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# Evaluating The Fracture Resistance, Color Stability And Surface Roughness Of Feldspathic Dental Porcelain By Incorporating Silver Nanoparticles

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**Abstract**

**Introduction**

Ceramic material is being extensively used in dentistry because of its aesthetic appearance similar to the tooth structure. It has good biocompatibility, transmits light better with good mechanical properties. Technological development in the dental ceramic industry shifted the focus from Metal-Ceramic restorations to All-Ceramic restorations. All-Ceramic restorations have many advantages over Porcelain Fused Metal restorations. Some of them include excellent esthetic appearance because of their favorable optical properties, natural tooth color, and chromatic stability. But the main disadvantage of All-Ceramics is high cost, brittleness, and they crack under masticatory stresses because of low fracture toughness and tensile strengths. Conventional Feldspathic Porcelain used for layering metal copings has various advantages like low cost and ease of material availability compared to advanced ceramics. Its limitation is low fracture toughness. The new-generation nanoparticle

reinforced feldspathic porcelain has a predictable resistance towards fracture. Silver nanoparticles are selected because of their prominent catalytic effect, low toxicity levels, higher stability, efficiency, ease of availability, and low cost. This study was done to know whether incorporation of Silver nanoparticles in Feldspathic porcelain has any effect on fracture resistance, color stability and, the surface roughness of dental ceramics.

**Methodology**

A total of 120 ceramic discs were fabricated from the commercially available VITA Feldspathic porcelain. The control group I (n=30) prepared without the addition of silver nanoparticles. Other groups are fabricated by incorporating silver nanoparticles in three different concentrations. They are Group II 500ppm (n=30), Group III 1000ppm (n=30) and Group IV 2000ppm (n=30). The control group samples were prepared by mixing VITA porcelain powder(2.1gm) in distilled water without silver nanoparticles. The other three groups are prepared with VITA porcelain powder (2.1gm) mixed with silver nanoparticle dispersed solution (0.75gm) of different concentrations [1].

Silver Nanoparticles concentrations(ppm) are measured with a digital weighing scale (AC22.300). Silver oxide in the form of nanopowder with a particle size of 100nm, was used. It contained sodium citrate as a stabilizer, with a concentration range of 0.02mg/ml in aqueous buffer and 99.5% of trace metal bases which is expected to reinforce the Feldspathic Porcelain. To obtain a uniform dispersion the nanoparticles are dispersed in purified water in the presence of the dispersion agent carboxymethyl cellulose. The concentration of silver nanoparticles in the prepared solution was adjusted to 500ppm, 1000ppm, 2000ppm.

A custom-made stainless steel die was fabricated with an outer ring measurement of 33mm in diameter and a height of 37mm. The inner movable plunger is measuring 15mm in diameter and 35.5mm in height. This die has a depression of 1.5mm, which accounts for the thickness of sample preparation. The design of the die was done using CNC (Computer Numerical Control- Zen machine tools). The specimen's dimensions were verified using Digital vernier calipers ( Digital electronic).

A Ceramic separator is applied to the mold with the help of a brush. The slurry was placed in the cylindrical metal mold, and a uniaxial pressure of 17.7 Mpa was applied for 10 minutes by using an Unident hydraulic press to produce green pellets[1]. The green pellet is placed carefully over the ceramic firing disc and firing is done in the Automatic programmable vacuum porcelain furnace (Dentsply). Specimens are then according to the specified dimensions using sintered diamond abrasive burs and polished with VITA ceramic polishing paste.

| Group (n=30) | The Concentration of silver Nanoparticles |
|---|---|
| Group I | Control group (0ppm Ag) |
| Group II | 500 ppm Ag |
| Group III | 1000 ppm Ag |
| Group IV | 2000 ppm Ag |

Further each group is sub divided into three subgroups for testing Fracture resistance (n=10), Color stability (n=10) and Surface roughness (n=10).

