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Flexural strength of different veneering materials on co-cr alloy with various surface modifications - an invitro study

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Abstract

Purpose: With the advent of newer indirect composite resin materials for crown and bridge prosthesis, it has become imperative to evaluate their strength to serve as long term replacements as a substitute to metal ceramic restorations. This study aimed to evaluate and compare the flexural bond strength of ceramic and composite resin veneering material to commercial cobalt-chromium alloy (Co-Cr) with different surface modifications.

Materials and Methods: Metallic frameworks (25×3×0.5 mm^3; ISO 9693)(N=72) were cast in Co-Cr and airborne-particle abraded (Al_2O_3: 110µm) at the central area of the frameworks (8×3mm^2) on 48 samples and divided into six groups (N=12), with different surface modifications: GrA-ceramic vennered on metal with sand blasting, GrB-ceramic veneered on metal with acid etching, GrC-ceramic vennered on metal with retention beads, GrD-indirect composite vennered on metal with sand blasting, GrE-indirect composite vennered on metal with acid etching, GrF-indirect composite vennered on metal with retention beads. The flexural bond strength of all specimens was tested with universal testing machine under three point loading. The data were analyzed using 2-way ANOVA and Tukey's test (α=0.05).

Results: Gr F: Bredent composite group of die specimens surface treated with retention beads had more mean flexural strength value than other groups. Chemical surface treatment with did not significantly influence the mean flexural strength values ($p>0.05$). Mechanical retention with retention beads improved the flexural bond strength values ($p<0.05$).

Conclusion: Bredent group had better flexural strength than ceramic group with mechanical surface treatment with retention beads. Mechanical retentive features were more significant than chemical retentive features

Keywords: Flexural bond strength, indirect composites, veneering ceramics, cobalt- chromium alloys.

Introduction

In day to day clinical practice, several veneered and metal-free restorations are applied because they provide functional and cosmetic requirements with desirable results in dentistry. Due to high success rate, metal-ceramic prosthesis were extensively used in restorative dentistry.[1] Until the mid 1980s, the standard biomaterial for restorative dental applications was a feldspar ceramic supported by a metal framework. The biocompatible alloys and ceramics are used for the construction of porcelain fused-to-metal (PFM) restorations.[2] Flexural forces are the bending forces which were generated in clinical situations and the dental materials need to resist repeated flexing and twisting forces. Dental biomaterials require high flexural strength (bend strength), as occlusal stresses might cause permanent deformation.[3]

Most of the ceramics are brittle, and the tensile stress caused by an occlusal load can result in crack formation.[4-7] According to several studies, chipping of ceramics and resins occurred as a result of occlusal discrepancy. To improvise the bond strength of composite resin to metal ceramic restorations mechanical and chemical bonding methods were suggested.[8,9] Various surface conditioning treatments such as roughening with diamond bur and air abrasion with aluminum oxide[10]and use of retention beads can be used to treat the surfaces of the both metal and ceramic to enhance the mechanical bonding. Hydrofluoric acid[11], acidulated phosphate fluoride or ammonium hydrogen bifluoride were used to enhance the chemical bonding of ceramics by means of acid etching. Adhesive primers and silane coupling agents enhance chemical bonding in composites after initial mechanical surface treatments.[12]

This study hypothesizes that the difference between fracture/ exfoliation and flexural strength of the veneered portion is related to the materials and retention methods.

Materials &Methods

A Brass rectangular shaped die of 25x3x0.5mm is fabricated using an electric discharge machine, according to metal ISO 9693 standardization.

This Die is duplicated to form an index using polyvinylsiloxane material, and seventy two (72) wax patterns are fabricated using the index with modeling Wax/Base Plate wax (MAARC-Type III). Retention beads (88microns) were applied uniformly to the (24) wax patterns. To these wax patterns, Wax sprues of 3mm diameter (YETI dental products, Germany) were attached, and all 72 wax patterns were invested in phosphate bonded investment (METAVEST DELTA Products, Germany) at 40ml/160g (L/P ratio) according to manufacturer recommendations. After investment sets (approximately 30min), they are placed with the ring inside the Furnace (preheated furnace at 315-degree centigrade).

In the preheated furnace (315-degree centigrade), the temperature was increased quite rapidly up to 950-degree centigrade. It was maintained at upper temperature (950-degree Celsius) for 30 min for wax elimination. After

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burnout, using a centrifugal casting machine, the casting was done with Co-Cr alloy (Dent Chrom C-DELTA Product, Germany).

In the centrifugal casting machine, spring is wound from two to five turns. Alloy is melted by a torch flame (open flame) in a glazed ceramic crucible attached to the broken arm of the casting machine. Once the alloy melts, the heated casting ring is placed in position, and the arm is released, hydrostatic pressure developed along the length of the broken arm leads to the filling of the mold.

After complete solidification, castings were removed from investment. Casting sprues were removed by using carborundum discs. After divesting & trimming, the surfaces of the samples were examined. Then the metal samples were sandblasted (cleaned) with 110µm aluminium oxide particles (ALUMINOX -110, DELTA products, Germany) at a pressure of 0.3Mpa.

The samples are divided into six groups each of 12 samples where,

GROUP A- Porcelain fused to metal with sand blasting (110 µm aluminium oxide particles).

GROUP B- Porcelain fused to metal with acid etching (10% hydrofluoric acid) GROUP C- Porcelain fused to metal with retention beads (88µm)

GROUP D- Indirect composite fused to metal with sand blasting (110 µm aluminium oxide particles).

GROUP E- Indirect composite fused to metal with acid etching (10% hydrofluoric acid)

GROUP F- Indirect composite fused to metal with retention beads (88µm)

GROUP A- Porcelain fused to metal with sand blasting (110 µm aluminium oxide particles).

After the metal samples are sandblasted with Al_2O_3 in the central area of the frameworks (8 × 3 mm) ceramic layering i.e. opaque, dentin, enamel, and glaze of a thickness of 1mm is done using ceramic (VITA VMK Master, Germany).

GROUP B- Porcelain fused to metal with acid etching (10% hydrofluoric acid)

After the metal samples are acid etched with 10% hydrofluoric acid (Angelus, Brazil) in the central area of the frameworks (8 × 3 mm) ceramic layering i.e. opaque, dentin, enamel, and glaze of a thickness of 1mm is done using ceramic (VITA VMK Master, Germany).

GROUP C- Porcelain fused to metal with retention beads (88µm)

The metal samples with retention beads (88µm) (DPI, India), in the central area of the frameworks (8 × 3 mm) ceramic layering i.e. opaque, dentin, enamel, and glaze of a thickness of 1mm is done using ceramic (VITA VMK Master, Germany).

GROUP D- Indirect composite fused to metal with sand blasting (110 µm aluminium oxide particles).

