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Comparative Surface Roughness Evaluation of a Novel Aesthetic Restorative Material using Profilometer - An In Vitro Study

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Abstract

Aim: To evaluate and compare the surface roughness of nano ionomer, microhybrid composite, and resin modified glass ionomer cement.

Method: A total of 30 PVC moulds of dimension (diameter 8mm height 2mm) were prepared. The total of 30 specimens was divided into three groups each consisting of 10 discs each. Group1- 10 discs made of microhybrid composite (Z250, 3M ESPE, St. Paul, MN, USA), Group 2- 10 discs made of resin modified GIC (Fuji II LC, GC), Group 3-10 discs made of nano ionomer (Ketac N100, 3M ESPE, St. Paul, MN, USA). After polymerization the discs were subjected to finishing and polishing using Sof-lex finishing polishing kit(3M ESPE, St. Paul, MN, USA). After finishing the specimens were thoroughly washed and air dried before subjecting them to profilometric analysis. The profilometric values were statistically analyzed using ANOVA and Tukey Hoc tests.

Results: The surface roughness values were statistically significant between group 1 and group 2 and between group 2 and group 3 but there was no statistically significant difference between group 1 and group 3.

Keywords: Surface roughness, composite resins, polishing, Nano ionomer, profilometer.

Introduction

Effective finishing and polishing of dental restorations results in optimal esthetics, provides an acceptable oral health of soft tissues and marginal integrity of restorative interface, thereby enhancing both the esthetics and longevity of the restorations. Restorative finish, surface roughness, surface integrity and physiochemical properties of the material can influence its clinical performance.[1, 2] Finishing is defined as a gross contouring or reduction of a restoration to obtain ideal anatomy whereas polishing refers to reduction of roughness and scratches created by finishing instruments. The finishing and polishing of dental restoration uses three basic procedural steps of Gross reduction-contouring and margination; intermediate abrasive finishing; final abrasive polishing based on sequential application of progressively finer grits of abrasive medium in various types of devices.[1] Over the years several changes have taken in the fabrication of dental resin composites to obtain better color stability, wear resistance and clinically acceptable surface smoothness. Composite resin surface roughness is usually dictated by size, hardness, amount of filler content and by the flexibility of the backing material hardness and grit size of abrasives.[3,4,5]

Composite and Glass ionomer cement (GIC) stand at the two ends of the continuum of tooth colored restorative materials. As a restorative material glass ionomer cements have numerous desirable properties including fluoride release, adhesion to dentin and enamel, similar thermal expansion to dentin and low solubility in oral fluids when set. To overcome the moisture sensitivity and low early mechanical strength associated with conventional glass ionomer

cements while maintaining their clinical advantages resin modified glass ionomer cements were introduced.[6] The advent of nanotechnology has made breakthrough changes in dentistry. The successful introduction of nanofiller particle in composite resin[7] paved the path for introduction of world first nano glass ionomer cement incorporated with nanofillers. Nano ionomer is said to be an ideal alternative esthetic glass ionomer solution for everyday dentistry. Incorporation of nanofiller particles in nano ionomer have been claimed to have advantages over resin modified glass ionomer cements. These are of superior polish and excellent esthetics. (Ketac N100 technical profile 3M ESPE, St. Paul, MN, USA). Although the surface finish of composites and resin modified gics have been widely investigated both in vitro and in vivo, the quality of surface finish of nano ionomer has not yet been reported. With the introduction of this new nano ionomer it is important to evaluate for surface characteristics to determine the best material for clinical use among all contemporary materials which fulfills both the esthetic and physical requirements of the restoration. Hence the aim of this study was to evaluate and compare the surface roughness of nano ionomer, resin modified gic and microhybrid composite. The Null hypothesis of this study is that there is no difference in the surface roughness of nano-ionomer, resin modified glass ionomer cement and microhybrid composite.

