



## **Biocompatibility and Alloy Bonding Tests of Dental Porcelain Powders Produced from Okpella Potash Feldspar in Edo State, Nigeria**

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**ABSTRACT:** This research is aimed at developing biocompatible ceramics porcelain powders that can be suitable as fillers and substitutes for damaged and decayed tooth, with a view to domesticating its production in Nigeria and reducing the money spent on their importation into Nigeria. The only source of biocompatible means of dental prostheses is considered highly exorbitant and requires importation. Okpella Feldspathic deposit was used in forming the dental porcelain powder with careful fritting preparation. In-vitro biocompatibility test was used to determine the biocompatibility of the locally produced dental porcelain powder by growing tooth mucous on the dental porcelain. Alloy bonding test was carried out using Electrical porcelain vacuum furnace to determine the bonding ability of dental porcelain on most commonly used alloy “Nickel-Chromium” in dental clinics. Results of biocompatibility and alloy bonding showed the ability of locally produced dental porcelain in mimicking the properties of natural human tooth.

**Keywords:** Porcelain, Biocompatibility, Leucite

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### **INTRODUCTION**

Ceramics is one of the most important materials in human civilization. Its socioeconomic impact is as important today as it has been throughout human history. The importance of ceramics associated with its chemical and physical properties has generally increased its applications in diverse areas of life which continues to strengthen the relevance of ceramics to human civilization. Ceramics high modulus, hardness, low density, resistance to high temperature and corrosive environment, has tremendously increased its value in demanding structural applications such as heat engines, turbines and automotive components where their use would result in long life, operation at high temperatures and weight saving. Ceramics has an added advantage in possessing high compressive strength and

modulus values as well as low density and chemical inertness which makes them better when compared to metal. There have been tremendous developments in the mechanical properties and methods of fabrication of ceramic materials which have furthermore revolutionized the use of ceramics to improve the quality of life; one of such developments is the innovative use of specialty designed ceramics for the repair and reconstruction of diseased or damaged hard parts of the body.

Ceramics which have been used as implants materials are called bioceramics. Heness and Ben-Nissan (2003) defined bioceramics as ceramics substance suitable for inclusion in body systems which augment or replace the function of bodily tissues or organs without rejection. Basically the inorganic composition of teeth and

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bones are ceramics “Hydroxyapatite”. Hence this ceramics like hydroxyapatite, wollastonite etc. are used as bone graft materials. They have anentire plethora of synthetic techniques like wet chemical, sol-gel, hydrothermal methods etc. Also they are added as bioactive filler particles to other inert materials like polymers or coated over metallic implants. These ceramics are collectively called bioceramics. They are generally refractory in nature and possess high compressive strength and used to replace or fix hard connective tissues such as teeth, bones or joints. These bioceramics can be used inside the body without rejection due to their biocompatibility, low density, chemical stability and high wear resistance.

Ceramics materials have been used to create inlays, veneers, and crowns, as facings on metal substrates, and even as bridges, which can be made completely from high-strength ceramics. Restorations in ceramics are generally made by building up the correct aesthetic combinations of pre-fired, pigmented particles, and then re-firing under vacuum to sinter them together and eliminate voids (O’Brien, 2002). Porcelain is a specific type of ceramic used extensively in dentistry and in other industries. The uses of ceramics are encouraged by their biocompatibility, aesthetics, durability and easier customization. The specialty of ceramic teeth is the ability to simulate the natural tooth in colour and translucency along with strength. Ceramics have excellent intraoral stability and wear resistance adding to their durability. Ceramics or dental porcelain has evolved since their inception in 1838, when dental porcelain that

almost mimics natural teeth was produced by Elias Wildman (Chevalier, 2006). This made crowns and bridges incorporating ceramic materials become one of the most popular treatments to restore teeth. According to Van Noort (2007), ceramic restoration materials should comprise certain critical characteristics such as, biocompatibility with the surrounding oral tissues, longevity and resistance to fracture and appearance to be aesthetically acceptable.

### **Biocompatibility of Dental Ceramics**

As people retain their teeth for much longer than in the past due to the biocompatibility of dental ceramics, the need for aesthetically acceptable restorations continues to increase. In that sense, ceramic holds a special place in dentistry because it is still considered to produce aesthetically the most pleasing biocompatible results. Its color, translucency and vitality cannot as yet be matched by any other materials such as resin or metal. This is reflected in the growing use by dentists of restorative procedures using ceramics. According to Anusavice (2003), Ceramics will continue to be important restorative materials for many years to come. The aesthetic appeal is not only reason for dental application of ceramics but its ability to form a bond with the tooth gum and not react with the dental environment. Ceramics possess several properties that make them suitable for use as dental materials. These properties include compressive strength, dimensional stability, radiopacity and durability with the oral environment (George and Eichmiller 1995).

