

The Use of Local Ceramic Materials for the Production of Dental Porcelain

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ABSTRACT: The use of local ceramic raw materials (Edda clay as source of Kaolin, Feldspar and Quartz) sourced in Nigeria was studied in this research. The Edda clay sample was chemically analyzed using the atomic absorption spectroscopy AAS (Model AA 320N) to determine its chemical (oxides) composition. The dental porcelain was produced by pressing method using POP mould. The specimens produced were tested for linear shrinkage and apparent porosity properties in order to ascertain their compatibility and acceptability. The chemical analysis showed that the local clay is kaolinite in nature with silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) contents of 56.00%, 21.64% and 0.12% respectively. The physical test results reveal a firing linear shrinkage value of 2.40%, and apparent porosity value of 4.21%. These test results fall within the range of acceptable values for the production of standard dental porcelain.

KEYWORDS: Atomic absorption spectroscopy, dental porcelain, POP mould, linear shrinkage, apparent porosity.

I. INTRODUCTION

Porcelain is an inorganic compound made by heating a blend of three silicate clay minerals: Kaolin, Quartz and Feldspar, each of which reacts upon one another when subjected to appropriate high temperature (Eke, 2006). Kaolin serves as the plastic material while quartz (silica) and feldspar are the non-plastic materials. Porcelain generally can be classified into dental, electrical, translucent and hard porcelain. Porcelain as a clay body when fired becomes very hard, strong and translucent. It is normally very white with smooth surface when glazed. Porcelain also is unreactive and must contain little or no iron impurities. Dental porcelain, also known as dental ceramic is a material designed with the purpose of producing dental prostheses which is used to replace missing or damaged dental structures, e.g. teeth (Rosenblum & Schulman, 1997). The procedure consists of rebuilding the missing tooth with a porcelain covering (Jacket).

The raw material of dental porcelain contains crystalline ingredients; feldspar ($\text{K}_2\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$), Silica (SiO_2) and Kaolin ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) held together in a clear liquid like glass structure (Craig, *et al.*, 1979). The feldspar is an alkali flux which lowers the firing temperature and controls density and porosity of the clay body. Silica controls shrinkage and gives rigidity and support to the porcelain body. Kaolin gives soft plastic base, shape and opacity to the fired porcelain (Eke, 2006).

Jones (1985) classified dental porcelain according to its fusing temperature into:

- High fusing ($1200 - 1450^\circ\text{C}$) which is used for denture teeth.
- Medium fusing ($1050 - 1200^\circ\text{C}$) used for inlays, jacket crown and bridge pontic construction.
- Low fusing ($850 - 1050^\circ\text{C}$) used mainly in the fabrication of porcelain bonded to metal crowns.

II. FUNCTIONALITY OF DENTAL PORCELAIN IN DENTISTRY

Dental ceramics are used to replace the natural dentitions or portions of it, to preserve existing dentitions, or to strengthen or enhance the existing aesthetic appearance. The science of dental, ceramics for any given application particularly in dentistry involves a study of the materials' compositions, properties and interactions with the applied environment. Therefore, the selection of the materials must be undertaken with confidence and sound judgment (McCabe & Walls, 1998).

Many dental ceramics are fixed permanently into the patient's mouth and removed only intermittently for cleaning. Such materials must have the capacity to withstand the effect of most hazardous environment, variations in temperature, acidity/alkalinity and high stresses. The dental ceramics fabricated for use as replacement for natural tissues place a very high demand upon the chemical, physical and biological properties. For effective functionality as a dental aid, the dental porcelain must be:

- Compatible with biological tissues and without eliciting any adverse reactions.
- Capable of responding successfully to the stresses and strains.
- Able to withstand the corrosive or chemical environment.
- Capable of stimulating in most cases, the appearance of natural tissues in terms of both colour and translucency.
- Capable of being reasonably easy to fabricate by traditional methods. (McCabe & Walls, 1998).

III. THE ROLE OF GLAZING IN DENTAL PORCELAIN

Glazing is the process of covering the porcelain body with a thin layer of glass. A suspension (slip) of the finely ground constituent glaze material is applied to the body which is then dried and fired. The glassy state is developed during firing. Thus, dental glazes are composed of colourless glass powder which is applied to the fired crown surfaces so as to produce a glossy surface (McLean, 1974). According to McLean (1979), the main purpose of glazing includes:

- To make the porcelain more pleasing to touch and to eye.
- To provide an impervious coating which makes the ceramic more hygienic, resistant to chemical attack and mechanically stronger.
- To seal the opening pores in the surface of a fired dental porcelain.