| CERAMIC SAMPLE GROUPS | SUB GROUPS | | |
|---|---|---|---|
| Silver Concentration (ppm) | Fracture resistance (n) | Color stability (n) | Surface roughness (n) |
| 0ppm (n=30) | 10 | 10 | 10 |
| 500ppm (n=30) | 10 | 10 | 10 |
| 1000ppm (n=30) | 10 | 10 | 10 |
| 2000ppm (n=30) | 10 | 10 | 10 |

**Fracture resistance test**

Fracture resistance is the resistance of a material against crack propagation. The fracture toughness test of ceramic discs (n=10) from each group was determined by the Chevron notch test using a Universal testing machine (UTM). A custom-made jig was prepared and disc specimens were centered in the jig and load was applied to the middle of the specimen by a circular cylinder which is attached to the upper member of the UTM. A Crosshead speed of 0.1mm/min was applied until the specimen fractured. Maximum load (N), represents the fracture resistance. It was then calculated according to this equation as follows.

Resistance or toughness, KIC ($MPa.m^{1/2}$). $K_{IC}=0.026 \frac{E^{1/2}\ P^{1/2}}{d\ a^{3/2}}$

Where **E** is Young's modulus (MPa); **P** is the indentation load (N); **a** is half the crack length (m) ; **d** is the diagonal length.

**Color Stability Test**

In this study, VITA Easy shade V digital spectrophotometer is used. This device helps in determining the shade of natural dentition, bleached teeth, and ceramic restorations precisely, quickly, and independently. The Spectrophotometer, measurement ranges from 400-700nm. It displays L, a, b, and Ch values. Ten ceramic specimens (n=10) from each group were tested with a spectrophotometer. The spectrophotometer is calibrated as per the manufacturer's instructions before taking each reading. It is then carefully placed at right angles to the center of the ceramic disc. Color measurements CIE L*a*b* were taken. Color change (ΔE) between the groups was calculated by using the formula:

$\Delta E=\sqrt{}[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 ]^{1/2.}$

L* indicates values of darkness to lightness (0 to 100); a* indicates the values of red to green (+80 to -80); b* indicates the values of yellow to blue (+80 to -80).

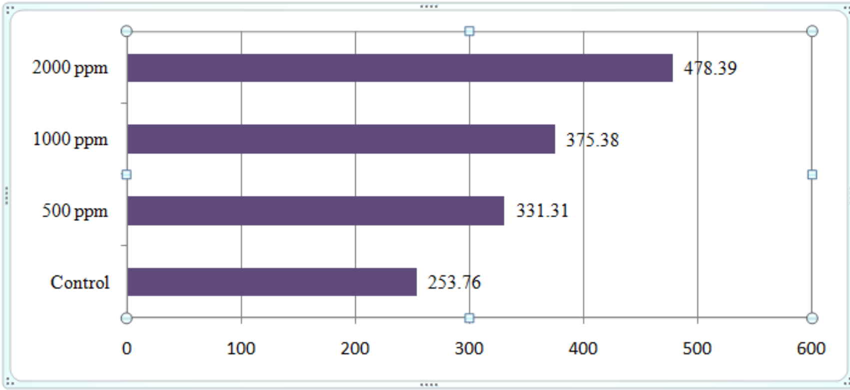
ΔL is the difference in lightness calculated from differences in the L* readings between the two different concentrations. Δa and Δb refer to the difference in the chroma. The difference between two colors in an L*a*b* color space is measured in terms of Delta E.

**Surface Roughness Test**

A Profilometer (Mitutoyo, Japan) was used to test ten samples (n=10)from each group. The device consists of a diamond stylus that moves vertically to contact the surface of the sample, and it is moved laterally across the surface of the disc at a specified distance of about 5mm with a specified contact force. This device is used to measure minor surface detail variations. The height and position of the diamond stylus generate a signal that can be converted into a digital signal.

**Results**

**Graph 1:** Comparision of fracture resistance values of ceramic samples (n=10) for the Control group (I) and groups (II,III,IV) with 500ppm, 1000ppm and, 2000ppm silver nanoparticle concentrations.




**Graph 1,** shows the inter comparison of the fracture toughness of different groups in which the $K_{IC}$ values show a rise in the graph when the concentration of silver nanoparticles are increased in the samples when compared to the control group.