Materials and methods

One microhybrid composite (Z250, 3M ESPE, St. Paul, MN, USA), one resin modified gic (Fuji II LC, GC) and a nano ionomer (Ketac N 100,3M ESPE St. Paul, MN, USA) were used in the study (Figure 1,2,3). The properties of these materials are shown in Table no.1. The finishing and polishing system used was Sof-lex finishing polishing kit (3M ESPE St. Paul, MN, USA). Table no.2 shows the details about the polishing system used. A total of 30 specimens (10 specimens of each restorative material) were fabricated by placing them in custom made circular PVC (polyvinyl chloride) moulds of dimensions (diameter 8mm height 2mm) and covered with mylar strips (Figure 4,5). A glass slide was placed over this and placed a 2,000-gram axial load over it for 30 seconds to eliminate excess material. All the restorative materials were cured according to manufacturers' instructions with a curing unit (Elipar Free light2, 3M ESPE St. Paul, MN, USA). The intensity of light source was checked with a radiometer Blue phase(Ivoclar Vivadent, Liechtenstein) before starting the experiment with mean output of 1200 mW/cm^2 and was kept constant for all specimens.

After light polymerization Mylar strips were discarded and the specimens were stored in distilled water at 37^0C for 1week. After storage the specimens were finished/ polished with graded series (coarse, medium, fine, extra fine) of Sof-lex discs by single evaluator. Finishing/polishing was carried out dry at 10,000 rpm for coarse and medium discs and 30,000 rpm for fine and extra fine discs as per manufacturer's instructions in planar motion. Discs once used were discarded. After each polishing all the specimens were thoroughly rinsed with water and air dried before next step until final polishing.

Surface analysis

After that the specimens were thoroughly rinsed and air dried. Then the specimens were subjected to profilometric evaluation with non contact optical profilometer Vecco NT 1100 (Vecco Metrology group, USA). The sampling length was adjusted at 100 microns at a resolution of 20X magnification and surface roughness parameters were recorded digitally (Figure 6).

Statistical analysis

Once the profilometric readings were obtained they were subjected to statistical analysis using One way ANOVA and Tukey Hoc tests.

Results

Means and standard deviations of surface roughness (Ra, nm) produced by Sof-lex discs on the three restorative materials (Z250, Fuji II LC, and Ketac N100) are listed in Table-3. The samples were evaluated for scanning region of 301.6 microns × 229.5 microns at a sampling length of 100 microns with 20X magnification. The surface roughness values in terms of peaks and valleys in accordance with a color coded bar against a mean plane were evaluated (Figure 7, 8, 9). For all three materials Ra values depicting surface roughness of three restorative material after finishing and polishing were lowest for group 1 (Z 250, microhybrid composite) closely followed by group 3 (Ketac N 100, nanoionomer) but were significantly greater for group 2 (Fuji II LC, resin modified gic). After Tukey Hoc test it was found that there was statistically significant difference ($p< 0.001$) between group 1 and group 2 and also between group 3 and group 2.

But there was no statistically significant difference between group 1 and group 3. The results are graphically depicted in Figure 10. Hence the null hypothesis was rejected.

Discussion

The materials evaluated in this study represent the entire continuum of direct aesthetic restorative material currently available to the dental practitioner. High-quality finishing and polishing of resin based material are important steps to enhance both the esthetics and longevity of restored teeth. Unfortunately, polishing is complicated by the heterogeneous nature of these dental materials, i.e., hard filler particles embedded in a relatively soft matrix.[8] Due to this heterogenous nature there is preferential removal of softer resin / hydro gel matrix between harder glass particles. Eventually the glass particles are left unsupported and are displaced.[9] An effective finishing and polishing system needs to consist of abrasive particles relatively harder than the filler materials. The hardness of aluminium oxide as an abrasive is significantly higher than most filler materials used. The Sof-lex discs provides a smoother surface as this has the ability to flatten the filler particles and abrade the softer resin matrix at an equal rate.[10] A graded abrasive disk system was selected as it has been shown to give the best surface finish among the different finishing /polishing systems for most direct tooth colored restoratives.[11, 12]

Fruit et al (1996) comparing different polishing motions showed that for all possible combination of materials and abrasive grits the planar motion achieved the lowest average roughness values. The planar motion is a rotational movement with the axis of rotation of the abrasive device perpendicular to the surface being smoothed (abrasive disc).[13] In this study all the specimens were finished with Sof-lex discs using planar motion.