## **MATERIALS AND METHODS**

### **Introduction**

It has been proved that no foreign material placed within a living body is completely compatible. The only substances that conform completely are those manufactured by the body itself (autogenous) and any other substance that is recognized as foreign, initiates some type

of reaction (host-tissue response). However ceramics have been used for biocompatible applications. Alumina and zirconia, for example, have been used as inert materials for a range of applications from the 1960’s. Their high hardness, low friction coefficient and excellent corrosion resistance offers a very low wear rate

at the articulating surfaces in medical applications. Ceramics encompass such a vast array of materials that a concise definition is almost impossible. Being an omnipotent material, its applications are innumerable wherein a definite boundary cannot be established. In order to realize the purpose behind this study being an experimental research, general analysis were done on the data subsequent to subjecting them to the required standard for producing dental prosthesis. This entails material processing and percentage combination of the raw materials in such a way that not until any of the result from the material experimentation meets the objectives, more test were conducted by readjusting and recomposing the result that did not yield a suitable result.

**Material Composition**

The dental porcelain compositions of this research emanated from the standard triaxialwhiteware porcelain compositions as reported by Singer and Singer (1971) and Kingery et al. (1999) and shown in Figures 1 and 2 which identified dental porcelain on a single

blend composition closely concentrated with feldspar in ceramics whitewaretriaxial compositions suggesting a 90-95% of feldspar to 5-10% of quartz/kaolin in dental porcelain compositions.

This is made possible with locally available and abundant feldspathic ceramic materials situated in Ijero-Ekiti of Ekiti State and Okpella of Edo State, been the required material for the production of dental porcelain.

**Biocompatibility and alloy bonding test on the produced porcelain powders**

The appropriate dental porcelain powder for porcelain fused to metal restorations should be porcelain with firing temperature well below the melting range of the metal and also have sufficient high thermal expansion, which should be compatible with the metal. Fundamentally the interaction and the bond formation between the opaque porcelain layer and the metal substrate determine the longevity of the metal ceramic restorations. The coefficient of thermal expansion of the metal substrate should not be higher than that of the dental porcelain otherwise

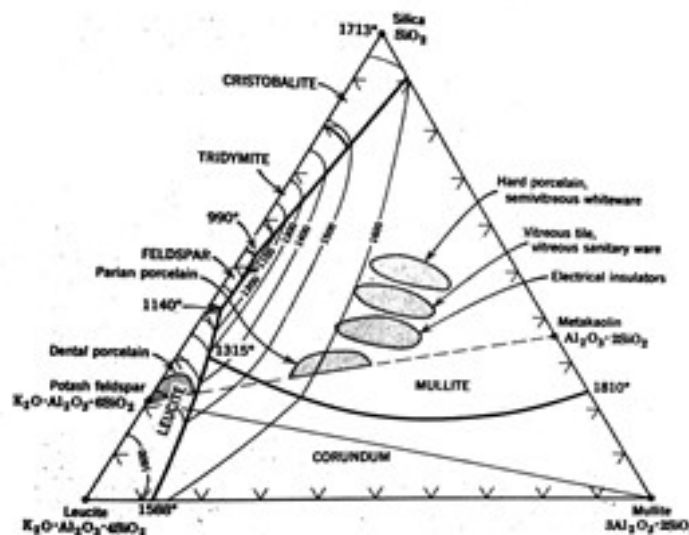
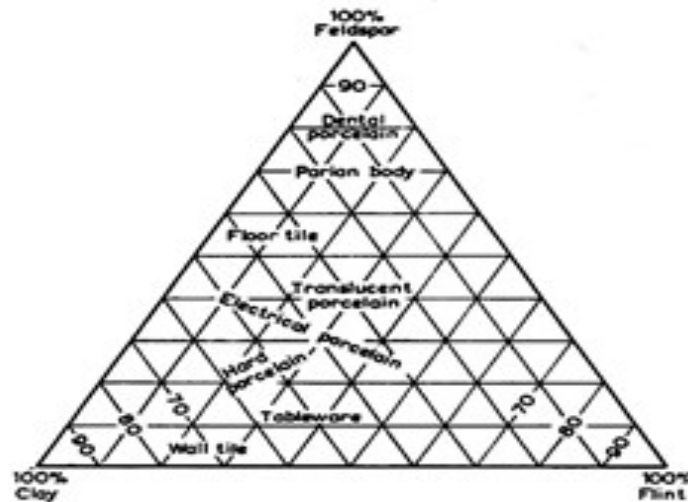