**Table 1.** 'p' value of Fracture resistance of the above ceramic samples (n=10)

| Group | N | Mean ± SD | P-value |
|---|---|---|---|
| Control | 10 | 253.76±20.7 | 0.001* |
| 500ppm | 10 | 331.31±21.3 | |
| 1000ppm | 10 | 375.38±21.8 | |
| 2000ppm | 10 | 478.39±33.3 | |
| | | | |

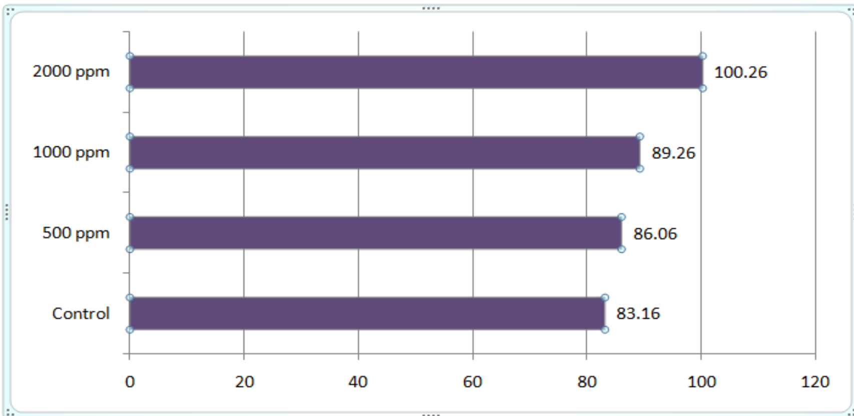
**Graph 2:** Comparison of L, a, b values of ceramic samples (n=10) for the Control group (I) and groups (II,III,IV) with 500ppm, 1000ppm and, 2000ppm silver nanoparticle concentrations .

The above graph shows the study group samples in which there is an exponential rise in the ΔE values in the ascending order in which color change is gradually increased from ceramic samples of 500ppm to 1000 and 2000ppm concentration silver nanoparticles.

**Table 2:** 'p' value of Color stability of the above ceramic samples (n=10)

| Group | N | Mean ± SD | Chi-square test statistic | P-value |
|---|---|---|---|---|
| 500 ppm | 10 | 11.48±3.71 | 35.53 | 0.001* |
| 1000 ppm | 10 | 27.56±2.68 | | |
| 2000 ppm | 10 | 32.7±3.13 | | |

**Graph 3:** Comparison of surface roughness values of ceramic samples (n=10) for the Control group (I) and groups (II,III,IV) with 500ppm, 1000ppm and, 2000ppm silver nanoparticle concentrations .




The above graph shows that there is a gradual increase in the surface roughness in the ascending order when the concentration of silver nanoparticles are increased in the ceramic samples.

**Table 3:** 'p' value of Surface roughness of the above ceramic samples (n=10)

| Group | N | Mean ± SD | P-value |
|---|---|---|---|
| Control | 10 | 83.16±16.26 | 0.001* |
| 500 ppm | 10 | 86.06±11.5 | |
| 1000 ppm | 10 | 89.26±14.85 | |
| 2000 ppm | 10 | 100.26±11.17 | |

**Statistical Analysis:** Data based on the ten ceramic discs in each group were analyzed by a two -way ANOVA test and a Post hoc test. All the statistical methods were carried out through MINITAB (version 14) software. The significance of the p-value is a probability of obtaining the result as extreme as the observed results of a statistical hypothesis test assuming that the null hypothesis is correct. A smaller p-value means that there is stronger evidence in favor of the alternate hypothesis.

**Discussion**

MacLean and Hugues[2] were the first to develop stronger feldspathic porcelains by reinforcing the porcelain core with Aluminium oxide ($AL_2O_3$) in 1965, thus yielding a dental core with a flexural strength up to 400MPa. Incorporating various strengthening components into the feldspathic glass matrix enables the increase in strength of ceramic infrastructure, which eliminates metal and helps in developing different types of new All-Ceramic systems

Conventional dental feldspathic Porcelain used in this study is an amorphous non-crystalline structure that displays a high compressive strength (330MPa) and, low tensile strength (34MPa) and may fracture under tensile stresses[4]. The study was started by taking into consideration the null hypothesis that the addition of Ag nanoparticles to the conventional feldspathic ceramic has no significant effect on fracture resistance, color stability, and surface-roughness of dental ceramics.

