth structure remains to hold a restoration; therefore, placing a dowel that protrudes occlusally provides this coronal retention [2]. The custom cast posts gain their final retention by cementation into the prepared post-hole. The need for such cementation that was recognized by Fauchard [3] who made specially formulated mastic compound for this purpose. Zinc phosphate cement was advocated by Evan [4] The major problem associated with their use was that of poor post retention [5].

Recently, adhesive resinous cement has been introduced for cementation of posts because they bond the post to tooth structure with greater retention than other cements. The retention of the dowel can be improved by the removal of smear layer within the prepared channel to allow the cement to flow into the dentinal tubules. Micromechanical retention is enhanced because of increased surface area available to the cement and chemical adhesion is also possible when the ionic or covalent bond of dentinal adhesive are used [6].

When smooth-sided custom cast post is used, the post should be sandblasted with aluminum oxide since this technique has been shown to lead to a significant increase in retention of cast crowns by increasing the surface roughening and topography and also by removing debris and contamination [7].

MATERIALS AND METHODS

Two types of nickel-chromium alloys were used in this study, Max-White A and CB Blando-72 the third alloy used was silver palladium, which is a noble alloy called Palliag M.

Bonding and Luting Agents

All Bond 2 which is a universal dental adhesive system (Dual-cured) was used as intermediate resin.

Aureocem, which is resin based adhesive luting cement (Bis-GMA) was used in this study, Zinc oxyphosphate is also used as a luting cement.

Ninety intact maxillary permanent canines were selected for this study. Clinical crowns of the teeth were removed with a diamond saw about (1) mm coronal to the Cemento-Enamel Junction. Any remaining pulpal tissue was removed with a barbed broach. The root length was determined by insertion of a number (10) file into the canal until it appears at the apex. The working length was recorded as (0.5) mm shorter than that length. Instrumentation of the canal continued from the number (10) file to a number (20) file with circumferential filing and then continued to the number (90) file. The canals were irrigated with (2.25%) sodium hypochlorite solution after use of each file.

The canal space was thoroughly dried with size (80) paper points. Endodontic sealer (Dorident, Austria) was mixed according to the manufacturer's instructions. A size (90) primary gutta-percha cone was coated with a sealer and inserted into the canal.

Excess gutta-percha was removed with a warm instrument flush with the cut tooth surface. The root canal sealer was allowed to set.

All teeth were fixed in a plastic cylindrical ring of (20) mm length and (25) mm outer diameter. Using acrylic resin, with the coronal (1) mm of the root left exposed above the surface. The mounting of teeth were carried out by the aid of the surveyor to make the long axis of the root perpendicular to a horizontal plane, the preparation of the post space is done by using a slow-speed straight hand piece fixed on the swiveled arm of the surveyor.

Pesso reamers were used for the preparation of the post space with a diameter of (1.8) mm to a depth of (8) mm with the aid of copious water-cooling. Then a direct acrylic pattern was made and undergoes casting procedure immediately.

Ninety metal post samples were prepared from three alloys Max-White A, CB Blando-72 and Palliag M thirty posts from each type of the alloys (figure 1). All samples were carefully inspected and any post with imperfection on the surface to be treated were discarded.

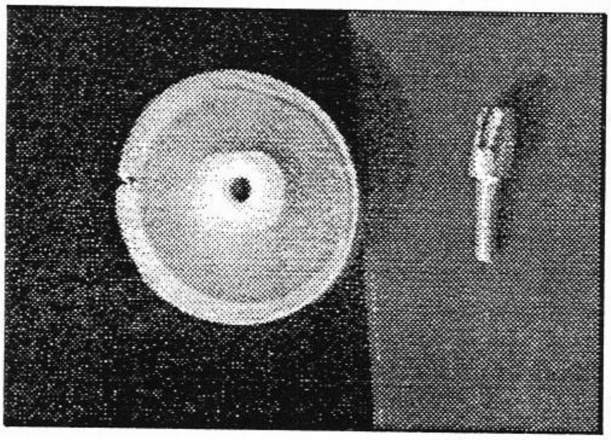

Figure (1): The sample with it is corresponding post

Surface Treatment and Grouping of the Posts

Each type of the three alloys post was divided randomly into three groups (10) posts samples in each group according to the surface treatment All posts samples were cleaned with no. (400) grit abrasive paper before a surface treatment.