IV. RESEARCH OBJECTIVES

Teeth damage or loss of teeth is one of the major health challenges facing the human race globally. More often than not, the victims sought for artificial teeth as an alternative. In Nigeria for instance, these artificial dental restoratives are imported and costly too, hence unaffordable by the rural poor teeming population. Ironically, Nigeria is richly endowed with these raw materials (kaolin, feldspar and silica) and other clay minerals that can be exploited for the production of dental porcelain and other ceramic products (RMRDC, 2009). Regrettably, these natural resources are left untapped and unutilized.

Based on the background of the problems identified, the objectives of this research are:

- To produce dental porcelain that will be used as a replacement for a damaged or lost dental structure (tooth) using local ceramic raw materials.
- To produce affordable and compatible dental ceramics of acceptable standard using the local raw materials.
- To re-awaken the technological consciousness of Nigeria with a view to exploiting her abandoned rich natural mineral resources especially clay minerals.
- To maintain and improve the quality of life of dental patients.

V. MATERIALS AND METHODS

RAW MATERIAL SOURCING

The ceramic raw materials used in the production of the dental porcelain were:

- Edda clay (source of kaolin) obtained from Edda in Afikpo South L.G.A of Ebonyi State, Nigeria.
- Feldspar obtained from Ijero-Ekkti in Ekiti State, Nigeria.
- Quartz obtained from Abakaliki, Ebonyi State, Nigeria.

These raw materials were consequently washed, air dried, crushed, ground and sieved using jaw crusher, pan mill and mesh 100 respectively.

CHEMICAL ANALYSIS : The chemical composition of the raw Edda clay sample was carried out at the Research Centre, Caritas University, Enugu, Nigeria using Atomic Absorption Spectrophotometer, AAS (Model No. AA 320N).

MODEL PREPARATION : The design of the proposed dental porcelain (8cm x 1cm) was drawn on a plain sheet of paper, and spread on a smooth table surface. A blend of 100g Plaster of Paris (POP) and 100ml water was stirred vigorously and poured into the design on the table. The mixture poured was allowed to set, forming leather hard clay. It was later shaped and trimmed accordingly using saw blade and scraper. The carved model was allowed to dry in air for 24 hours.

MOULD PRODUCTION : 150ml of water and 250g of POP were measured using measuring cylinder and digital electronic weighing balance respectively. The water measured was poured into a plastic 150ml of water and 250g of POP were measured using measuring cylinder and digital electronic weighing balance respectively. The water measured was poured into a plastic bucket while the POP was gently sprinkled into it. The blend was stirred thoroughly till flocculation. The suspension was gradually poured into the retaining wall of the model and allowed for 15 – 20 minutes to set. Therefore, the retaining wall was dismantled, hence the produced mould was trimmed using scrapper and saw blade. Lock was created on the two sites of the mould produced to enable it lock effectively when in use. The same procedure was repeated to produce the other side of the mould. The mould was finally dried in the oven for 24 hours at 110⁰C.

PRODUCTION OF DENTAL PORCELAIN : The production sequence adopted in producing the dental ceramics was; communitation, sieving, batching and mixing, forming/shaping, drying, firing and glazing. The air dried raw materials were crushed and ground to fine aggregates to liberate the mineral constituents. The powdered samples were also sieved using 100 mesh sieve. Thereafter, the raw samples were batched (with a total weight of 500g) and mixed thoroughly with water forming a plastic paste. This paste was allowed to age for 24 hours in order to obtain a workable mix. The aged plastic paste was pressed into the mould and tapped adequately. After one hour, the formed sample was removed from the mould and air dried for 48 hours in the ceramic workshop. Thereafter, the dental porcelain was dried in a drying cabinet for 3 days at a temperature of 110⁰C. Consequently the product was high bisque fired with an electric kiln to a temperature of 1200⁰C. Finally, the dental porcelain was glazed, after which it was subjected to gloss firing at 1230⁰C for 8 hours in the kiln.

PHYSICAL TESTING OF DENTAL PORCELAIN :The following properties associated with dental ceramics were determined:

Linear Shrinkage :Linear shrinkage was determined by measuring the dimensional changes that occurred in the green (wet), dry and fired test samples of the porcelain with the same body composition.