Various methods employed to assess the effectiveness of finishing and polishing instruments include Visual evaluation (aided with an optical microscope; unaided with the naked eye), Scanning electron microscopy (SEM), Atomic force microscopy, Profilometric analysis (mechanical or optical). The optical profilometric analysis method supersedes all as it gives a quantitative aspect through the calculation of (Ra) which cannot be obtained with scanning electron microscope. Ra represents the roughness average, the arithmetic mean of the absolute values of the surface departures from the mean plane. Second the optical profilometer uses a light that sweeps the sample surface detecting tiny variations that the stylus of mechanical profilometer would not be able to penetrate.[14, 15]

Although restoratives cured against a matrix are not devoid of surface imperfections they represent the smoothest surface possible for most direct tooth-colored restorative materials.[5] These surface imperfections are the reproduction of flaws on the matrix strips.[16] Matrix finished surfaces are polymer-rich[17] and this layer is relatively unstable.[18] Despite careful placement of matrices, removal of excess material and recontouring of restorations is often clinically necessary. This requires some degree of finishing and polishing that will violate the smoothness obtained with a matrix. The latter accounts for the significantly greater Ra values observed after finishing/polishing of most materials.[6] The finishing /polishing was delayed for one week for post irradiation hardening of compsite and matrix formation of the glass ionomer cements.[5, 19, 20]

Results may be explained by in part by the microstructure and mean particle size of restorative materials. The materials evaluated can be considered biphasic with one phase embedded in the other. Glass ionomers consist of glass particles in hydro gel matrix and composites consist of filler in resin matrix. Size of filler particles plays a major role in determining surface roughness. During finishing and polishing there is preferential removal of hydro gel matrix between harder glass particles /fillers. Eventually the glass particles/fillers are left unsupported and displaced. Materials with large glass particles/fillers sizes are therefore expected to be rougher after finishing.[9] The filler particle size for Z250 is in the range of 0.6 µ whereas filler particle size for Fuji II LC is 3-4 µ.

The filler content of Ketac N 100 consists of an acid reactive Fluoroaluminosilicate glass (FAS) and a unique combination of nanofiller. The FAS(fluoroaluminosilicate) glass is has an approximate particle size of less than 3 µ (average particle size approximately 1 micron), and provides the basis for the glass ionomer reaction In addition nano-ionomer restorative further contains a unique combination of two types of surface treated **nanofillers** (approximately 5-25 nm) and **nanoclusters** (approximately 1.0 to 1.6 µ). Nanofillers are discrete nonagglomerated and non-aggregated fillers of 5-25nms in size whereas nanocluster fillers are loosely bound agglomerates of nano-sized zirconia/silica that appear as a single unit enabling higher filler loading, radioapacity, and strength. Owing to these variations restorative material with larger filler size presented with higher Ra values.

There was no significant difference between the surface roughness values between group 1 (Z250) and group 3 (Ketac N 100) although the lowest surface values were obtained with Z250. The probable reasons for higher Ra values for Ketac N 100 may be with FAS component of dual filler system with approximate particle size of less than 3 microns (average particle size approximately 1 µ) which is greater than the average filler particle size of Z 250 (0.6µ). The results from this in vitro study only correlate to the clinical situations where there are accessible and relatively flat surfaces. Further studies are needed where different modes of finishing and polishing techniques can be used to evaluate the surface properties of the new material for better simulation with clinical conditions.

CONCLUSION

Within the limitations of this in-vitro study the following conclusions can be drawn from the results of this study.

1) The surface roughness values for Z250 and Ketac N 100 were statistically significant in comparison to Fuji II LC.
2) The surface roughness values were statistically insignificant for Z250 and Ketac N 100.
3) The surface roughness values were lower for Z250 And Ketac N100 as compared to Fuji II LC.
4) The surface roughness value for any restorative material is material dependent.

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Figure Legends

Figure 1 – Z 250 (micro hybrid composite)
Figure 2 – Fuji II LC (resin modified GIC)
Figure 3 – Ketac N 100 (nano ionomer)
Figure 4 – PVC moulds
Figure 5- Prepared specimens
Figure 6 – Sample focused at a sampling length of 100 microns and 20X magnification
Figure 7– 3 dimensional profilometric analysis for Z250 polished specimen
Figure 8 –3 dimensional profilometric analysis Fuji II LC polished specimen
Figure 9 – 3 dimensional profilometric analysis Ketac N 100 polished specimen
Figure 10 – Graph depicting mean surface roughness values