After the metal samples sandblasted with Al_2O_3 are in the central area of the frameworks (8 × 3 mm) and fused with indirect composite (BREDENT) with a thickness of 1mm in the following manner according to manufacture guidelines:

The procedure for bonding Bredent indirect composite to metal specimen include:-

To the die specimens sandblasting was done, after sand blasting metal primer (MEZ PRIMER, BREDENT) was applied. Later OPAQUE layer which is in the form of catalyst (OPAQUER KATALYST.COMBO.LIGN) and base (OPAQUER LIGHT,COMBO.LIGN)mixed in 1:1 ratio and was applied uniformly and placed in bredent curing unit (bre.Lux Power Unit 2) and the curing was done with curing time fixed according to the manufacturer guidelines. After opaquer, Modelling liquid was applied over the surface of opaque and was allowed to cure. As the curing was completed indirect composite material

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[crea.lign paste, bredent. (Dentin A3) was placed incrementally and was placed in curing unit (bre.Lux Power Unit 2), and the procedure is followed until the required dimensions were obtained.

GROUP E- Indirect composite fused to metal with acid etching (10% hydrofluoric acid)

After the metal samples are acid etched with 10% hydrofluoric acid (Angelus, Brazil) in the central area of the frameworks (8 × 3 mm) and fused with indirect composite (BREDENT) with a thickness of 1mm.

GROUP F- Indirect composite fused to metal with retention beads (88µm)

The metal samples with retention beads (88µm) (DPI, India), in the central area of the frameworks (8 × 3 mm) and fused with indirect composite (BREDENT) with a thickness of 1mm.

After the samples are ready all of them are subjected to 3 point bending test in which the samples were held on either along the length of the samples on two parallel supports separated by 10 mm, and loaded until fracture using 3rd point for flexural strength measurement using Universal Testing Machine (UTM) Instron8801 at a crosshead speed of 1.5mm/min. Supports and loading pistons were steel knife edges rounded to a radius of 0.8 mm. Ones the ceramic cracks and metal flexes upon load application, the machine is stopped, and the reading is recorded for each sample automatically. To the obtained data, statistical analysis is done using SPSS VERSION 21.0 software. The statistical tests performed are One-Way ANOVA to compare the mean between the group, post hoc test and paired t-test for pair wise comparison between the groups.

Results

The flexural fracture force of the veneering materials was 250.48, 261.74, 280.78, 322.86, 328.33 and 332.78 N•cm for Group A, Group B, Group C, Group D, Group E and Group F respectively.

Post Hoc Test Results

	COMPARISON GROUPS	Paired Differences				
		Mean Difference	P-value	Std. Error Mean	95% Confidence Interval of the Difference	95% Confidence Interval of the Difference
					Lower	Upper
Pair 1	Group A - Group B	-25.037	.942	27.491	-105.727	55.653
Pair 2	Group A - Group C	-72.399	.104	27.491	-153.089	8.291
Pair 3	Group A - Group D	-160.852*	.000	27.491	-241.542	-80.162
Pair 4	Group A - Group E	-173.000*	.000	27.491	-253.690	-92.310
Pair 5	Group A - Group F	-187.813*	.000	27.491	-268.503	-107.123
Pair 6	Group B - Group C	-47.362	.522	27.491	-128.052	33.328

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Pair 7	Group B - Group D	-135.815*	.000	27.491	-216.505	-55.125
Pair 8	Group B - Group E	-147.963*	.000	27.491	-228.653	-67.273
Pair 9	Group B - Group F	-162.776*	.000	27.491	-243.466	-82.086
Pair 10	Group C - Group D	-88.453*	.024	27.491	-169.143	-7.763
Pair 11	Group C - Group E	-100.601*	.006	27.491	-181.291	-19.911
Pair 12	Group C - Group F	-115.414*	.001	27.491	-196.104	-34.724
Pair 13	Group D - Group E	-12.148	.922	27.491	-92.838	68.542
Pair 14	Group D - Group F	-26.961*	.000	27.491	-107.651	53.729
Pair 15	Group E - Group F	-14.813	.994	27.491	-95.503	65.877

Post hoc test, Tukey HSD concludes that P value is significant for pair 3, pair 4, pair 5, pair 7, pair 8, pair 9, pair 10, pair 11, pair 12, pair 14 but not for pair 1, pair 2, pair 6, pair 13, pair 15.

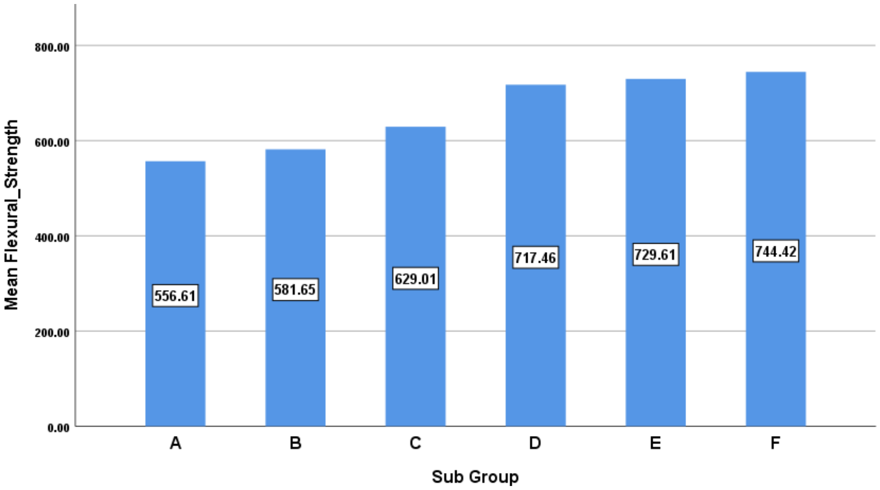
Paired T-Test

Group Statistics

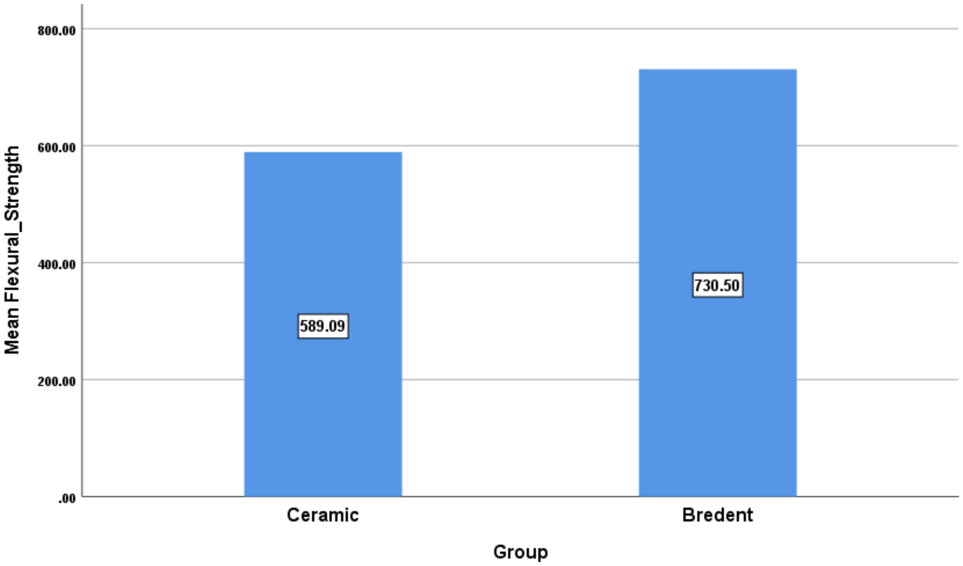
Group	N	Mean	T	P-value
CERAMIC	36	589.0898	-8.658	<0.0001VHS
BREDENT	36	730.4994	-8.658	<0.0001VHS

There was a significant difference between the composite resin veneered and the porcelain veneered specimens (p<0.01).