Group I: Sandblasting with 100 µm Aluminum Oxide

The samples in this group were sandblasted individually with aluminum oxide abrasive for (40) seconds at a distance of (10) mm from the nozzle at (60) psi air pressure.

The device used was a sandblasting unit. The surface of the posts were exposed to the abrasive particles for (20) sec. and then the sample was rotated (180°) to sandblasting the other surface for (20) seconds also. After that the samples were placed in an ultrasonic cleaner with distilled water for (10) minutes, then dried.

Group II: Sandblasting with 50 µm Aluminum Oxide

The samples in this group were sandblasted by the same procedure of sandblasting described for group I (sandblasting with (100) µm aluminum oxide) except that the abrasive used for this group was (50) µm aluminum oxide.

All samples after sandblasting were examined under a reflected light microscope x(100) to ensure a proper sandblasting. Any sample with improper treatment was sandblasted again. After finishing the sandblasting and cleaning procedure, all samples were stored in a closed container until bonding.

Group III Control Group

No surface treatment was done for the samples in this group.

Each of these three groups were further subdivided randomly into two subgroups five samples for each depending on the type of luting agents used.

Group A:

The samples in this group were cemented by using All Bond 2 (dentin bonding agent) and Aureocem (resin cement) as a luting agent.

Group B:

The samples in this group were cemented by using zinc phosphate cement (Drala, Germany) as a luting agent.

Tensile Testing

The tensile load between the dentinal canal wall and metal posts samples was measured using a tensile strength tester The sample was placed at the base of the apparatus and fixed by a special grasping unit. A stainless steel orthodontic wire (0.7) mm inserted through a hole made within the core, then this wire attached to the upper clamp of the grasping unit of the machine. Vertical tensile load was used to separate the post from the canal at a speed of one cycle per minute. The amount of load required for separation of the posts recorded in kilogram (kg). A magnifying lens was used to determine the type of failure that occurred after tensile testing.

Statistical Analysis

1. One way analysis of variance (ANOVA).
2. Duncan's Multiple Range Test.

RESULTS

The results of this study presented according to the three alloys used (MAX-White A, CB-Blando 72, Palliag M). The effect of surface treatments of the three alloys cast posts and the type of luting agents used on the tensile strength of cast posts were determined.

1. Tensile Strength of (MAX-White A) Alloy Posts Cemented Within the Prepared Canal space:

ANOVA was done & results showed that there is a significant difference in tensile strength (p= 0.0001) between different treatment groups .

Duncan multiple range test was performed at ($p \leq 0.05$) (table 1) and proved that there is a significant difference in the tensile strength between posts sandblasted with (100) µm aluminum oxide cemented with resin cement (mean tensile strength 49.40 kg) and the other treated groups.

The results also showed that there is statistically significant difference ($p \leq 0.05$) between the post sandblasted with (50) µm aluminum oxide cemented with either resin or zinc phosphate cement and the control group (without surface treatment) cemented with either resin or zinc phosphate cement.

On the other hand, there is a highly significant difference in the tensile strength between the posts sandblasted with (100) µm aluminum oxide cemented with resin cement and the control groups either cemented with resin or zinc phosphate cement. The lowest mean tensile strength was obtained with the control group cemented with resin cement (16.20 kg).

Table (1): Duncan multiple range test and mean tensile strength of MAX-white A alloy posts for the three surface treatment groups and two luting cements

Type of Treatment	Type of Luting Cement	Mean*	SE	Duncan Group	N**
Sandblasting with 100 µm Al_2O_3	Resin Cement	49.40	± 3.28	A	5
	Zinc Phosphate Cement	33.00	± 2.19	B	5
Sandblasting with 50 µm Al_2O_3	Resin Cement	36.00	± 2.00	B	5
	Zinc Phosphate Cement	28.60	± 2.27	B	5
Control	Resin Cement	16.20	± 1.56	C	5
	Zinc Phosphate Cement	19.80	± 2.97	C	5

*Mean tensile strength (kg), mean with same letters are not significantly different at $p \leq 0.05$.