Table No.1: Properties of Restorative materials used in the study

Material	Category	Composition	Manufacturer	Batch no
Z 250	Microhybrid composite	Bis –GMA TEGDMA Zirconia silica filler particles	3M ESPE	8E125
Fuji II LC	Resin modified GIC	Powder Alumino silicate glass, pigments Liquid Polyacrylic acid, distilled water, HEMA (17%), dimethacrylate monomer, Camphoroquinone	GC Corporation	0707021
Ketac N 100	Nano GIC	Aqueous paste (acidic polyalkenoic acid, reactive resins and nano fillers) Non aqueous paste (FAS glass, reactive resins, and nano fillers) Filler content (69%) 27% FAS glass (acid and free radically reactive) 42% methacrylate functionalized nano fillers (acid and free radically reactive	3M ESPE	3527

Table No. 2: Description of finishing /polishing system

Finishing /polishing	Description	Manufacturer
Sof –Lex system	Coarse disc aluminium oxide (55µ) Medium disc aluminium oxide (40µ) Fine disc aluminium oxide (24µ) Extra fine disc aluminium oxide (8µ)	3M ESPE

Table No.3: Mean Values of Surface Roughness

Study Groups	Mean	SD	F* Value	P Value	Significant Pairs**
Group 1 (Z250)	163.40	10.90	46.68	P<0.001 Highly Significant	Group 1& Group 2 Group 2& Group3
Group 2 ((Fuji II LC)	263.74	36.00			
Group 3(Ketac N 100)	175.45	17.92			

* Oneway ANOVA TEST
** Tukey Post Hoc test

Figure 1 – Z 250 (micro hybrid composite)

Figure 2 – Fuji II LC (Resin modified GIC)

Figure 3 – Ketac N 100 (Nano ionomer)