Figure 1: Triaxial Diagram Showing focus area of Dental Porcelain (Kingery, 1976)



**Figure 2: Triaxial Whiteware Compositions showing focus area of Dental Porcelain (Singer and Singer (1971))**

the ceramic will be in a beneficial state of residual compressive stress at room temperature. Naturally, porcelain is much stronger in compression than tension, and residual tensile stress in the porcelain must be avoided to prevent fracture of the restoration. In order to achieve this objective, a leucite crystal porcelain, in controlled amount, was formed as directed by Kacicz and Fonvielle (1986) which is usually in glassy phase to permit selective adjustment of the thermal coefficient of expansion of the porcelain composition.

The method used for forming a leucite porcelain of the required controlled coefficient of thermal expansion was composing the locally sourced feldspathic raw material together by mixing two different compositions of dissimilar coefficient of thermal expansion together in addition with less than 5% lithium carbonate which further controls thermal expansion of glass-ceramic phase at high temperature and also quenching the molten glass-ceramics in water to arrest leucite forming crystals at high temperature so as to form the produced dental porcelain. Alloy bonding between the produced dental porcelain and metal was made possible with the composition of highly efficient opaque dental

porcelain which contains opacifiers in form of Tin Oxide, Titanium Oxide, Zirconium Oxide and Zinc Oxide at less than 20% percent opacifiers in addition with already formed leucite base dental porcelain, to make Opaque Porcelain P, AP, and PB Respectively. Alloy bonding test was now carried out by melting the opaque dental porcelain powder over the metal substrate to completely cover the dark colour of the metal substrate, so as to make it look lifelike. The outcome after firing under vacuum atmosphere in Federal Medical Centre Owo was the detected via visual observation and shown below in Table 1.

**Biocompatibility**

Ceramics materials are naturally inert in nature. When used as implant in the body system, this means they are supposed to be non-immunogenic, non-thrombogenic, non-carcinogenic, and non-irritant when it comes in contact with the body. According to Williams, (2008) a material can be classified as biocompatible if it performs its desired function with respect to a medical therapy, without eliciting any undesirable local or systemic effects in the recipient or beneficiary of that therapy, but generating the most beneficial cellular or tissue

**Table 1: Results of Alloy Bonding Test Conducted on Dental Porcelain Powder**

Porcelain Powders	Heat Rate	Firing Temp	Firing Time	Cooling Time	Detailed Observation
P Opaque Porcelain	60°c/Min	960°c	60 sec	240 sec	Bonds with Nickel Chromium alloy up to 70%. minimal flaking and peeling at room temperature
PB Opaque Porcelain	60°c/Min	960°c	60 sec	240 sec	Bonds with Nickel Chromium alloy up to about 75% with very minimal flaking and peeling of the dental porcelain when suddenly brought from 500°c to room temperature (25%)
AP Opaque Porcelain	60°c/Min	960°c	60 sec	240 sec	Bonds with Nickel Chromium alloy up to 85%. no flaking or peeling at room temperature

response in that specific situation, and optimizing the clinically relevant performance of that therapy. Biocompatibility of bioceramic products can be done in different ways such as in vitro tests (cell-culture), in vivo tests (animal experiments) and clinical tests (clinical trial of the material) this is to determine their safe use as medical devices. The first step when conducting the biological behavior of biomaterials is to start with simple in vitro test. Promising results from the in vitro test determines the material's efficiency as biocompatible substance, which further leads to comprehensive studies in form of in vivo evaluation and clinical trials.

#### **In Vitro Biocompatibility Test conducted on the Produced Dental Porcelain**

Tooth mucous were collected from two individuals before tooth brushing using tooth picks. The samples were taken and dropped into a sample bottle containing sterile water. One ml of the solution was placed along with the

produced dental porcelain sample in a sterile dish and incubated at 37°C for 72hrs to give room for the microorganism in the mucous to grow to its maturity. Smear of the growth was observed after staining with Grams reagent. The slide was viewed under the microscope using X100 (Oil Immersion). The organism observed as shown in Figure 1 were Gram +ve inform of streptococcus (Strep Mutans).

