# QUANTITATIVE DETERMINATION OF CHANGES IN TEXTURE (ROUGHNESS) PRODUCED ON THE SURFACE OF CAST NICKELLCHROMIUM ALLOY AFTER EXPOSURE TO VARIOUS SURFACE TREATMENT PROCEDURES

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**This in vitro study evaluated the quantitative determination of changes in texture (roughness) produced in surface of cast Ni-Cr alloy after exposure to various surface treatment procedures.**

**MATERIAL AND METHODS:** Ni-Cr base metal alloy was selected for the study. Samples were divided into four groups and ten pairs of samples were included in each group.

Group I: No surface treatment and act as control group. Group II: Specimens received surface treatment with 50 μm Al203. Group III: Electrolytically etched. Group IV: Laser surface treatment with Nd: Y AG laser.

One representative sample from each group was studied under scanning electron microscope at various magnifications and surface roughness was assessed with the help of stylus type measuring instrument. Data were analyzed with one tailed't' test.

Group II, III and Group IV samples showed significant increase in the average roughness as compared to control group (Group I). Roughness of Group III significantly greater than of Group II samples ($P < 0.001$) and less than that of Group IV. Roughness of Group IV is significantly less than that of Group II samples.

Studies revealed that all surface treatment procedures are capable for remarkably enhancing surface roughness of cast Ni-Cr alloy. Surface treatment with aluminum oxide and with Nd:YAG laser produce nearly equivalent surface roughness but less than that of electrochemical etching.

Electrochemical etching procedure was found to produce greater surface roughness than air-abrasion and laser ablation.

## INTRODUCTION

Resin bonded fixed partial dentures have gained considerable popularity since the technique of splinting mandibular anterior teeth was described by Rochette [1-3] in 1973.

In contrast to the conventional fixed prosthesis, this prosthesis relies on adhesive bonding between etched enamel and metal castings. They are held in place by resin, which locks mechanically into chemically etched enamel with microscopic undercuts in the castings [4, 5].

The metal resin bonding can be classified as either mechanical or Chemical.[6-9] Mechanical bonding is subdivided into micromechanical retention, which uses etching to create microscopic porosities, and macro-mechanical retention which was etching to create microscopic porosities and macro-mechanical retention which relies on visible undercuts, usually with a mesh or pitted metal [10]. Chemical bonding generally employs tin plating of metal framework and specific resin adhesives for metal and enamel. [11-16]

The metal alloys are protected by a passivating oxide layer. This oxide layer is claimed to be important in forming bonds with adhesive resin luting agent [17, 18]. Sandblasting seems to rarify the reactive oxide coating even though a micro retentive

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surface is provided. Electrochemical etching procedure, on the other hand, is extremely technique sensitive. Great care and costly equipment is required to incorporate the desired precision [19].

Quantitative changes in teeth after laser beam impact have been reported in several recent laboratory studies. Effects caused by absorption of focused laser at the surface of solids are heating, melting, vaporization, atomization, excitation and ionization. The optical energy is turned into heat at point at which light is absorbed. The intense local heating causes a rapid rise in surface temperature of material. Heat is conducted into interior of target and a thin molten layer is formed below the surface. Further heating causes vapori zation leaving craters with raised edges and splattered molten particles surrounding the crater [20]. This reported observations initiated the use of laser for ablading the alloy surface to produce micro retentive surface.

This study explores laser ablation as a possible method of achieving a micro retentive surface and compares the effect of three different surface treatment procedures.

## MATERIAL AND METHODS

The present study is an in-vitro evaluation of changes in surface topography of cast Ni-Cr alloy produced as a result of exposure to air abrasion, electrochemical etching and laser ablation.

Ni-Cr base metal alloy was selected for this study due to its wide application in fabrication of fixed prosthesis.

Square patterns 1 cm x 1 cm were cut from 4 cm x 10 cm x 2.5 mm acrylic resin sheets. These patterns were sprued, invested with phosphate bonded investment material by vacuum investment technique in Muffle furnace using fresh Ni-Cr alloy for each casting operation. Castings were divested and the residual surface investment was removed with sandblasting unit with 110 µm aluminum oxide sand and castings were cleaned in ultrasonic cleaner with distilled water.

Depending upon type of surface treatment used, the samples were divided into four groups and ten pairs of samples were included in each group. Each pair of sample contains one mounted and one unmounted sample.