In the green state, the test sample was marked with a shrinkage line of 8.5cm and noted as the original (green) length. After drying, the linear length of the test sample at this state was measured using vernier calipers. The linear drying shrinkage was calculated using the relationship:

$$S_d = \frac{L_g - L_d}{L_g} \times 100 \quad \dots\dots\dots (1)$$

Where, S_d = Linear drying shrinkage
 L_g = Green/original length of sample
 L_d = Dry length of sample

Consequently, the dried test sample was fired in the kiln at a temperature of 1230⁰C. Upon cooling, it was removed and its fired length, L_f measured. The linear firing shrinkage, S_f was calculated using the formula:

$$S_f = \frac{L_d - L_f}{L_d} \times 100 \quad \dots\dots\dots (2)$$

The combined effect of the drying and firing known as the total linear shrinkage, S_t was determined and calculated thus:

$$S_t = \frac{L_g - L_f}{L_g} \times 100 \quad \dots\dots\dots (3)$$

Apparent Porosity : The test sample was dried in a dry cabinet at 110⁰C for 24 hours and fired to 1230⁰C in an electric kiln. The fired test sample was weighed in air W₁ and later transferred into a beaker of water, boiled for 5 hours and allowed to cool. The sample was removed from the water, cleaned and weighed to determine the boiled weight, W₂ Apparent porosity, AP was determined using the relationship:

$$AP = \frac{W_2 - W_1}{W_1} \times 100 \quad \dots\dots\dots (4)$$

VI. EXPERIEMENTAL RESULTS

Tables 1 and 2 show the chemical analysis of the local clay (Edda clay) used and body composition of the dental porcelain. The results of the linear shrinkage and apparent porosity tests are shown in tables 3 and 4.

Table 1: Chemical analysis of Edda clay

Composition	Weight %
SiO ₂	56.00
Al ₂ O ₃	21.64
MgO	1.23
Fe ₂ O ₃	0.12
Na ₂ O	2.10
K ₂ O	1.90
LOI	15.34

Table 2: Body Composition of the Dental Porcelain

Materials	Composition	
	g	%
Edda Clay	150	30
Feldspar	300	60
Quartz	50	10

Table 3: Linear Shrinkage Test Result

Green Length (cm)	Dry length (cm)	Fired length (cm)	Linear Shrinkage, %		
			Drying	Firing	Total
8.50	8.41	8.30	1.10	2.40	2.35

Table 4: Apparent Porosity Test Result

Fired Weight W ₁ (g)	Boiled Weight W ₂ (g)	Apparent Porosity %
61.80	64.40	4.21

VII. DISCUSSION OF RESULTS

Convincing evidence suggests that dental porcelain or dental ceramics must be biocompatible, esthetic, insoluble (less porous) low firing shrinkage and have hardness of 7 on the Mohr's scale (Della & Kelly, 2008).

VIII. BIOCOMPATIBILITY

According to UIPAC recommendation (2012), biocompatibility is the ability of a material to be in contact with a living system without producing an adverse effect. Ceramic materials have been used in dentistry for over 200 years. Hence, they are the most biocompatible of dental restorative materials because they are chemically very stable (Derek Jones, 1998).

Aesthetics : Aesthetics also known as the judgements of sentiment and taste is scientifically defined as the study of sensory or sensori-emotional values. A desirable feature of ceramics is that their appearance can be customized to stimulate the colour, translucency and fluorescence of natural teeth.

Chemical Analysis : The chemical composition of the Edda clay (source of kaolin) is presented in table 1. The silica (SiO₂) and alumina (Al₂O₃) contents are 56% and 21.64% respectively. The iron oxide content is 0.12%.

These results indicate that the Edda clay is actually kaolinite clay, hence a source of kaolin. Furthermore, the iron content is very low and is of required acceptable standard for a dental porcelain.

Linear Shrinkage : The results of the linear shrinkage (drying, firing and total) are shown in table 3. It revealed low shrinkage values of 1.10%, 2.40% and 2.35% for the drying linear shrinkage, linear firing shrinkage and total linear shrinkage respectively. Thus, these values fall within the acceptable shrinkage values of dental porcelain.

Apparent Porosity : Table 4 shows the apparent porosity test result of the dental porcelain. An apparent porosity of 4.2% was obtained. This low value (4.21%) indicated that the dental ceramic depicts increase in durability and strength, less porous, and confirmed with the suggested evidence (acceptable standard) of Della and Kelly, 2008.

IX. CONCLUSION

From the production and physio-chemical tests, the following can be concluded.

- The local clay (Edda clay) is kaolinite in nature, hence a source of kaolin.
- The chemical analysis revealed a very low iron impurity (0.12%) required of an acceptable standard dental porcelain.
- Though the investigated properties gave results that are acceptable for a standard dental porcelain, the dental ceramic produced using local raw materials is a prototype, hence requires a clinical/medical compatibility test.

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