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ORIGINAL ARTICLE

Effects of rice husk nanosilica on color stability of metal-ceramic crowns

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ABSTRACT

Background: Metal-ceramic crowns remain a primary choice for dental restoration due to their adequate mechanical strength and relatively low cost. However, their esthetic success depends on the color stability of the porcelain, particularly the opaque layer that masks the underlying metal. Nanosilica derived from rice husks is an environmentally friendly material with potential as a reinforcing agent, but data on its effect on color changes in metal-ceramic crowns remain limited. This study aimed to analyze the effect of adding 0.5% rice husk nanosilica to the opaque layer on color changes in metal-ceramic crowns.
Methods: An in vitro experimental study used Co-Cr metal samples coated with porcelain, with color evaluation based on the CIELAB system (L*, a*, b*) via colorimeter before and after nanosilica addition. Nanosilica was synthesized from rice husks and characterized using particle size analysis and scanning electron microscopy. Data were analyzed with Shapiro-Wilk test, Levene test, Welch t-test, and paired t-test.
Results: Characterization results showed nanosilica particles in the nanoscale range with two main distribution peaks and amorphous, spherical morphology with agglomeration tendency. L* values increased significantly, whereas changes in a* and b* values showed no significant differences.
Conclusion: These findings indicate that adding 0.5% rice husk nanosilica to the opaque layer increases brightness and total color change in metal-ceramic crowns, requiring esthetic control in its application.

Keywords: metal-ceramic crowns, rice husk nanosilica, opaque layer, color change, CIELAB

Introduction

Metal-ceramic crowns represent one of the most commonly used restorations in dental practice to replace lost or damaged tooth structure, thereby restoring masticatory function, speech, and esthetic appearance.[1] Based on their composition, fixed crown restorations are generally classified as full metal crowns, full ceramic crowns, and metal-ceramic crowns, each with distinct characteristics in strength, esthetics, and biocompatibility.[2,3] Metal-ceramic crowns remain widely used because they combine the structural strength of a metal coping with the esthetic appearance of porcelain at a lower cost than full ceramic restorations.[4] In construction, metal-ceramic crowns consist of a metal core overlaid with a porcelain system, producing a durable restoration through chemical and mechanical bonding between the materials.[5]

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The porcelain layer of metal-ceramic crowns comprises three main layers: opaque, dentin, and enamel.[6] The opaque layer masks the underlying metal color and establishes the initial shade of the restoration, while the dentin and enamel layers determine the final color and translucency. Variations in porcelain thickness and optical properties, particularly in the opaque layer, can affect the clinical perception of restoration color.[7] Thus, color stability of each porcelain layer is essential for maintaining long-term esthetic quality.[6]

Color change is a common issue with ceramic restorations and can lead to patient dissatisfaction with treatment outcomes.[8] Several studies report color differences between metal-ceramic crowns and adjacent natural teeth in clinical practice, even when restorations follow established standards.[9] This highlights that restoration success depends not only on mechanical strength but also on color stability and esthetic quality.[10,11]

Efforts to improve metal-ceramic crown performance include modifying porcelain with reinforcing agents. Silicon is the second most abundant element in the earth's crust after oxygen and naturally undergoes hydration and dehydration in the environment, yielding amorphous nanosilica particles.[12] Rice plants absorb silicon as monosilicic acid, which undergoes biomineralization and accumulates in the husk with silica content ranging from 8.7% to 12.1%.[13,14] Nanosilica derived from rice husks has been widely explored in dentistry for its environmental friendliness, economic value, and ability to enhance mechanical properties of dental materials. The small particle size and high surface area of nanosilica offer potential to improve the physical and optical properties of restorative materials.[15,16] Some studies report that adding nanosilica at certain concentrations, particularly 0.5%, significantly increases the mechanical strength of porcelain in metal-ceramic crowns.[17–19] In contrast, higher nanosilica concentrations can reduce mechanical quality due to particle agglomeration and increased porosity.[20] Moreover, most prior studies have focused on mechanical properties, with limited evaluation of nanosilica's effect on color change in metal-ceramic crowns.[21,22] Yet color change is a primary factor in the long-term esthetic failure of metal-ceramic restorations. This study aimed to analyze the effect of adding 0.5% rice husk nanosilica to the opaque layer on color changes in metal-ceramic crowns.

Method

This study was conducted as an in vitro laboratory experimental study using a posttest-only control group design. The research took place from August to October at several facilities: the NRE Lab for synthesis, mixing, and characterization of rice husk nanosilica; the Dental Laboratory Unit of the Faculty of Dentistry, Universitas Sumatera Utara, for metal coping fabrication and porcelain application; and the Prosthodontics Department of the Faculty of Dentistry, Universitas Sumatera Utara, for color measurements using a colorimeter. The samples consisted of rectangular cobalt-chromium (Co-Cr) metal specimens with dimensions of 25±1× 3±0.1 mm × 0.5±0.05 mm, coated at the center with porcelain measuring 8±0.1 mm ×3 mm ×1.1±0.1 mm, in accordance with ISO 9693:2012. The sample size was determined using Federer's formula, yielding 16 samples per group with two repetitions, for a total of 32 specimens.

Nanosilica was obtained through silica extraction from rice husks (*Oryza sativa* L. Tuhur) using acid-base leaching. The rice husks were first ground to a fine powder, soaked in HCl solution to remove impurities, rinsed, and dried. The dried material was then reacted with NaOH solution to produce sodium silicate, which was gradually neutralized with HCl to form silica precipitate. The precipitate was repeatedly washed, dried, and ground. Particle size reduction was achieved using an ultrasonic homogenizer to yield nanosilica. Characterization involved scanning electron microscopy for particle morphology and particle size analysis for size and distribution. The resulting nanosilica was added to opaque porcelain at a concentration of 0.5% and examined by SEM to assess its distribution within the porcelain matrix.