Half specimens out of 80 were then mounted in circular bases of autopolymerizing resin. After mounting the exposed surface of all specimens received metallographic treatment with series wet emery paper of 200-, 320-, 420- and 600- grit respectively and then polished with 5µm diamond polishing plate on a 50 µm. The entire specimen were then ultrasonically cleaned with soap solution for 15 min and rinsed with distilled water, dried and stored in respective containers.

**Group I**: 20 specimens received no surface treatment (Control group)

**Group II**: 20 Specimens received surface treatment with 50 µm aluminum oxide for 10 sec at pressure of 60 psi, at distance of 10 mm from the nozzle after masking the surface with a water proof Teflon tape except for a 5 $mm^2$ area in center.

**Group III**: 20 Specimens were electrolytically etched with 0.5 N nitric acid solutions at 3 volts of direct current for 5 min. A stainless steel plate was used as cathode and specimens were made anode. Metal membrane formed during etching was removed by ultrasonically cleaning the samples in 18% HCI for 10 minutes.

**Group IV**: 20 Specimens were exposed to laser radiation of Q-switched Nd: YAG lasers of 100 nsec pulse duration, having wavelength of 1.064 micron were used. After focusing the beam, the spot size obtained was 100 microns.

First, we made an Auto-CAD plot file for the required etching and then fed it through the computer. The specimens were ultrasonically cleaned in distilled water for ten minutes both before and after irradiation.