**Number of samples

2. Tensile Strength of CB-Blando 72 Alloy Posts Cemented Within the Prepared Canal Space

ANOVA results showed that there is a significant difference in the tensile strength (p = 0.0001) between different treatment groups

Duncan multiple range test was done at (p ≤ 0.05) (table 2) and proved that there is significant difference in the tensile strength between posts sandblasted with (100) µm aluminum oxide cemented with resin cement (mean tensile strength 43.00 kg) and other treatment groups.

The results also showed that there is a significant difference between posts sandblasted with (50) µm aluminum oxide cemented with either zinc phosphate cement or resin cement and the control group (without surface treatment) cemented with either resin or zinc phosphate cement.

While there is a highly significant difference in the tensile strength between the posts sandblasted with (100)µm aluminum oxide cemented with resin cement and the control groups either cemented with zinc phosphate or resin cement. The lowest mean tensile strength was obtained with the control group cemented with resin cement (16.00 kg).

Table (2): Duncan multiple range test and mean tensile strength of CB-Blando 72 alloy posts for the three surface treatment groups and two luting cements

Type of Treatment	Type of Luting Cement	Mean*	SE	Duncan Group	N**
Sandblasting with 100 µm Al_2O_3	Resin Cement	43.00	± 1.71	A	5
	Zinc Phosphate Cement	37.00	± 1.48	B	5
Sandblasting with 50 µm Al_2O_3	Resin Cement	32.20	± 1.43	B	5
	Zinc Phosphate Cement	34.60	± 1.78	B	5
Control	Resin Cement	16.00	± 2.00	C	5
	Zinc Phosphate Cement	18.60	± 1.29	C	5

*Mean tensile strength (kg), mean with same letters are not significantly different at $p \leq 0.05$.

**Number of samples

3.Tensile Strength of Palliag M Alloy Posts Cemented within the Prepared Canal Space

When (ANOVA) was performed, the results showed that there is a significant difference in the tensile strength ($p = 0.0001$) between different treatment groups (table 3). Duncan multiple range test was done at ($p \leq 0.05$) (table 3) and proved that there is a significant difference in the tensile strength between posts sandblasted with (100) µm aluminum oxide cemented with resin cement (mean tensile strength 52.00 kg) and other treatment groups. Also there is a significant difference between posts sandblasted with

(100) µm aluminum oxide cemented with zinc phosphate cement and the control groups cemented with either resin or zinc phosphate cements.

On the other hand, the results showed that there is a significant difference between posts sandblasted with (50) µm aluminum oxide and the control groups cemented with either resin or zinc phosphate cements.

While there is a highly significant difference in the tensile strength between the posts sandblasted with (100) µm aluminum oxide cemented with resin cement and the control groups either cemented with zinc phosphate or resin cement.

Table (3): Duncan multiple range test and mean tensile strength of Palliag M alloy posts for the three surface treatment groups and two luting cements

Type of Treatment	Type of Luting Cement	Mean*	SE	Duncan Group	N**
Sandblasting with 100 µm Al_2O_3	Resin Cement	52.00	± 2.82	A	5
	Zinc Phosphate Cement	36.40	± 2.21	B	5
Sandblasting with 50 µm Al_2O_3	Resin Cement	34.40	± 1.86	BC	5
	Zinc Phosphate Cement	29.75	± 2.39	C	5
Control	Resin Cement	15.00	± 2.00	D	5
	Zinc Phosphate Cement	18.8	± 0.86	D	5

*Mean tensile strength (kg), mean with same letters are not significantly different at $p \leq 0.05$.