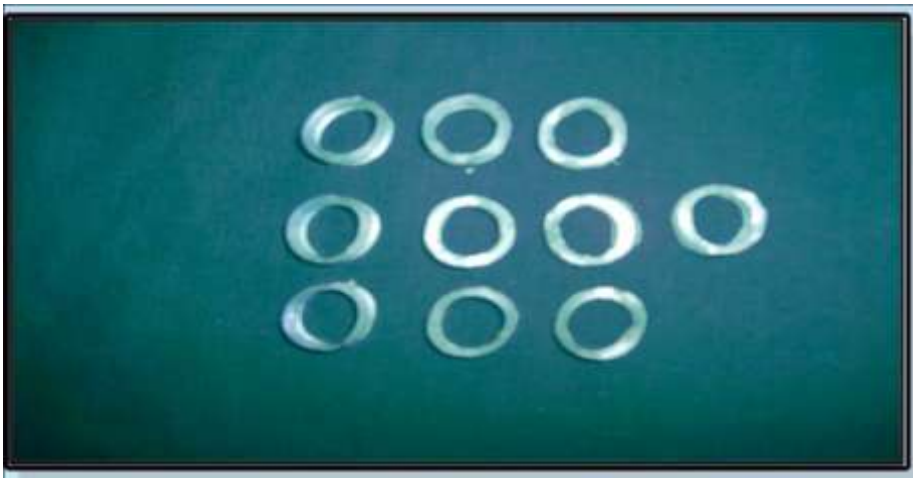

Figure 4 – PVC moulds

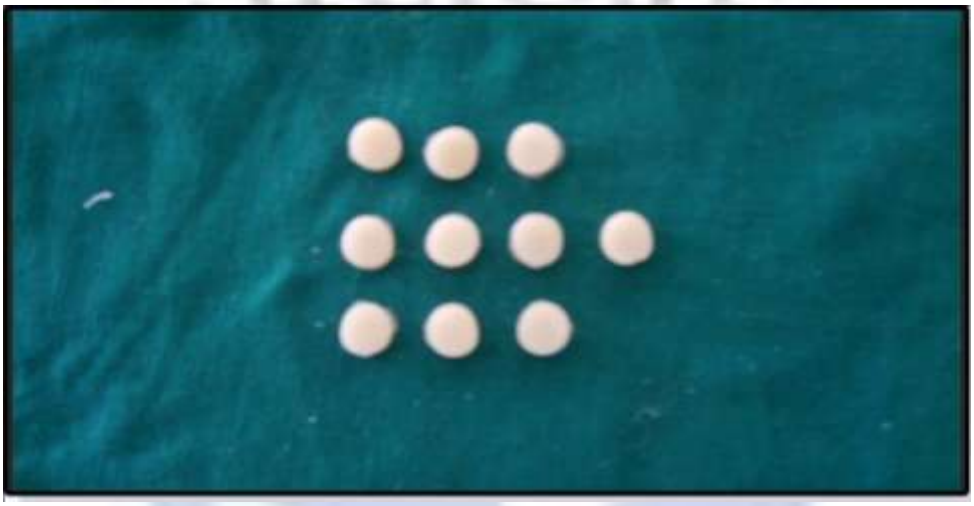

Figure 5- Prepared specimens

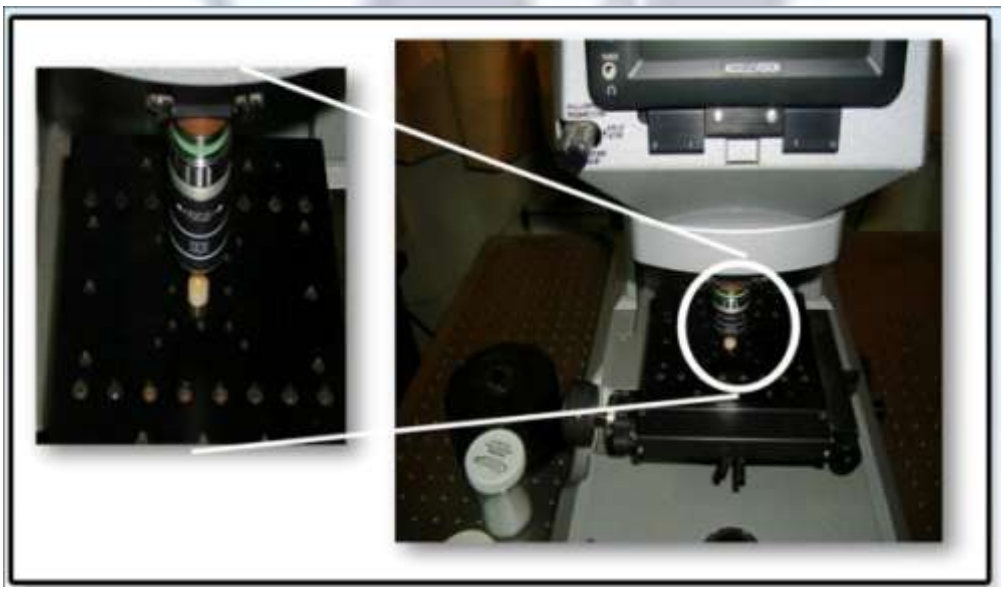

Figure 6 – Sample focused at a sampling length of 100 microns and 20X magnification