Ceramic samples were subjected to Fracture resistance testing by using UTM, Color stability test by using VITA easy shade Spectrophotometer, and Surface roughness test was done by using Profilometer. On examining the obtained values the null hypothesis was rejected. The findings suggest that porcelain specimens show an increase in fracture resistance after sintering the samples in the presence of Ag nanoparticles, which is further and more directly confirmed by the toughness value of $K_{IC}$.

$K_{IC}$ is one of the reliable parameters for evaluating the resistance to crack propagation caused by various external forces. $K_{IC}$ values were significantly improved from the control group(253.76±20.7MPa) to the in the samples prepared with the concentration of 500ppm(331.31±21.3MPa),1000ppm(375.38±21.8MPa), 2000ppm(478.39±33.3MPa). P-value (<.001) was obtained, indicating a marked toughening of Feldspathic Porcelain with the addition of silver nanoparticles.

Mechanical properties of nanoparticles incorporated samples improved when compared to the control group, which may be due to the generation of beneficial compressive stresses [5]. The median crack length of samples was also smaller when silver nanoparticle concentration is increased, which may be due to the generation of residual compressive stress due to exchange of ions and differential thermal expansion of silver metal particles [5,1]. These compressive stresses result in less crack propagation thereby increase the fracture resistance. Fracture strength has increased for silver nanoparticle incorporated samples due to an increase in the coefficient of expansion in comparison to the glass matrix [6] and due to metallic bridge formation in the ceramic matrix, which interrupts the crack propagation [7].

When it comes to the color change($\Delta E$) test, the samples became lighter to darker from the control group to the increased concentration of silver nanoparticles. The increase in values as observed are 500ppm(11.48±3.71), 1000ppm(27.56±2.68), and 2000ppm(32.7±3.13) . The color difference when the concentration of silver nanoparticles increased in the samples is due to the formation of grayish silver oxides when compared to the control group [5,6].

The surface roughness also increased from the control group ( 83.16 ± 16.26 ) ceramic samples to the samples prepared with the concentration 500ppm ( 86.06

± 11.5 ), 1000ppm ( 89.26 ± 11.7), and 2000ppm ( 100.26 ± 14.85). ‘p’ value <0.001 shows statistical significance. The surface roughness ($R_a$)values increased may be attributed to excess metallic nanoparticle inclusion [8].

In all the parameters, the p-value is less than 0.001, which indicates the statistical significance.The studies which had similar findings and coinciding with the present study were done by Tokushi fujieda et al.[5](2012) ; Mitsunori Uno et al.[1] (2013) , Sergio J. Esparza-Vázquez et al.[9] (2014) , Cherif A Mohsen et al.[6] (2015) , Azucena Perez de la Fuente et al.[7] (2016) and Vasudevan Karthikeyan et al.[10] (2019) .

From the findings, it was observed that by incorporating silver nanoparticles in Feldspathic Porcelain the fracture resistance has improved which is desirable. An increase in surface roughness with the addition of silver nano-particles is not a favorable factor. Also, there is an increase in color intensity in the samples when the silver nanoparticles concentration increased which may not be aesthetically acceptable. Therefore judicious use of adding silver nanoparticles is to be considered for fabricating ceramic restorations.

**Conclusion**

With the limitations of the study, the following conclusions were drawn**.** The fracture resistance, color change and, surface roughness have increased with the concentration of silver nanoparticles highest being with the concentration of 2000ppm. The ceramic discs became darker in shade with the increase in the concentration of silver nanoparticles affecting the color stability. Reinforcement with various metallic nanoparticles can improve the properties to enhance clinical application. Chipping or fracture of layered ceramics can be overcome by the addition of silver nanoparticles. Other factors of increase in color intensity and surface roughness should be taken into consideration before determining the concentration of nanoparticles to be incorporated.

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