A bar shows the comparison of mean values of flexural strength among the 6 groups:



A bar shows the comparison of mean values of flexural strength between ceramic and bredent groups:



Discussion

Dental products have developed very rapidly and, consequently, the number of studies designed to evaluate their characteristics is also increasing. Practitioners are aware of the importance of previous laboratory and clinical trials before putting the material into use in their practice. In this way, the knowledge of their mechanical properties is essential to support the correct indication of these materials and to expect long-term performance. Once in the oral cavity, a dynamic situation is established, and then, adverse conditions to the material can be expected.[3]

Metal-ceramic fixed partial dentures (FPDs) have been a standard replacement for missing teeth for many years. Studies on the longevity of FPDs fabricated using high-noble alloys have shown survival rates of 80 to 98%, 81 to 97%, and 74 to 85% after 5, 10, and 15 years, respectively.[13]

For patients with poor periodontal structures who require occlusal coverage, stress-absorbing materials like indirect resin composites are indicated. When compared to porcelain and porcelain-fused-to-metal restorations, the transfer of masticatory forces is considerably less. Composite materials have shown a greater capacity to absorb compressive loading forces and reduce the impact forces by 57% more than porcelain.[14]

The problem of a clinically sustainable connection between metal and veneering resin composite which would be stable in the oral environment has been a constant topic in crown and bridge prosthetics for the last two decades. The clinical success of the composite veneered restorations largely depends on the durability of the resin-to-metal bond in the oral environment.[15]

To eliminate this problem, several bonding systems have been introduced. There are several ways of promoting retention of the composite on the metallic surface: micromechanical (airborne particle abrasion, electrolytic etching, porous metal coating), macro-mechanical (mesh, beads, rough surface with particles), chemical (4-META composites, phosphate-based composites), and adhesive layer (tin plating, silanization), the latter being relatively new.[16]

The advantage to beads is that retention is visualized and contamination of the surface is unlikely. With this retention, however, the casting is thicker and achieving color is arduous because the opaque pools between the beads. If the opaque is not a composite, a decrease in the bond strength can be observed from ―opaque pooling.‖ It was also observed that gaps occurred between the opaque and metal as a result of curing shrinkage. No chemical techniques produced this problem.[17]

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Surface treatments like acid etching, grit-blasting with aluminum oxide or sandblasting with silica-coated particles are the most common methods of surface treatment described in the literature.[18]

Acid etching provides a clean surface with enhanced capacity for micromechanical retention and, as a consequence, increased bond strength potential. Three types of acid etchant have been reported in the literature for the surface preparation of dental ceramics: hydrofluoric acid, acidulated phosphate fluoride, and phosphoric acid.

Hydrofluoric acid*:* Hydrofluoric acid (HF) acts on the silicon dioxide (SiO2) of the glass phase of ceramics, creating surface microporosity, which allows the formation of a mechanical interlock with the composite resin. HF is, however, poisonous and caustic and poses a health hazard owing to its toxicity and volatility. The recommended etching time for HF has been reported to range from 20 seconds to 20 minutes, depending on the concentration of the acid and the type of ceramic substrate. The concentration of HF used for ceramic repair varies between 5% and 10%.[18]

Acidulated phosphate fluoride: Acidulated phosphate fluoride (APF) gel is commonly used for topical fluoride applications. Laboratory studies have failed to reveal any significant differences in adhesive bond strength between composite resin and feldspathic porcelain treated with either 9.5% HF for four to five minutes, or 1.23% APF gel for 10 minutes. Interestingly, surface analyses of HF-etched and APF gel-etched ceramics have revealed different etching patterns. HF interacts with silica in the glass matrix in feldspathic porcelain, resulting in the selective removal of the glassy matrix, exposure of crystalline structures, and an increase in surface roughness. In contrast, APF attacks the glass phase of ceramics, probably due to the selective release of sodium ions, interrupting the silica network, and creating small pits around the leucite crystals in the ceramics, producing micro surface porosity whereas existing literature indicates an etching time of 4 to 15 minutes with APF gel.

Phosphoric acid: While phosphoric acid etching fails to effect any change in the morphology of ceramic substrates, it may be used to good advantage for surface cleaning, following mechanical roughening.

Grid Blasting with aluminum oxide[18]: The grit- blasting of fractured ceramic surfaces is usually performed using purified aluminum oxide particles of 30–250 μm diameter, delivered in a 2–3 bar airstream applied for approximately 15 seconds. The nozzle of the grit-blasting handpiece should be held perpendicular to and 10 mm from the ceramic surface.

It is important to note that the terms ‗surface etching‘, ‗surface conditioning‘, airborne particle abrasion‘ ‗grit-blasting,‘ ‗roughening,‘ ‗sandblasting,‘ ‗silica- coating‘ all appear in the literature, often used as synonyms. This variation in terms often leads to misunderstanding and, in certain situations, confusion in respect of methods and techniques.

Tribochemical Silica-coating and Silanization: Probably the most widely used silica-coating system is the tribochemical Rocatec™ System, introduced by ESPE (Seefeld, Germany) in 1989. Silanization is a specially engineered grit- blasting system based on special chemically designed silica-coated alumina particles for extra-oral conditioning of the substrate surface. This method can increase the bond strength due to the significant increase in silica content of the substrate surface.[17]

In this study Brass alloy was used, Electric Discharge Machining (EDM) was used to machine the brass die to desired dimensions. Impression of the brass die was made using Polyvinylsiloxane impression material (addition

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silicone). With the help of obtained putty index, wax patterns were fabricated.

The obtained wax die specimens were invested using Phosphate bond investment material and wax elimination procedure before casting is done. Base metal alloys(Co-Cr) were used in this study for fabrication of metal die specimens with centrifugal casting machine.

Three different surface modifications were done on twenty four metal samples which include sand blasting with Al_2O_3 particles. On other twenty four samples, acid etching was done with 10% HF for 20 sec. On remaining twenty four samples, retentive beads of 88μm were used as surface modification.

After the surface modifications are done, two different veneering materials which include ceramics and indirect composite were used to bond to metal surface.

Ceramic layering i.e. Opaque, dentin, enamel, and glaze of a thickness of 1mm is done using ceramic on twelve metal samples with sand blasting, twelve metal samples with acid etching, and twelve metal samples with retention beads.

Opaquer combo.lign colour paste, Opaquer Combo.lign catalyst paste.1:1 mix of the dual curing combo.lign opaquer (opaquer paste: catalyst paste) was prepared. The mixed opaquer is applied thinly as a wash opaquer and polymerised for 180 seconds. A thin layer of crea.lign opaquer is applied and allowed to polymerise for 180 seconds. The procedure is repeated until the framework is covered completely masking the underlying metal, after curing, direct composite material was added incrementally and followed by curing until the uniform required thickness was obtained. The final polymerisation for 360 seconds is essential.[19]

Flexural strength was measured in this study which is an important factor with respect to resistance to restoration deformation or rupture by occlusal loads. Flexural strength (FS) provides a reliable predictor for clinical durability.