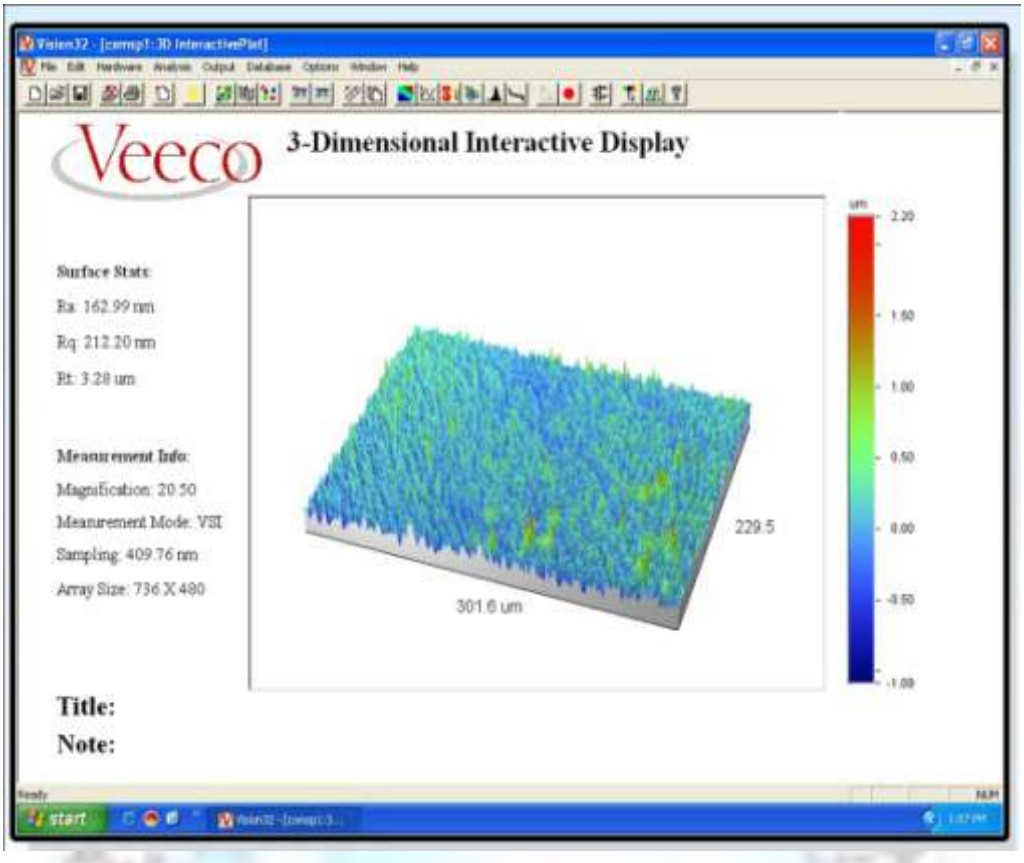

Figure 7– 3 dimensional profilometric analysis for Z250 polished specimen

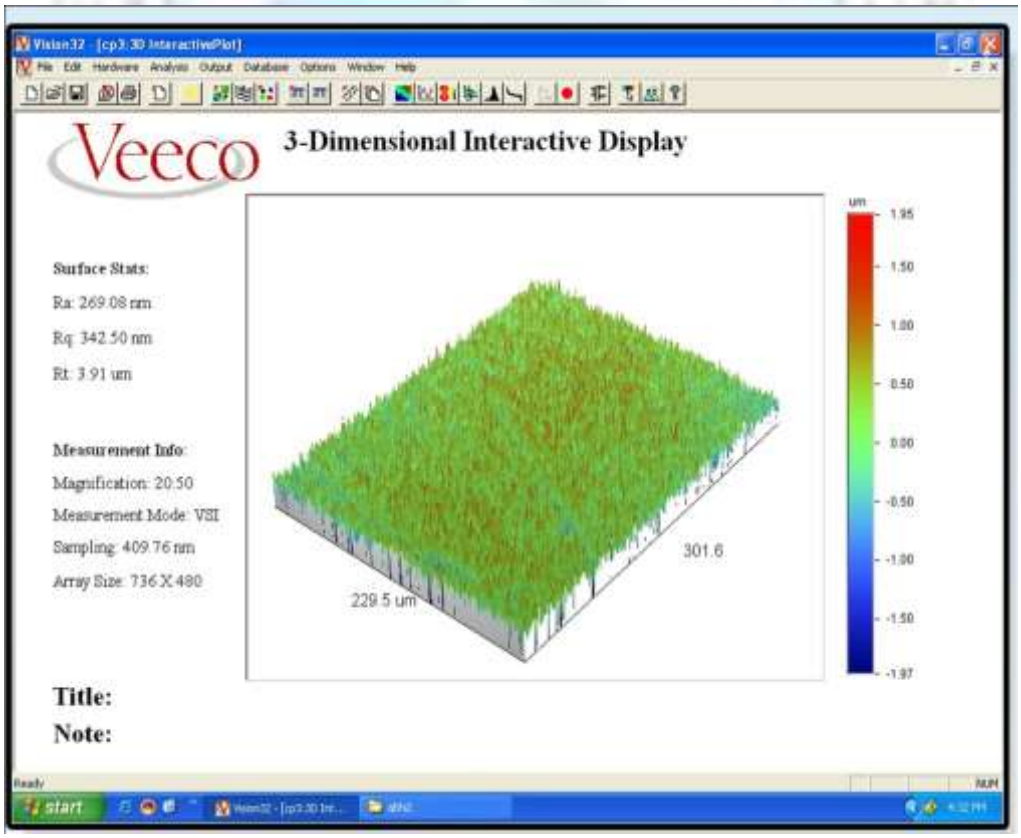

Figure 8 – 3 dimensional profilometric analysis Fuji II LC polished specimen