**Number of samples

3. Interaction between Alloys, Surface Treatment Procedures and Luting Agents

The results showed that the surface treatment of the posts and the luting agents used has a highly significant effect on tensile strength (p = 0.0001), while the type of alloys used have no significant effect on the tensile strength of cast posts as presented in table (4)

Table (4): Analysis of variance (ANOVA) for surface treatment, luting agents and alloys used

Source	df	SS	MS	F-value	p
Alloys	2	13.26	6.63	0.31	0.74
Surfaces	2	9172.14	4586.07	213.05	0.0001**
Luting	1	400.84	400.84	18.62	0.0001**
Alloy x Surfaces	4	109.96	27.49	1.28	0.29
Alloys x Luting	2	176.09	88.04	4.09	0.02*
Surfaces x Luting	2	995.84	497.92	23.13	0.0001**
Alloys x Surfaces x Luting	4	129.98	32.49	1.51	0.21
Error	71	1528.35	21.53		
Total	89	96095.00			

*Significant at a level of $p \leq 0.05$

** Highly significant at a level of $p \leq 0.01$

The mean and Duncan multiple range test of the interaction between alloys, surface treatment and luting agent are shown in table (5). The highest tensile strength is found with Palliag M alloy posts when surface treated with (100) μm aluminum oxide and cemented with resin cement. The lowest tensile strength is found also with Palliag M alloy posts when used as a control group (without surface treatment) and cemented with resin cement.

Table (5): Mean and Duncan multiple range test of interaction between alloys, surface treatment procedures and luting cements

Type of Treatment	Type of Luting Cement	Surface Treatment Procedures		
		SB with 100 μm Al_2O_3	SB with 50 μm Al_2O_3	Control
MAX-white A	Zinc Phosphate Cement	33.00CDE	28.60E	19.80 F
	Resin Cement	49.40 A	36.00 CD	16.20 F
CB-Blando 72	Zinc Phosphate Cement	37.00C	34.60 CDE	18.60 F
	Resin Cement	43.00 B	32.20 CDE	16.00 F
Palliag M	Zinc Phosphate Cement	36.40 CD	29.75DE	18.80 F
	Resin Cement	52.60A	34.40CDE	15.00 F

Mean with same letters vertically and horizontally are not significantly different, else it will differ at $p \leq 0.05$.

SB: Sandblasting

Al_2O_3: Aluminum oxide

A comparison between alloys shows that there was no significant difference in the tensile strength between different alloys used.

A comparison between surface treatment procedures using Duncan multiple range test for the three alloy posts used in this study (table 5) shows that sandblasting with (100) μm aluminum oxide gave the highest retentive strength. It is followed by sandblasting with (50) μm aluminum oxide, while the non-treated group (control) shows the lowest tensile strength.

A comparison between luting agents used the results shows that the resin cement provides the highest retentive strength when used in combination with (100) μm sandblasting than that of zinc phosphate cement. While zinc phosphate cement shows the higher tensile strength than resin cement when used with the control group, there is no statistically significant difference between them.

The interaction between alloys, surface treatment and luting agents shows that the MAX-white A alloy post sandblasted with (100) μm aluminum oxide cemented with zinc phosphate cement and Palliag M alloy post sandblasted with (50) μm aluminum oxide cemented with resin cement have no significant difference on the tensile strength.

It also shows that within the groups that sandblasted with (50) μm aluminum oxide the MAX-white A alloy group cemented with resin cement shows significantly a higher tensile strength than that cemented with zinc phosphate cement. However, there is no significant difference between the other groups within the same treatment procedure (sandblasting with 50 μm Al_2O_3) whether cemented with resin or zinc phosphate cement.

For the control groups, it shows no significant difference in the tensile strength between different alloys post used with different luting agents.

5. Mode of Failure

Examination of samples under magnifying lens showed three modes of failure which occurred in the samples cemented with resin cement, adhesive failure at the interface between resin and dentin of the prepared canal space ($A_{(d)}$). Adhesive failure at the interface between resin cement and metal posts ($A_{(m)}$), and a combination between these two modes ($A_{(d)}+A_{(m)}$).

Most of failures were adhesive at the resin-dentin interface ($A_{(d)}$). For the samples cemented with resin cement.

For the samples that cemented with zinc phosphate cement two modes of failure were obtained. Cohesive failure within the cement itself (Co.) and failure at the cement-metal interface (C-M), most of failures were cohesive within the zinc phosphate luting cement.