The three-point bending test was carried out in a Universal Testing Machine (Zwick 1445, Zwick, Utm, Germany) at a crosshead speed of 1.5 mm/min. The bars were subjected to three-point bending in a universal testing machine (model TT-BM, Instron Corp, Canton, Mass.) according to the IS0 4049 protocol for flexural strength. Specimens were placed on two parallel supports separated by 10 mm, and loaded until fracture. Supports and loading piston were steel knife edges rounded to a radius of 0.8 mm, measurement, and results were obtained.

Therefore, with the limitations of the study, it is found that the survey conducted for the evaluation of the flexural strength between two veneering materials (Ceramic and Bredent) fused metal substrate under three surface modifications was significant.

Conclusion

The study was conducted to compare and evaluate the flexural strength of in two different types of veneering materials [Ceramic and Bredent] veneered on co-cr metal under three different surface treatments.

Within the limitations of this study and the material and methods used, the following conclusions were drawn:

Group F. i.e., Bredent composite group of die specimens surface treated with retention beads had more mean flexural strength value than other groups and Group A Ceramic group surface treated with Al_2O_3 had less mean flexural strength than other groups in this study.

According to ANOVA, source of variation between the groups concluded significant i.e., P is <0.0001 where p<0.05 considered significant.The study concluded that bredent group had better flexural strength than ceramic group when repaired with mechanical surface treatment**.**

The effect of retention beads surface treated indirect composite groups showed improved flexural strength than

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HF treated groups and sand blasted groups. Mechanical retentive features were more significant than chemical retentive features.

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Legend Figure

Fig 1: Brass die (25x3x0.5)

Fig.2:Putty index

ISO Standardization

Fig.3:Length of metal

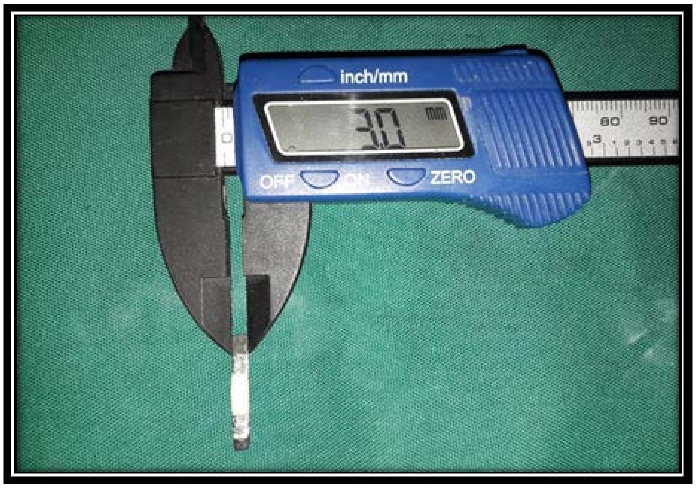

Fig.4:Width of metal samples

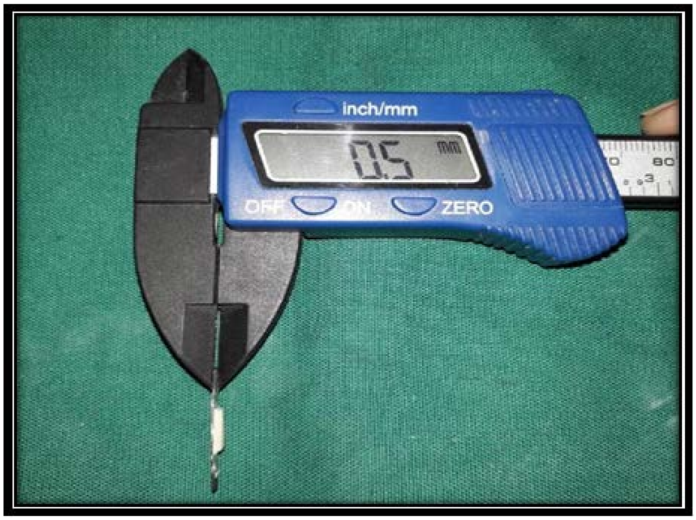

Fig.5: Thickness of metal samples

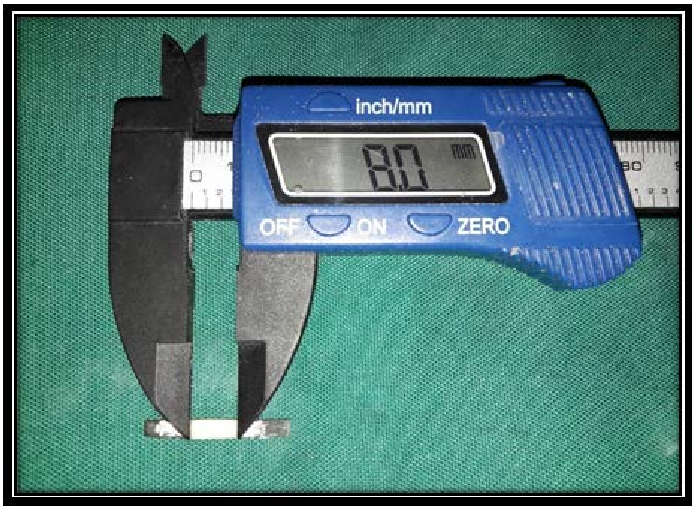

Fig.6: Length of ceramic layer

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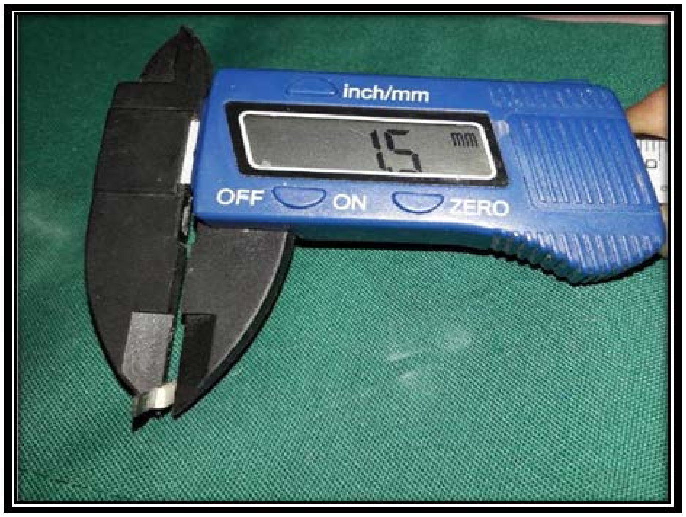