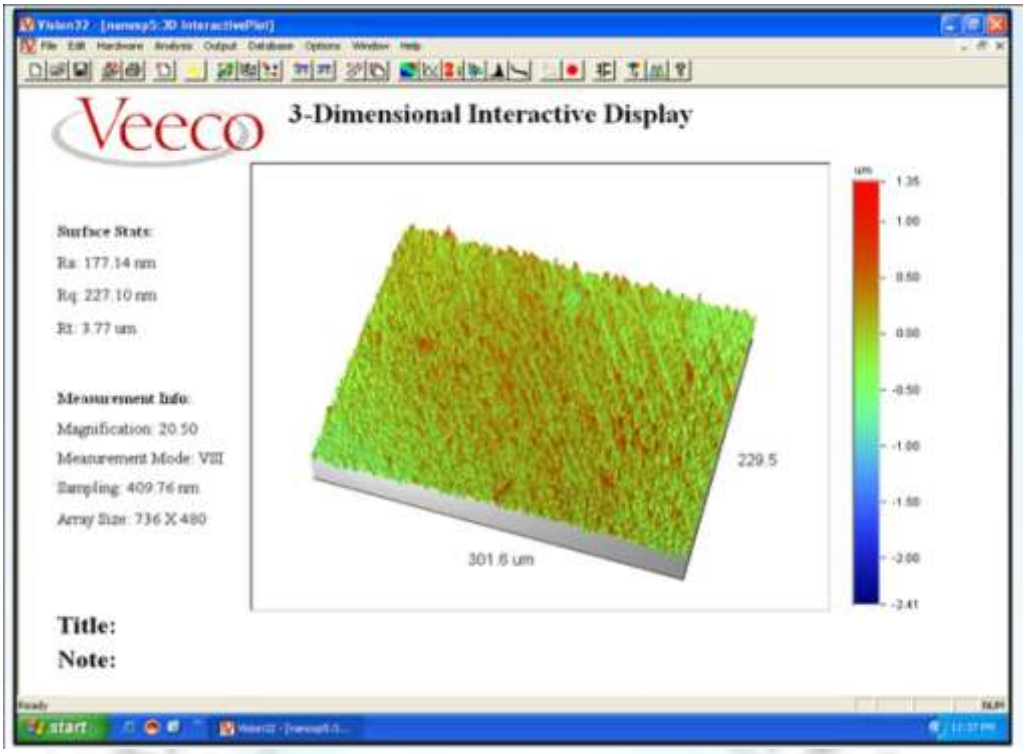

Figure 9 – 3 dimensional profilometric analysis Ketac N 100 polished specimen

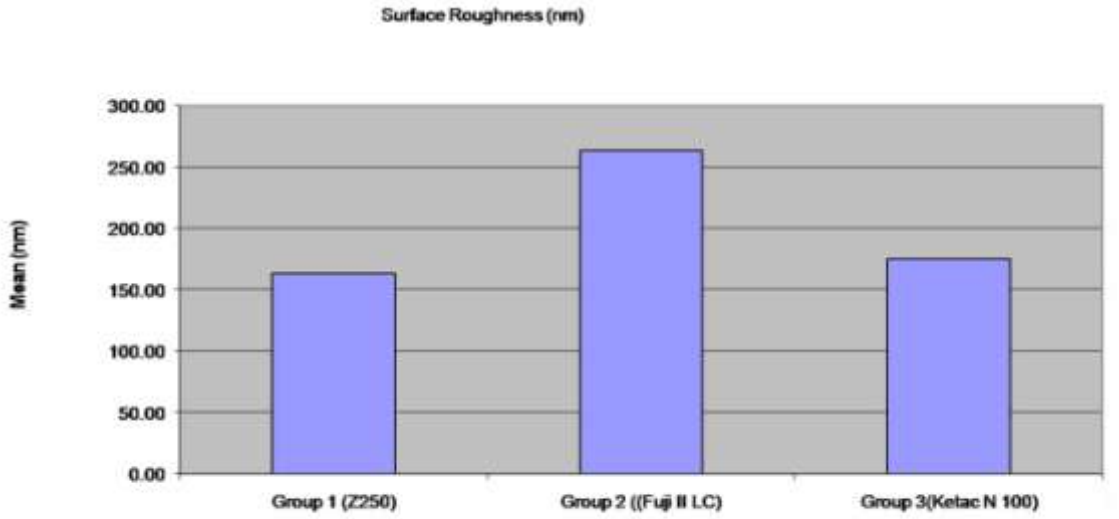

Figure 10 – Graph depicting mean surface roughness values