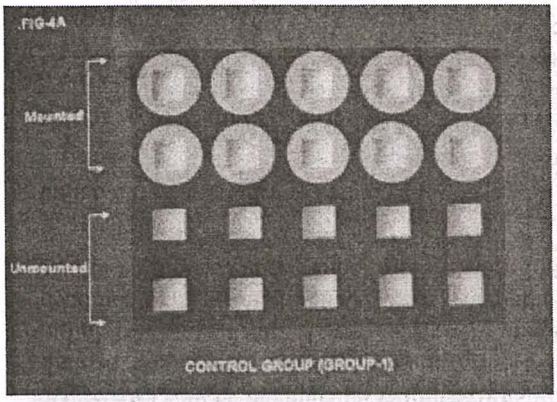



*Fig. 1 Control group (Group I)*

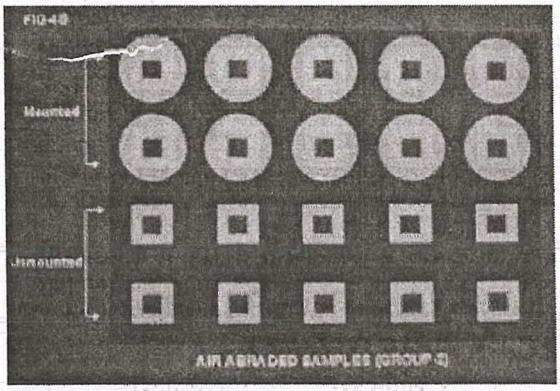



*Fig. 2 Air abraded samples (Group II)*

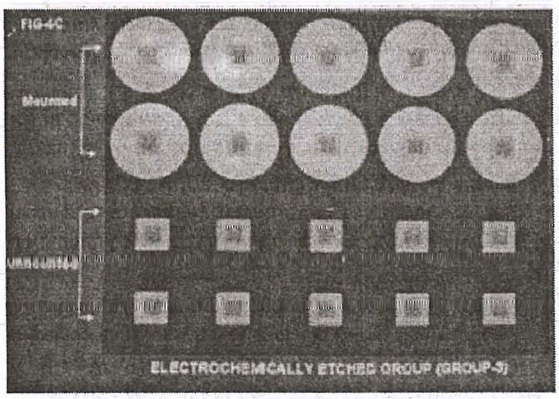



*Fig. 3 Electrochemically etched group (Group III)*

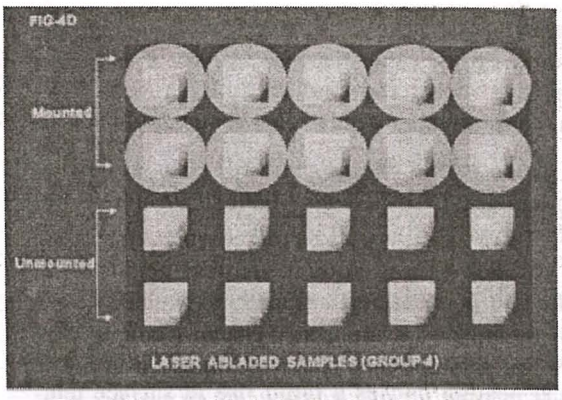



*Fig. 4 Laser abladed samples (Group IV)*

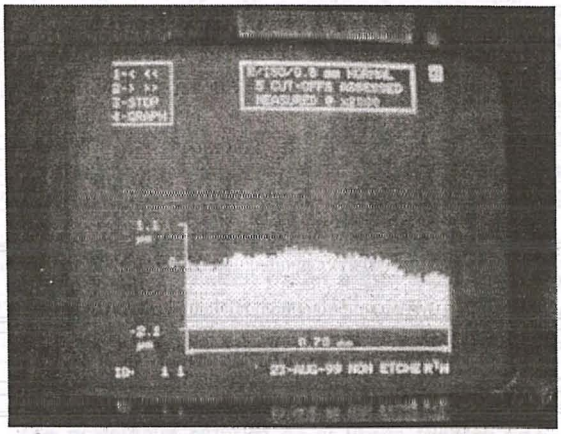


*Fig. 5 Profile of control samples on Taly surf-50.*

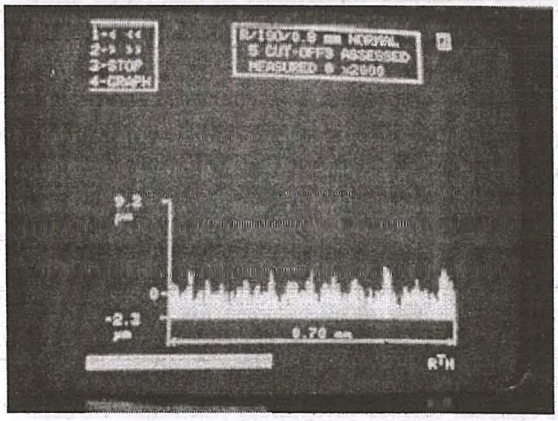


*Fig. 6 Profile of air abraded samples on Taly Surf-50.*

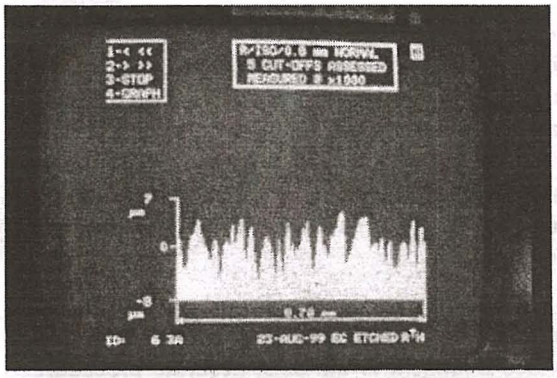


*Fig. 7 Profile of electrochemically etched Samples on Taly Surf-50.*

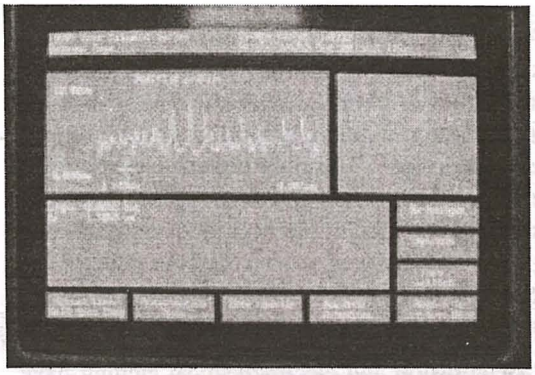


*Fig. 8 Profile of laser abladed samples on Taly Surf-50.*

One representative sample from each group was selected randomly and was studied under scanning electron microscope to assess surface topography. Surface roughness was assessed for representative samples from each group with the help of a stylus type measuring instrument (Taly Surf 50, Taylor Hobson) and Ra Values were computed as averages in microns.

**Statistical Analysis**

The data collected after measuring the surface roughness of 10 samples each from all four groups were analyzed using one tailed't' test.