Fig.7: Thickness of metal ceramic

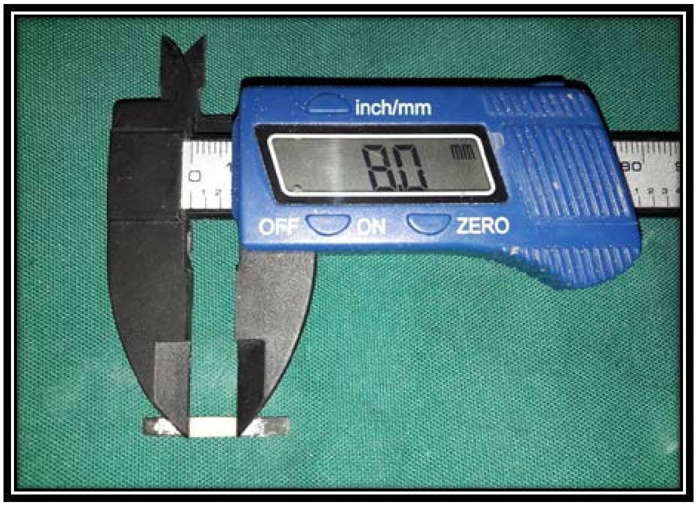

Fig.8: Length of indirect composite layer

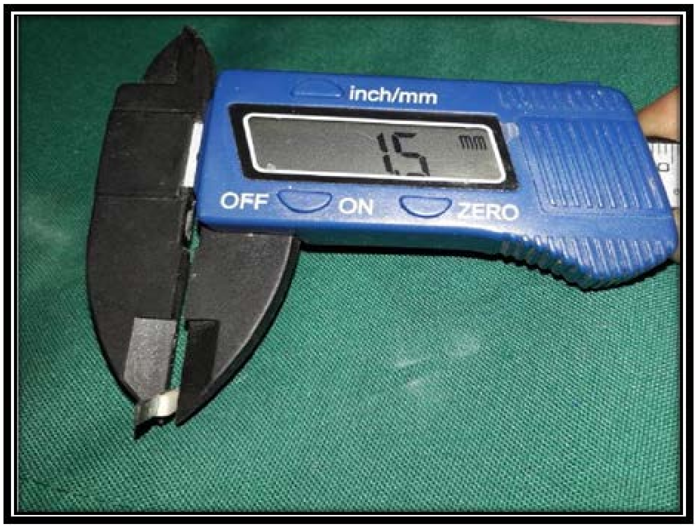

Fig.9: Thickness of metal indirect composite sample

Group A (Metal ceramic samples with sand blasting)

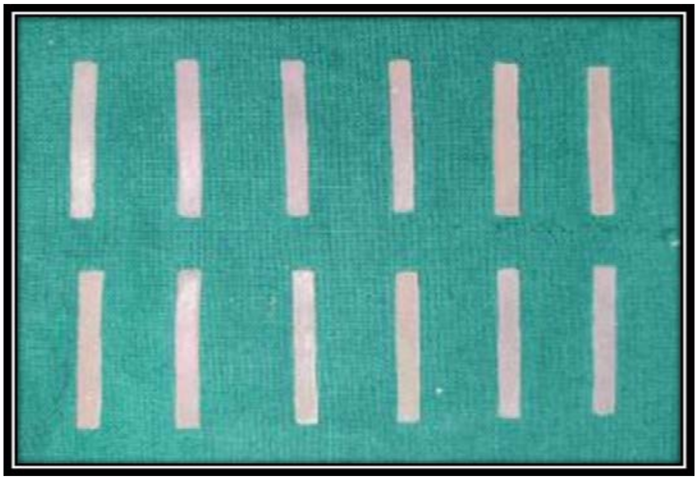

Fig.10: Wax patterns

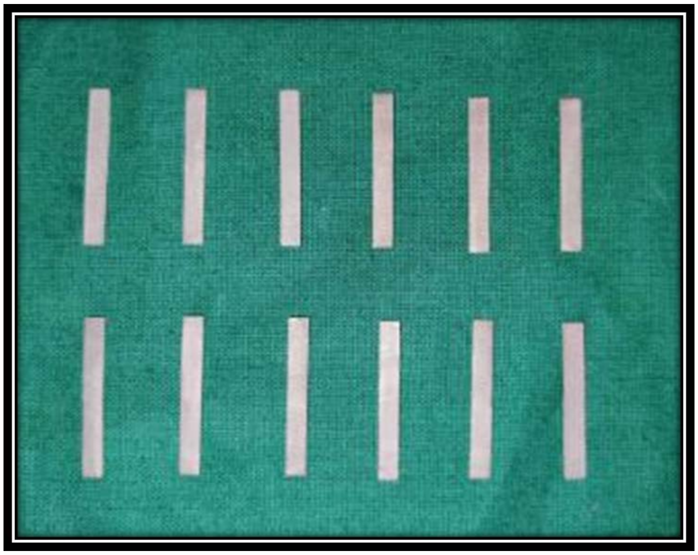

Fig.11: Metal samples

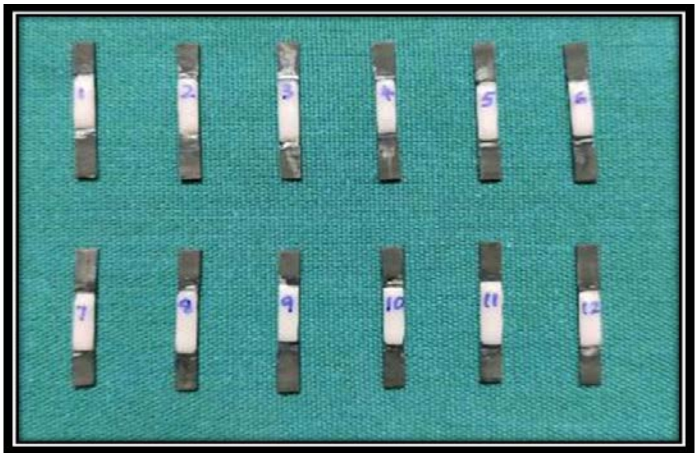

Fig.12: Metal ceramic samples with sand blasting

Group B (Metal ceramic samples with acid etching)

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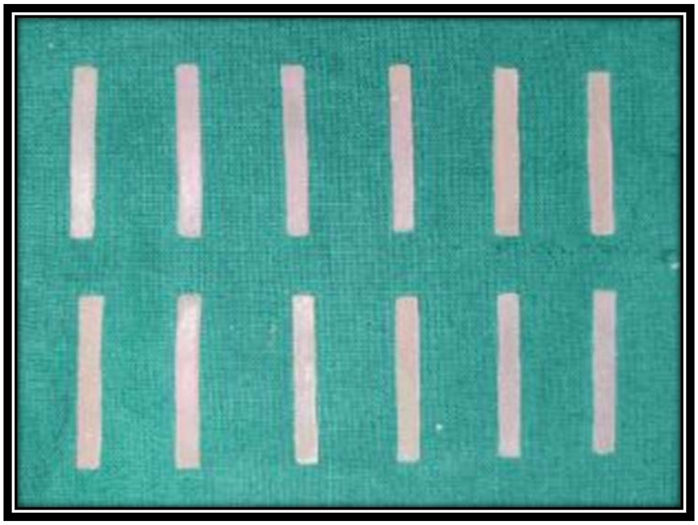