DISCUSSION

The results of this study showed differences in the tensile force. These may be due to the differences in the surface treatments, luting agents and differences in the metal used.

The results of sandblasting procedure produced higher bond strength than the control group. This related to the fact that the aluminum oxide roughened the metal surface, which elevated the reaction to resinous cement [8]

The microretentive feature that had been produced on the surface of the sandblasted post was not present on the surface of smooth post, resulted in a less retentive strength than the sandblasted posts. That is why sandblasting decreases the chance for a fracture of resinous material at the rounded end irregularities of the metal and increases the surface area for bonding [9].

There are much more irregularities in post treated with (100) μm aluminum oxide, that could be the cause that the surface treated with (100) μm aluminum oxide produces a higher bond strength than surface treated with (50) μm aluminum oxide [10]. Our results are more consistent with those of Standlee and Caputo [11] who found that the dowel surface design and texture could significantly influence the retention of a resin cemented dowel.

The present research indicates that the resin luting cement is superior to zinc phosphate cement in tensile force. This may be due to the fact that the resin cement in addition to its Micromechanical bonding to roughen metal surface, the dentin conditioning with (32%) H_3PO_4 remove the smear layer from the radicular dentin surface and opens the dentinal tubules. Then a resin tags enter the radicular dentinal tubules in the form of long projecting tags, thereby providing a Micromechanical bond [12].

The sandblasting metallic post cemented with resin cement produces the largest tensile force because the resulting procedure produces "double Micromechanical bonding" into the root canal, that is the strong luting resin bonded to the sandblasted post surface on one side and the radicular dentin on the other. Thus, forming an extremely strong bond and excellent retention than the smooth posts luted with resin cement because this attachment mechanism is not available at the resin-metal interface [13].

For zinc phosphate cement the retentive ability depends primarily on its penetration into irregularities in both the canal walls and the post mechanically binding the two surfaces together.

The lower tensile force for the sandblasted posts cemented with zinc phosphate cement, comparing with sandblasted posts cemented with resin cement, may be due to the fact that the tensile strength of zinc phosphate cement was (3-5 MPa) less than that for resin cement (41 MPa) This means that the fracture threshold of zinc phosphate determines the retention of the posts as the zinc phosphate cement locks into and remain attached to the rougher surface in both the prepared dentin and the post. A cohesive failure within the cement causes a loss of retention.

As for the smooth (control) posts, the results differed completely. Zinc phosphate luted posts showed greater retentive characteristics than post luted with resin cement. This may be attributed to the fact that the resin cement is highly affected by the roughness and irregularities in the metal posts. That is to say, it is loosely bonded with the smooth surface posts, which might explain the mode of failure that occurs after the tensile test for the smooth posts bonded by a resin cement. In which all the post in this group failed adhesively at the resin post interface result in loss of retention even less than that of posts cemented with zinc phosphate cement, which means that zinc phosphate cement is less affected by surface roughness of the metal.

Similar results have been recorded by Nakabayashi [14] who demonstrated that the 4-Meta molecule of Meta bond cement did penetrate the dentin and bond to collagen. This bonding to collagen, in addition to microextensions of cement into dentinal tubules could account for greater retention of Meta bond cement.

Palliag M that was sandblasted with (100) µm aluminum oxide produces no significant difference in tensile force than MAX-white A alloy posts and CB-Blando 72 alloy posts, which were sandblasted with (100) µm aluminum oxide. This means that the type of alloy used either noble or base metal plays no significant role in the tensile force. This can be explained on the bases of the film thickness of the cementing material. As the Palliag M is softer than the other two alloys, it is more affected by sandblasting procedure result in an increase in the gap between the post surface and the canal walls. When this gap is increased, the film thickness of the cementing material was also increased. Accordingly the retention of the post was decreased .The result of this study coincided with the finding of Maryniuk *et al.* (15). As they found that the retention of post does not depend on the metal used whether precious or non-precious, but air abrasion of the metal surface is recommended to improve retention.

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