**RESULT**

**Table Showing Statistical Analysis of data collected after testing Mean Surface Roughness Values (Ra) of all Four Groups.**

| Sample No. | Group-I | Group-II | Group-III | Group-IV |
|---|---|---|---|---|
| n | 10 | 10 | 10 | 10 |
| Mean | 0.224 | 1.396 | 2.272 | 1.3270 |
| S.D. | 0.0493 | 0.2704 | 0.2833 | 0.00341 |

*Group I = Control group; Group II = Air abraded; Group III = Electrochemically etched; Group IV = Laser abladed*

| | | | |
|---|---|---|---|
| t 1 vs 2 | 71.3185 | P < 0.001 | Significant Increase |
| t 1 vs 3 | 124.6248 | p < 0.001 | Significant Increase |
| t 1 vs 4 | 67.1197 | P < 0.001 | Significant Increase |
| t 2 vs 3 | 7.0741 | P < 0.001 | Significant Increase |
| t 2 vs 4 | 0.8070 | p> 0.10 | Insignificant Increase |
| t 3 vs 4 | 10.5947 | P < 0.001 | Significant Increase |

Group II, III and IV samples show significant increase in roughness as compared to control group. On comparing we find that roughness of group III samples is significantly greater than that of group II samples ($P < 0.001$). Roughness of group IV samples is significantly greater than that of group III but less than that of group II samples ($P > 0.10$).

## DISCUSSION

Reliable bonding between metal prosthesis and tooth surface is obtained after chemically etch the tooth surface and failure site is most often at metal cement interface [1, 2]. Surface treatment of the metal to enhance the bonding and to strengthen this weak link in the bond module has been studied extensively [3, 7, 9, 21, 22]. Micro perforations have been provided to better retention than macro retentive arrangements. [19]

Air abrasion and electrochemical etching have been tried for the purpose of roughening metal surfaces and are now accepted laboratory techniques. Etching provides excellent undercuts for locking the resin tags, but at the same time removes high-energy surface regions from metal surface, thus decreasing metal to resin bond strength. [18] Aluminum oxide roughens the surface. It also elevates the reaction to resinous cements and created micromechanical retention to improve bond strength. Although electrolyte etching is presently considered the best way to bond resin to the surface of a metal casting, there are a number of disadvantages such as current density, inter-electrode distance. Finally, it is difficult, if not impossible to determine visually whether the surface has been properly etched. [11]

In this experiment, we are using effect of laser for producing porosities on metal surfaces. Since Nd:YAG lasers are capable of providing the high energy output, which is used for the generating pits in the metal.

An appropriate quantitative judgment of the roughness produced as a result of surface treatment was achieved by using a stylus type surface roughness testing machine and recording the Ra (roughness parameter) values. Ra is the universally recognized, and most used international parameter of roughness. It is arithmetic mean of departure of profile from mean line. The graph obtained by the parameter studied gives a visual impression of the amount of roughness produced in profile. This and the Ra values obtained from samples of each group provided logical basis for the comparison of different amount of surfaces roughness produced for each group (from manufacturer's instruction manual). Since this instrument is stylus type, the smallest depression measured cannot be smaller than stylus tip. Therefore, the use of more accurate laser based interferometers is needed for enhancing accuracy.

The extremely consistent Ra values obtained for the group N samples suggest that this method of surface treatment is the most accurate procedure for achieving extremely even surface topography. Since all parameters of laser power, scan length, dwell time and increment were kept constant for all exposures with the help of Auto-CAD setup, such results were expected. These results reinforced our belief that as far as this technique was concerned; all parameters can be exceedingly well controlled according to requirement. Exhaustive experiments with different laser intensities and other variable should be carried out to pinpoint the optimum parameters. Other high power lasers can be tried for the same purpose and cost effectiveness and ease of handling determined.

All the three methods were found to substantially augment the surface roughness. These findings correlate with all the previous studies carried out with air abrasion and electrochemical etching. The innovative technique of laser ablation described and used in this experiment is unique in its efficiency, regularity of pitting and reproducibility.

## CONCLUSION

In this in-vitro experimental study, after compilation and statistical analysis of data, we came to the following conclusions:

1. All the three surface treatment procedures are capable for remarkably enhancing the surface roughness of cast Ni-Cr alloy ($P < 0.001$).
2. The surface treatment with 50 micron aluminum oxide sand and with Nd: YAG lasers produced nearly equivalent surface roughness.

3. The surface treatment with but electrochemical etching enhance greater surface roughness than 50 micron aluminum oxide sand.
4. The surface treatment with but electrochemical etching enhance greater surface roughness than Nd: YAG lasers.
5. Nd: YAG lasers provide an effective surface treatment procedure for fixed prosthesis.
6. Remarkably consistent results with Nd: YAG lasers may be obtained with the precise focusing and Auto-CAD system.

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