Fig.13: Wax patterns

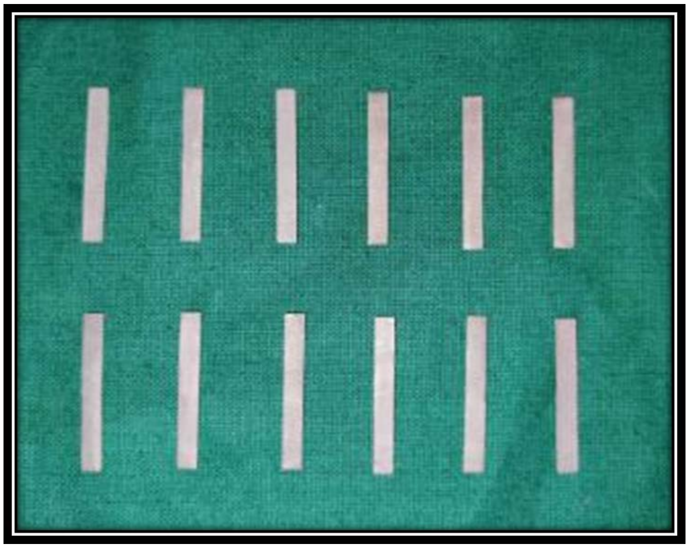

Fig.14: Metal samples

Fig.15: Hydrofluoric acid

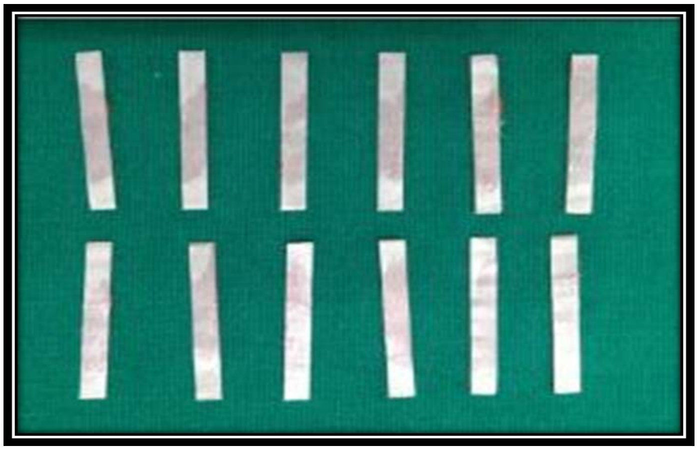

Fig.16: Metal samples with acid etching

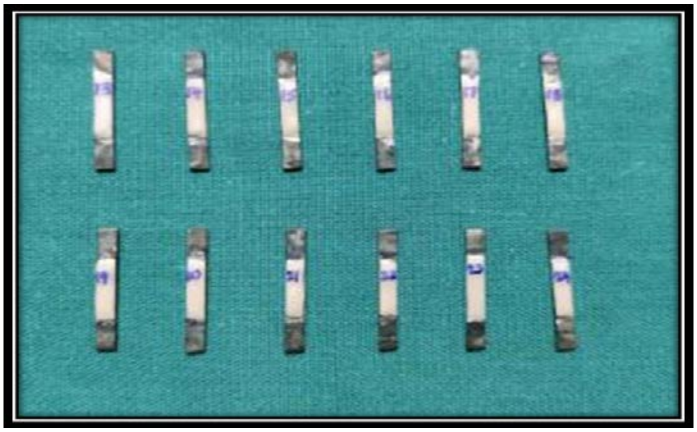

Fig.17: Metal ceramic samples with acid etching

Group C (Metal ceramic samples with retention beads)

Fig.18: Tooth moulding powder

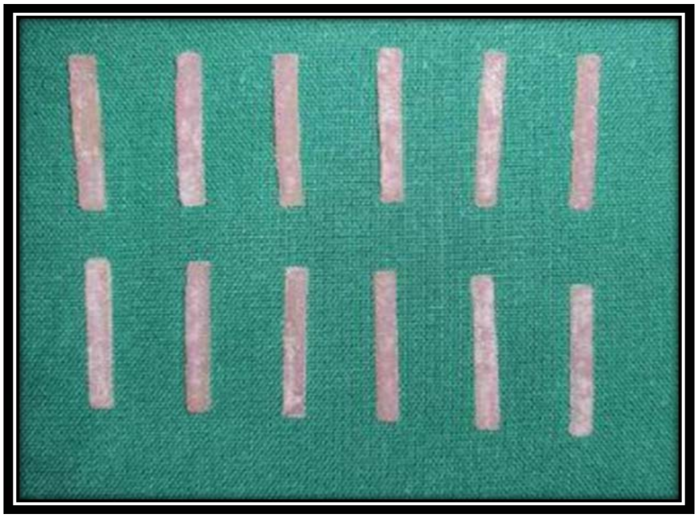

Fig.19.Wax patterns with retention beads

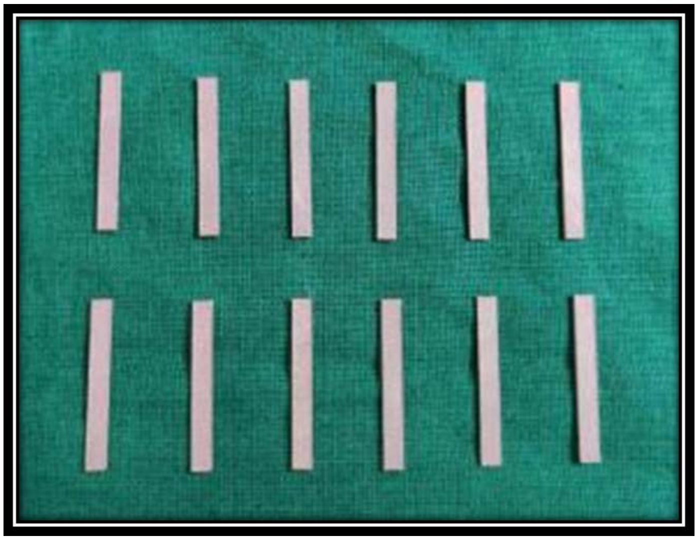

Fig.20: Metal samples with retention beads

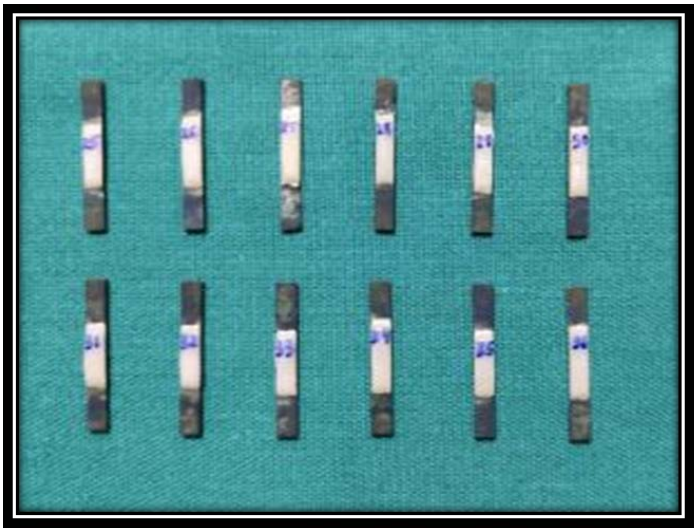

Fig.21: Metal ceramic samples with retention beads

Group D (Indirect composite veneered metal samples with sand blasting)

