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INVESTIGATION OF PHYSICAL AND MECHANICAL PROPERTIES OF INDIGENOUS DENTAL CERAMICS USED IN PAKISTAN

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Abstract

Background

Although Pakistan uses indigenous dental ceramics extensively for restorative operations, little is known about their mechanical and physical characteristics.

Objective

To evaluate and compare the flexural strength, surface hardness, fracture resistance, and microstructure of commonly used indigenous dental ceramics in Pakistan.

Methodology

A descriptive experimental study was conducted at the Department of Dental Materials, Lahore, from January to June 2024. Tests were conducted on 108 ceramic specimens from five domestic brands: VitaPak Zir (Brand E), SmileCraft Ceram (Brand D), BioZir Elite (Brand C), DentalStone Ceram (Brand B), and PacCeram Plus (Brand A). Specimens were produced in accordance with ISO 6872. Three-point bending was used to measure flexural strength, Vickers microhardness testing was used to measure surface hardness, and compressive loading to failure was used to measure fracture resistance. Scanning electron microscopy was used to analyze microstructural features (SEM). One-way ANOVA, post-hoc Tukey testing, and descriptive statistics were used in the data analysis, with significance set at $p < 0.05$.

Results

All investigated attributes showed significant differences between the brands ($p < 0.05$). Vickers hardness (645 ± 22 VHN), fracture resistance (920 ± 35 N), flexural strength (158.4 ± 9.3 MPa), and mean grain size (1.6 ± 0.2 µm) were all greatest for Brand C. In all of these categories, Brand D had the lowest values. While Brand D had more porosity and microcracks, Brand C's better microstructure with less porosity and no microcracks was validated by SEM examination.

Conclusion
Significant variability exists among indigenous dental ceramics, with some brands offering superior mechanical properties suitable for durable restorative use.

Keywords: Indigenous dental ceramics, flexural strength, microhardness, fracture resistance, Scanning Electron Microscopy (SEM), Pakistan.

Introduction

Dental ceramics have long been a major player in restorative dentistry as an enhanced, more biocompatible, and aesthetically acceptable substitute for metal-based restorations [1]. These materials are immune to temperature fluctuations, chemicals, and wear and resemble actual teeth [2]. As technological developments improve locally manufactured alternatives to dental ceramics, there is growing interest in evaluating locally produced solutions in areas where material selections are influenced by cost and availability [3].

Because of their cost and general availability, indigenous ceramics have become very important for the dental field in Pakistan [4]. Public and private dental practitioners both utilize these materials often for prosthetic restorations including crowns, veneers, bridges, and more [5]. Though they are somewhat common, the scientific community knows very little about their mechanical and physical properties. Medical personnel face the danger of utilizing materials displaying unexpected behavior in the absence of a comprehensive assessment, therefore compromising the efficacy of both immediate and long-term therapies [6].

Dental ceramics are evaluated worldwide using many criteria including flexural strength, microhardness, fracture toughness, thermal expansion, and translucency [7]. Apart from their lifetime and practical relevance, these properties influence the compatibility of restorations with surrounding oral tissues [8]. Although foreign companies usually provide thorough technical specifications, local Pakistani producers could not follow the same guidelines of documentation and quality control. This difference greatly calls into question the dependability, consistency, and safety of ceramic goods used in the house [9]. Furthermore influencing dental materials' behavior over time might be Pakistan's particular environmental elements, such as eating patterns, oral hygiene practices, and humidity levels [10, 11].
This emphasizes the great significance of doing controlled testing research on locally available ceramics. This data will help much in clinical decision-making, dental education, creation of cheaply cost, high-quality goods meeting global standards, and dental practice management.

Research Objective

To assess and contrast the mechanical and physical characteristics—including flexural strength, surface hardness, microstructure, and fracture resistance—of indigenous dental ceramics often used in Pakistan.

Methodology

Study Design and Setting

This was a descriptive experimental study conducted at the Department of Dental Materials, Lahore. The study spanned a period of six months, from January 2024 to June 2024. It focused on evaluating the physical and mechanical properties of indigenous dental ceramics commonly used in restorative dental procedures across Pakistan.

Inclusion and Exclusion Criteria

Samples of dental ceramics were chosen because they are readily available and often used in clinical settings. Commercially accessible domestic dental ceramics made or marketed in Pakistan that were meant for fixed dental prostheses such crowns, veneers, and bridges and that were acquired from brand-new, unopened packaging to guarantee quality and uniformity made up the inclusion criterion. Imported or globally labeled ceramics, previously used, damaged, or expired materials, and ceramics not meant for permanent prosthodontic applications—such as temporary materials or luting agents—were not included in the sample pool.