Having allowed the microorganism grow on the dental porcelain for 72hrs, the dental porcelain was removed from the solution and cleaned with common tooth paste containing fluoride. Sterile water was used to rinse the surface and smear of the solution obtained was observed after staining with Grams reagents. The slide was then observed under the microscope at X100 (Oil Immersion). Very scanty presence of the microorganism was observed after cleaning with close up showing the same result of the samples observed under the microscope after tooth brushing.

### **RESULTS AND DISCUSSION**

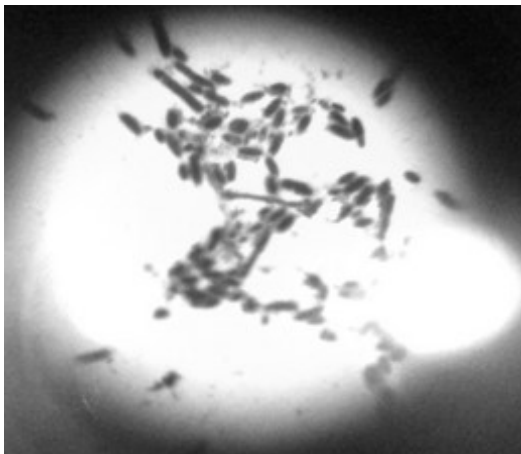
The alloy bonding test conducted on the produced dental porcelain powder using vacuum porcelain furnace showed that the porcelain fired like normal porcelain. It also bonded with nickel chromium alloy in about 90%

and gave finished appearance like Vita Shade A2-A3. On second opaque firing, there was a little bit of flaking of the second opaque coating, which served as final covering over the metal. After the second coating of the opaque

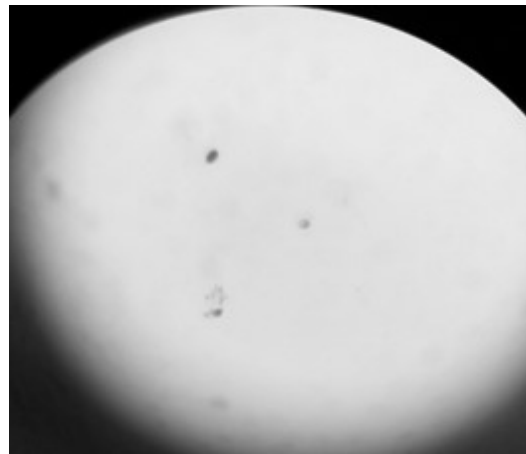
porcelain, it was observed that the porcelain still grinds like normal porcelain while grinding with a diamond bur which finally confirmed the alloy bonding ability of locally produced dental porcelain powders. Meanwhile other dental porcelain samples crazed, flaked off on sudden cooling to normal room temperature, with some residue of body porcelain attached to the opaque substructure.

A close observation was given the smear taken from the dental porcelain, the result displayed in Figure 3 showed the heavy presence of strep mutans microorganism after having cultured the dental plaque for three days, while the result shown in Figure 4 revealed a very scanty presence of strep mutans microorganism after

cleaning with close up. This result gave a similar result of the same sample observed under the microscope after tooth brushing. The result demonstrated the In vitro biocompatibility of the produced dental porcelain by behaving in like manner in the ability of dental porcelain to mimic the nature of human's teeth after cleaning with fluoride tooth paste. The biocompatibility tests conducted on the dental porcelain revealed the ability of locally produced dental porcelain in not allowing bacterial grow easily on the porcelain surface. The in-vitro biocompatibility also revealed the essence of cleaning natural and artificial teeth with common fluoride pastes by the removal of bacterial using the close up tooth pastes.



**Figure 3: Strep Mutans on Dental Porcelain On Dental Porcelain before Cleaning with Close Up**



**Figure 4: Dental Porcelain Cleaned with Close Up**

### CONCLUSION

Locally produced dental porcelain powders containing leucite for controlled coefficient of thermal expansion was detected to be suitable for producing dental prostheses. This is due to its ability to successfully bond with nickel-chromium alloy without crazing or flaking which in essence covers the dark colouration of the

alloy, thereby making the dental prosthesis look more life-like. The locally produced dental porcelain powder also possesses biocompatibility ability after showing a successful in-vitro test. The biocompatibility is considered very essential in determining the clinical success of dental ceramics.

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