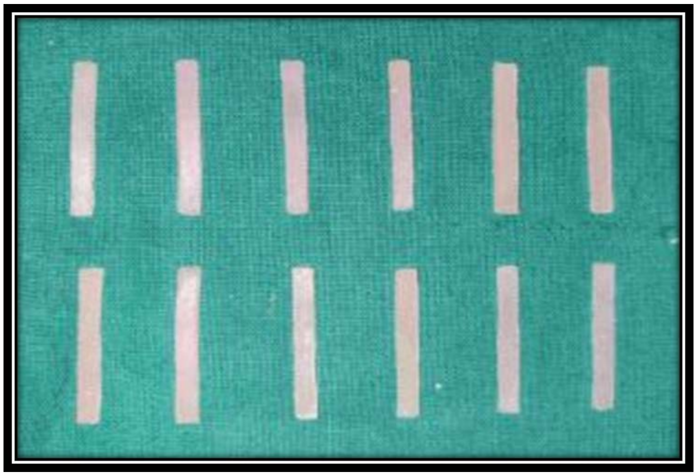

Fig.22: Wax patterns

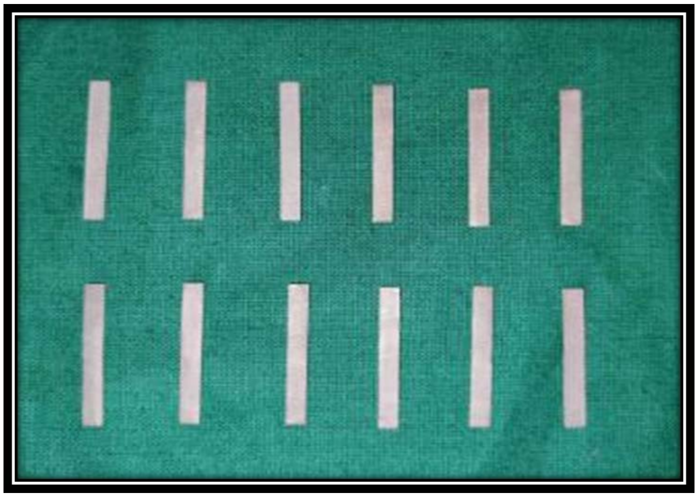

Fig.23: Metal samples

Fig.24: Bredent metal primer

Fig.25: Bredent curing unit

Fig.26: Bredent opaquer catalyst and base form

Fig. 27: Modelling liquid

Fig.28: Bredent indirect composite heavy body paste

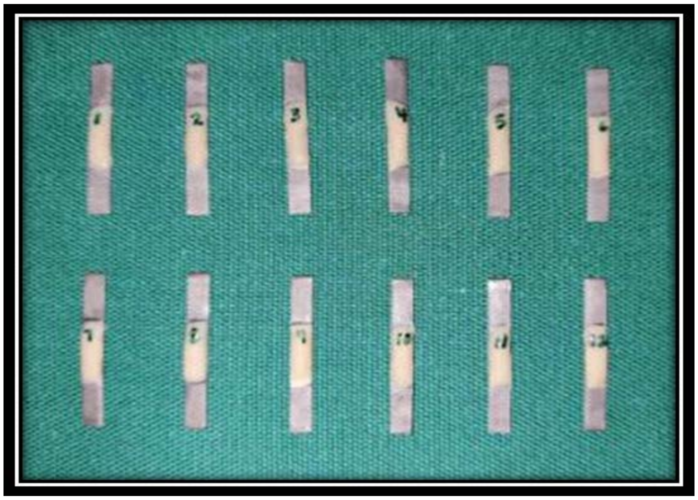

Fig.29: Indirect composite veneered metal samples with sand blasting

Group E (Indirect composite veneered metal samples with acid etching)

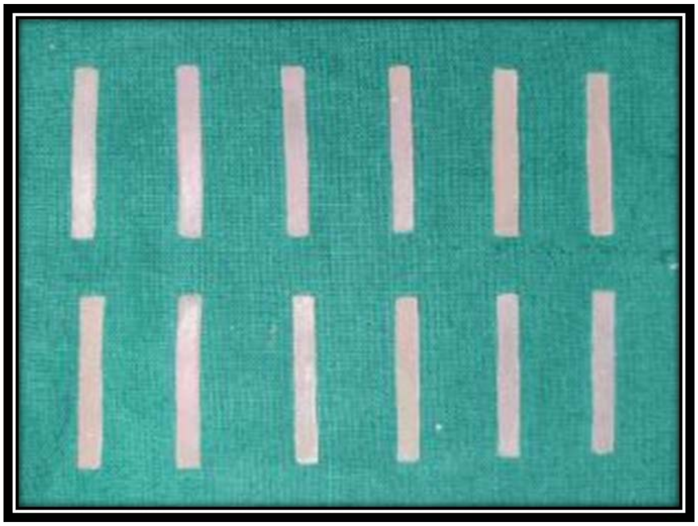

Fig.30:Wax patterns

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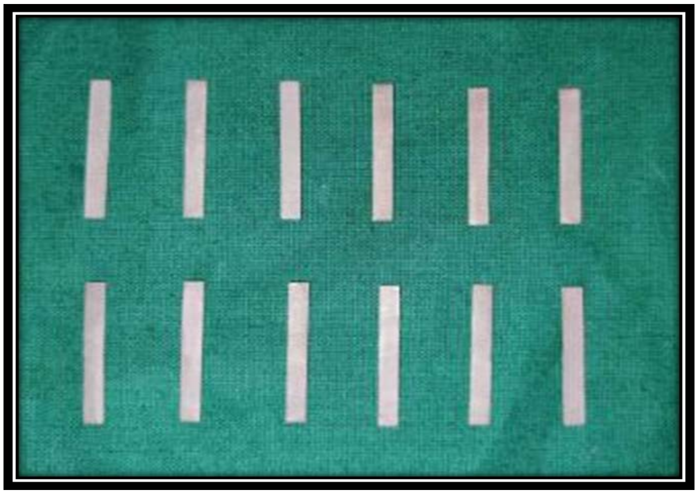

Fig.31: Metal samples

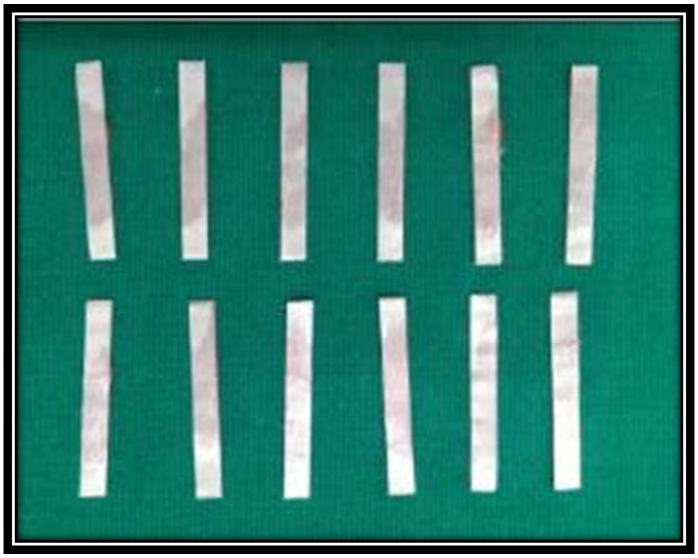

Fig.32: Metal samples with acid etching

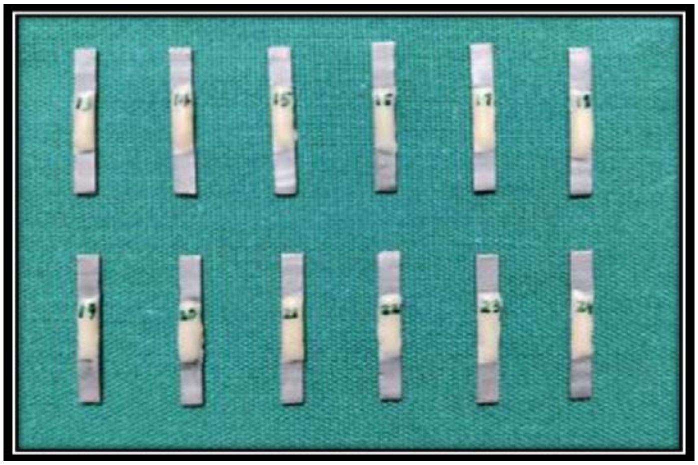

Fig.33: Indirect composite veneered metal samples with acid etching

Group F (Indirect composite veneered metal samples with retention beads)