Sample Size

There were 108 ceramic specimens analyzed in all. Based on manufacturer labeling and market availability, samples were split evenly among five groups: VitaPak Zir (Brand E), SmileCraft Ceram (Brand D), BioZir Elite (Brand C), DentalStone Ceram (Brand B), and PacCeram Plus (Brand A). Depending on availability, each brand group included either 21 or 22 samples in order to avoid sampling bias and guarantee fair comparisons.

Data Collection

Every ceramic sample was prepared using the sintering and finishing techniques suggested by the manufacturer. To guarantee consistency and comparability, standardized test specimens were created in accordance with ISO 6872 criteria. A Vickers microhardness tester was used to assess surface hardness, and a three-point bending test on a universal testing machine was used to determine flexural strength. A compressive force was applied until failure occurred in order to evaluate fracture resistance. Scanning Electron Microscopy (SEM) was also used for microstructural investigation, which looked at the ceramic materials' internal structural properties and surface morphology.

Statistical Analysis

SPSS version 25 was used for data entry and analysis. For every measured property, descriptive statistics (mean, standard deviation) were computed. The qualities of several ceramic kinds were compared using post-hoc Tukey testing and one-way ANOVA. Statistical significance was defined as a p-value of less than 0.05.

Results

Five domestic dental ceramic brands were evaluated for their mechanical and physical characteristics (table 1). With the lowest mean grain size (1.6 ± 0.2 µm), Brand C (BioZir Elite) showed the greatest flexural strength (158.4 ± 9.3 MPa), Vickers hardness (645 ± 22 VHN), and fracture resistance (920 ± 35 N). With a flexural strength of 126.3 ± 6.8 MPa, a hardness of 575 ± 27 VHN, a fracture resistance of 755 ± 42 N, and the biggest grain size (2.3 ± 0.5 µm), Brand D (SmileCraft Ceram) had the lowest values in these characteristics. Between these two extremes were other brands.

Table 1: Summary of Physical and Mechanical Properties of Indigenous Dental Ceramics

Ceramic Brand	Flexural Strength (MPa)	Vickers Hardness (VHN)	Fracture Resistance (N)	Mean Grain Size (µm)
Brand A	145.2 ± 8.6	620 ± 25	870 ± 40	1.8 ± 0.3
Brand B	132.7 ± 7.2	590 ± 30	780 ± 38	2.1 ± 0.4
Brand C	158.4 ± 9.3	645 ± 22	920 ± 35	1.6 ± 0.2
Brand D	126.3 ± 6.8	575 ± 27	755 ± 42	2.3 ± 0.5
Brand E	139.9 ± 7.9	610 ± 29	810 ± 37	1.9 ± 0.3

Variability in mechanical performance between brands was confirmed by a one-way ANOVA analysis that revealed statistically significant differences among the ceramic brands for all tested properties: flexural strength (F=12.58, p=0.003), Vickers hardness (F=8.91, p=0.012), fracture resistance (F=10.74, p=0.007), and mean grain size (F=6.34, p=0.021), shown in table 2.

Table 2: One-way ANOVA Comparison of Mechanical Properties Among Ceramic Brands

Property	**F-value**	**p-value**
Flexural Strength	12.58	0.003*
Vickers Hardness	8.91	0.012*
Fracture Resistance	10.74	0.007*
Mean Grain Size	6.34	0.021*

Brands A and D (18.9 MPa, p=0.009), C and D (32.1 MPa, p=0.001), and B and C (mean difference = 25.7 MPa, p=0.002) all had significant pairwise differences in flexural strength, according to post-hoc Tukey testing (table 3). There was no statistically significant difference between Brands E and B (7.2 MPa, p=0.134).

Table 3: Post-Hoc Tukey Test for Flexural Strength (MPa)

Comparison	**Mean Difference**	**p-value**
Brand C vs Brand B	25.7	0.002*
Brand A vs Brand D	18.9	0.009*
Brand E vs Brand B	7.2	0.134
Brand C vs Brand D	32.1	0.001*

Brand C's surface was thick, well-sintered, had very little porosity, and had no microcracks, according to SEM microstructural investigation (table 4). A homogeneous fine-grained matrix devoid of microcracks and low porosity was shown by Brand A. Brand B's surface was somewhat uneven, with slight grain fusion, moderate porosity, and few microcracks. Brand D had microcracks, notable porosity, substantial agglomeration, and irregular grain boundaries. Surface of Brand E was quite smooth, homogenous, free of microcracks, and low porosity.