Metal copings were fabricated by casting Co-Cr alloy using a rectangular master model, followed by burnout, casting, polishing, and sandblasting with 50-μm alumina particles. Specimens then underwent oxidation and ultrasonic cleaning. Porcelain application proceeded sequentially with opaque, dentin, and enamel layers using commercial porcelain (Vita VMK Master) per manufacturer instructions. Each layer was applied at a specified thickness, condensed by vibration, and fired in a furnace at designated temperatures. The final steps included glazing and ultrasonic cleaning to obtain a homogeneous sample surface before testing.

Color evaluation used a colorimeter positioned perpendicular to the center of the specimen surface. Each sample was measured three times, and the values were averaged for consistency. Color was expressed in the CIELAB system with parameters L*, a*, and b*. Total color change (ΔE) was calculated from differences in L*, a*, and b* values before and after nanosilica addition. Collected data underwent statistical analysis with the Shapiro-Wilk test for normality, Levene test for variance homogeneity, and paired t-test or Welch t-test based on data characteristics. Results were presented as means and standard deviations.

Results

To determine whether the addition of 0.5% nanosilica to metal-ceramic crowns produced differences, normality was assessed using the Shapiro-Wilk test because the sample size was less than 50. Homogeneity was then evaluated using Levene's test. If the data were normally distributed and homogeneous, a paired t-test was performed. If the data were normally distributed but not homogeneous, a Welch t-test was used.

Table 1. Welch t-test results for L and a values before and after mixing with 0.5% nanosilica

Parameter	Treatment	n	Mean ± SD	Welch t-test
L	Before 0.5% nanosilica	16	21.49 ± 0.30	0.000
	After 0.5% nanosilica	16	29.30 ± 0.65	
a*	Before 0.5% nanosilica	16	1.33 ± 0.3	0.095
	After 0.5% nanosilica	16	1.86 ± 1.05	

The results in Table 1 indicate a significant difference in L* values before and after the addition of nanosilica ($p < 0.05$). No significant difference was found in a* values before and after the addition of nanosilica ($p > 0.05$).

Table 2. Paired t-test results

Condition	n	b* (mean ± SD)
Before nanosilica addition	16	6.28 ± 0.61
After nanosilica addition	16	6.86 ± 1.03

The results in Table 2 indicate no significant difference in b* values before and after the addition of nanosilica ($p > 0.05$).

Discussion

This study used nanosilica extracted from rice husks as an additive in metal-ceramic crowns to evaluate color changes after incorporating 0.5% rice husk nanosilica. Characterization of the nanosilica synthesized from rice husks confirmed that the resulting material had nanoparticle size ranges, meeting the functional criteria for nanosilica. The nanoscale particle size distribution indicated successful synthesis, with potential effects on the physical and optical properties of the ceramic system. Morphological observations revealed that the nanosilica had an amorphous structure with a tendency toward spherical shapes, although the particles did not disperse individually and formed aggregates. The rough and heterogeneous surface characteristics are typical of nanosilica and can influence interparticle interactions and optical behavior within a material matrix.[23]

When nanosilica was mixed into opaque porcelain, the resulting microstructure showed integration of nanosilica particles into the porcelain matrix, although agglomeration occurred in some areas. Smaller nanosilica particles tended to fill spaces between larger porcelain particles, acting as a filler. This condition can alter the microstructure of the opaque layer and affect light interaction with the material. Such changes may increase light scattering within the opaque layer, contributing to the observed color changes in metal-ceramic crowns. These findings align with studies reporting that rice husk ash morphology features relatively smooth surfaces with characteristic silica microstructures.

Color evaluation of metal-ceramic crowns after adding rice husk nanosilica showed descriptively noticeable total color changes. The dominant increase in brightness indicated that nanosilica significantly affected the material's optical properties, particularly by enhancing light reflection and scattering. Changes in other color components showed greater variation between samples, with no consistent shifts along the red-green or yellow-blue axes. Statistically, the analysis confirmed that the primary effect of nanosilica addition was increased brightness, while color direction changes showed no significant differences. This suggests that nanosilica primarily modifies reflected light intensity rather than chromatic color characteristics.

The observed brightness increase can be explained by enhanced light scattering due to nanosilica particles in the opaque porcelain matrix. Nanoparticles increase light-material interactions through differences in refractive index and denser particle distribution. These findings align with Morsy et al.[24] who reported that adding SiO_2 nanoparticles as fillers improved optical properties, as evidenced by increased brightness. This consistency supports the conclusion that rice husk nanosilica contributes to opaque layer brightness in metal-ceramic crowns through altered optical properties.

This study has limitations that warrant consideration. The nanosilica concentration was limited to one level, precluding assessment of color changes at other concentrations. Particle agglomeration may also affect distribution homogeneity in the porcelain matrix. Future studies should examine varying nanosilica concentrations and optimize particle dispersion to better understand effects on optical properties of metal-ceramic crowns.

Conclusion

The silica synthesized from rice husks had nanoparticle size ranges, as shown by particle size analysis with nanoscale distributions. Application of rice husk nanosilica to the opaque layer of metal-ceramic crowns produced noticeable color changes, dominated by significant increases in L* brightness values, while a* and b* parameters showed no statistically significant changes. These results indicate that rice husk nanosilica has potential as an additive to modify opaque layer optical properties, particularly brightness in metal-ceramic crowns. Future research should evaluate varying nanosilica concentrations and improved mixing methods for more uniform particle distribution to further assess effects on color characteristics and optical properties relevant to restorative dentistry.

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