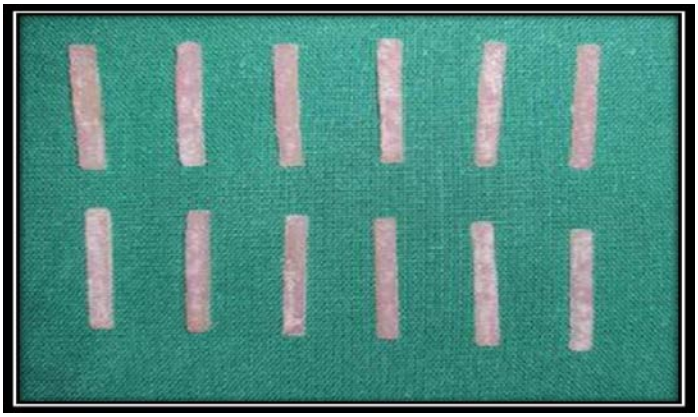

Fig.34: Wax patterns with retention beads

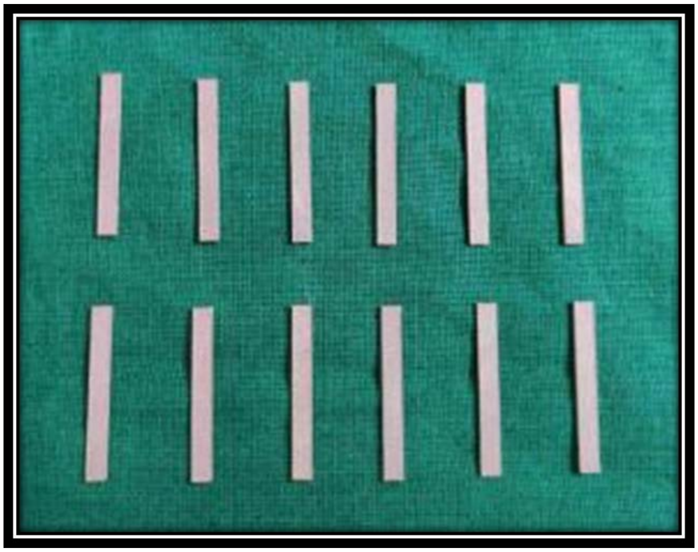

Fig.35: Metal samples with retention beads

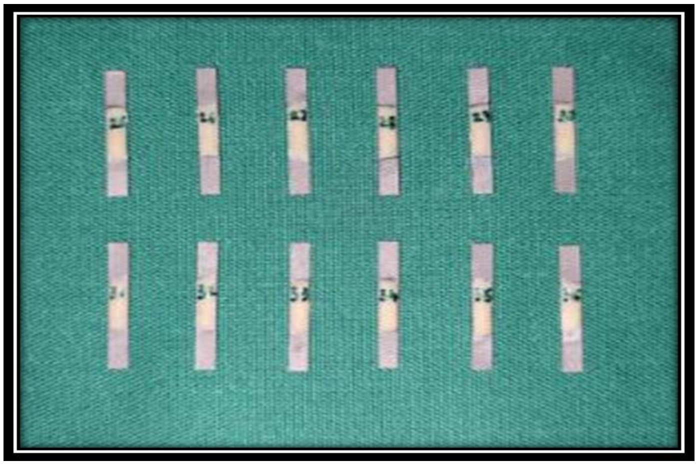

Fig.36: Indirect composite veneered metal samples with retention beads

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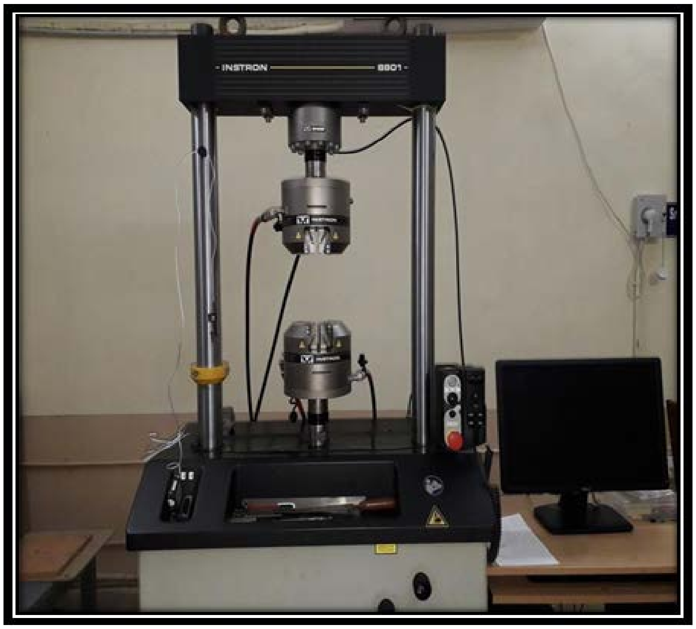

Fig.37: Universal testing machine (instron)

Fig.39: 3-point holding

3-point bend test (flexural strength measurments)

Fig.38

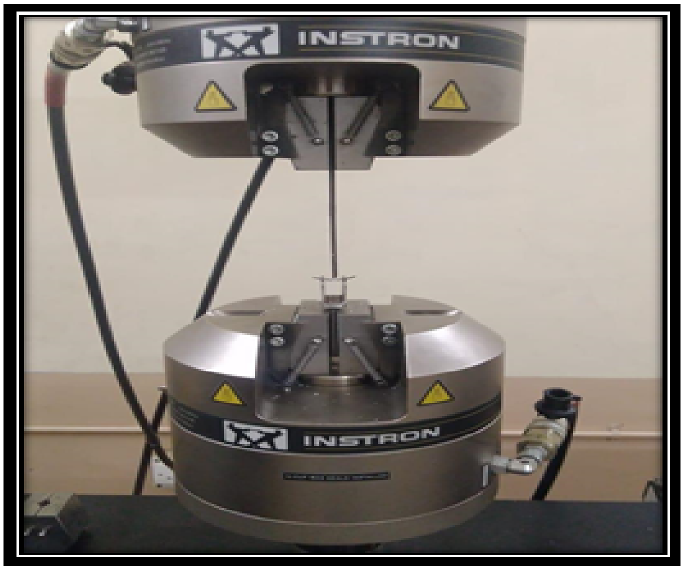

Fig.40: 3-point holding during testing

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Fig.41

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