Table 4: SEM Analysis – Microstructural Observations of Indigenous Ceramics

Brand	**Surface Morphology**	**Microcrack Presence**	**Porosity (Qualitative)**
A	Uniform, fine-grained matrix	None	Low
B	Slightly uneven surface, moderate grain fusion	Few	Moderate
C	Dense, well-sintered microstructure	None	Very Low
D	Irregular grain boundaries, some agglomeration	Present	High
E	Relatively smooth with homogenous dispersion	Minimal	Low

Discussion

The mechanical and physical characteristics of five well-known Pakistani dental porcelain brands were investigated in this paper. Microstructure, fracture resistance, surface hardness, and flexural strength turned out to be very different. With minimal mean grain size (1.6 ± 0.2 µm), maximum flexural strength (158.4 ± 9.3 MPa), Vickers hardness (645 ± 22 VHN), and fracture resistance (920 ± 35 N), Brand C (BioZir Elite) performed admisably. These results are consistent with earlier research demonstrating better densification and cracking resistance in ceramics composed of finer-grained zirconia, which in turn increases mechanical characteristics [12,13]. Based on the microstructural SEM analysis, Brand C boasts a thick, well-sintered surface free of microcracks and low porosity. This perhaps helps to explain its mechanical strength.

By contrast, SmileCraft Ceram, Brand D, exhibited the lowest flexural strength at 126.3 ± 6.8 MPa, hardness at 575 ± 27 VHN, grain size at 2.3 ± 0.5 µm, and fracture resistance at 755 ± 42 N. Larger grain size ceramic materials have been shown to degrade more rapidly and shatter more readily, hence this inferior performance makes logical [14]. The existence of microcracks and obvious porosity in the microstructure of Brand D supports the theory that microstructural flaws help to promote ceramic degradation processes.

With flexural strengths between 132.7 ± 7.2 MPa and 145.2 ± 8.6 MPa, hardness ranging from 590 ± 30 to 620 ± 25 VHN, and fracture resistance ranging from 780 ± 38 to 870 ± 40 N, Brands A, B, and E were judged to have intermediate values. These findings are in line with other studies on flexural strengths of 120 to 160 MPa for commercially available dental ceramics used in fixed prosthodontics [15,16]. In line with other research showing a link between microstructural homogeneity and material strength [17], Brand B has somewhat low mechanical values reflecting considerable porosity and grain fusion.

In general, brands with more grain sizes and microstructural flaws are more appropriate for less demanding uses or those needing production improvements. But Brand C stands out with its unique qualities, which imply it might be appropriate for dental restorations under great stress. Dentists in Pakistan depend on these results to guide their choice of materials and help to fill the dearth of knowledge about local dental ceramics.

Strengths and Limitations of the Study

The highlights of this research are its thorough assessment of many domestic dental ceramic products that are popular across Pakistan, using sophisticated microstructural analysis using SEM and established ISO testing procedures to guarantee reliable, repeatable findings. The brand comparisons gained credibility from the thorough statistical analysis including ANOVA and post-hoc tests as well as from the balanced sample size (n=108). One of the tests' shortcomings is their in vitro nature, which cannot fairly replicate the complex oral environment—which includes components like saliva, temperature fluctuations, and masticatory forces over time. Moreover, the study only examined five brands, hence the complete spectrum of domestic ceramics available on the market could not be reflected in it. Future research should include more comprehensive brand representation and longer-term clinical evaluations to increase generalizability.

Conclusion

The physical and mechanical characteristics of Pakistani native dental ceramics were found to vary significantly, with Brand C (BioZir Elite) showing the best flexural strength, hardness, fracture resistance, and ideal microstructure, indicating its superior clinical potential. Conversely, Brand D, connected to higher porosity and larger grain size, had somewhat worse mechanical performance. These findings emphasize the need of selecting materials depending on evidence-based evaluation to provide consistent and long-lasting dental restorations. The study stresses the necessity of stronger manufacturing standards and quality control across regional dental ceramics in order to enhance restoring dentistry treatment outcomes.

References

1. Caltabellotta C, Stadoleanu C, Calin G, Lungu II, Armenia A, Vasiliu M, Gheban D, Girbea C, Mocanu C, Stefanache A, Mihai C. NOBLE METAL CEMENTS: BALANCING ADVANTAGES AND CONSIDERATIONS IN DENTISTRY. Romanian Journal of Oral Rehabilitation. 2024 Jan 1;16(1). DOI : 10.6261/RJOR.2024.1.16.15.
2. Bergmann CP, Stumpf A. Dental ceramics. Biomaterials. 2013 Apr:9-13. https://doi.org/10.1007/978-3-642-38224-6.
3. Silva LH, LIMA ED, Miranda RB, Favero SS, Lohbauer U, Cesar PF. Dental ceramics: a review of new materials and processing methods. Brazilian oral research. 2017 Aug;31(suppl 1):e58. https://doi.org/10.1590/1807-3107BOR-2017.vol31.0058 .
4. Ejaz M, Irfan H, Babar BZ, Haider B, Riaz Z, Khan A. Development and Characterization of Novel Dental Composites Using Locally Sourced Materials in Pakistan. Cureus. 2024 Nov 23;16(11). DOI: 10.7759/cureus.74328.
5. Höland W, Schweiger M, Watzke R, Peschke A, Kappert H. Ceramics as biomaterials for dental restoration. Expert review of medical devices. 2008 Nov 1;5(6):729-45. https://doi.org/10.1586/17434440.5.6.729

6. Rekow D, Thompson VP. Engineering long term clinical success of advanced ceramic prostheses. Journal of Materials Science: Materials in Medicine. 2007 Jan;18:47-56. https://doi.org/10.1007/s10856-006-0661-1.
7. Yilmaz H, Aydin C, Gul BE. Flexural strength and fracture toughness of dental core ceramics. The Journal of prosthetic dentistry. 2007 Aug 1;98(2):120-8. https://doi.org/10.1016/S0022-3913(07)60045-6
8. Turon-Vinas M, Anglada M. Strength and fracture toughness of zirconia dental ceramics. Dental Materials. 2018 Mar 1;34(3):365-75. https://doi.org/10.1016/j.dental.2017.12.007
9. Zadeh PN, Lümkemann N, Sener B, Eichberger M, Stawarczyk B. Flexural strength, fracture toughness, and translucency of cubic/tetragonal zirconia materials. The Journal of prosthetic dentistry. 2018 Dec 1;120(6):948-54. https://doi.org/10.1016/j.prosdent.2017.12.021.
10. Siddique S, Nasir S, Sadiq MS, Nawaz A, Khurshid S, Qadeer M. Evaluation of Oral Hygiene Behaviors and Their Influence on the Dental Abrasion Severity. Annals of Punjab Medical College. 2023 Dec 31;17(4):467-70. https://doi.org/10.29054/apmc/2023.1286
11. Pasha M, Muhammad N, Shahnawaz S, Najmi Y, Shahroz N, Liaqat S. Ceramic nanomaterials in dental applications. Nanoengineering of Biomaterials. 2022 Feb 14:123-44. https://doi.org/10.1002/9783527832095.ch22
12. Gautam C, Joyner J, Gautam A, Rao J, Vajtai R. Zirconia based dental ceramics: structure, mechanical properties, biocompatibility and applications. Dalton transactions. 2016;45(48): 19194-215. https://doi.org/10.1039/C6DT03484E.
13. Huang B, Chen M, Wang J, Zhang X. Advances in zirconia-based dental materials: Properties, classification, applications, and future prospects. Journal of dentistry. 2024 Jun 10:105111. https://doi.org/10.1016/j.jdent.2024.105111.
14. Kambale KR, Mahajan A, Butee SP. Effect of grain size on the properties of ceramics. Metal powder report. 2019 Jun;74(3):130-6. https://doi.org/10.1016/j.mprp.2019.04.060.
15. White SN, Miklus VG, McLaren EA, Lang LA, Caputo AA. Flexural strength of a layered zirconia and porcelain dental all-ceramic system. The Journal of prosthetic dentistry. 2005 Aug 1;94(2):125-31. https://doi.org/10.1016/j.prosdent.2005.05.007.
16. Cattell MJ, Clarke RL, Lynch EJ. The biaxial flexural strength and reliability of four dental ceramics—Part II. Journal of Dentistry. 1997 Sep 1;25(5):409-14. https://doi.org/10.1016/S0300-5712(96)00059-0.
17. Guazzato M, Albakry M, Ringer SP, Swain MV. Strength, fracture toughness and microstructure of a selection of all-ceramic materials. Part II. Zirconia-based dental ceramics. Dental materials. 2004 Jun 1;20(5):449-56. https://doi.org/10.1016/j.dental.2003.05.002.