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Analysis of Zirconia Profile in In-Ceram Zirconia Dental Restoration

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The applications of all-ceramic materials in dental crowns and bridges were limited, due to their brittle characteristics and relatively low fracture toughness [1-3]. In recent years, a new In-Ceram Zirconia dental restoration has been developed, comprising of cerium oxide stabilized zirconium oxide in In-Ceram Alumina, with both serving as block and slip materials [4-5]. The concentration of zirconia particles in the dental restoration is a critical factor for the ultimate microstructure and mechanical properties. In this study, a variable pressure SEM with imaging analysis software was used to investigate the concentration profile of zirconia along the cross-sections of specimens.

Four VITA In-Ceram Zirconia (VITA Zahnfabrik H. Rauter GmbH & Co.) specimens were prepared following the manufacturer's instructions with slip-casting and a series of firing processes. The dimension of specimens was 25mm x 4mm x 2mm. The examined cross-section sides were polished with 600 Grit SiC paper to remove any surface texture duplicated from the silicone rubber mold in casting process. From the bottom to the top surface, five equally spaced layers with 5 points on each layer were imaged by SEM with a backscattered electron detector.

As illustrated in Fig. 1A, zirconia and alumina particles showed different darkness index on the backscattered electron images, owing to the difference in atomic numbers. The white particles are zirconia with a higher atomic number of 123 and the rest of grey areas are alumina with lower atomic number of 102. The image was further processed by AnalySIS Pro image analysis software as white and black regions representing zirconia and alumina (Fig.1B). The area percentages of two different regions were calculated to be 76.76% for alumina and 23.24% for zirconia using AnalySIS Pro. Based on the densities of alumina (3.97 g/cm^3) and zirconia stabilized by cerium oxide (6.07 g/cm^3), the weight percentage of each component was converted to be 68.36% and 31.64%. The measured weight percentages were within the manufacturer's specification for alumina (69%) and cerium oxide stabilized zirconia (31%), with a variation of ±2% for different batches posted by the manufacturer. The agreement indicates that the imaging analysis method is well suitable for the determination of component weight concentration in the Vita In-Ceram Zirconia specimens.

By using the imaging analysis method, a mean weight percentage was obtained from five testing points on each layer; and the mean number of five different layers represents the concentration profile of the sample. Four samples were analyzed this way and the results are listed in Table 1. The mean concentration profile (Fig. 2) represents the changing trend of zirconia in In-Ceram Zirconia dental restoration specimens. As shown in Fig. 2, the zirconia concentration decreased from 27.25% to 26.20% from the bottom side to the top. This variation is considered to be result of two factors. 1) Much higher density of zirconia than alumina makes it easier to sediment to the bottom in slip casting mixture, even with the Vita In-Ceram Zirconia additive added for homogeneity of the mixture. 2) The average particle size of zirconia is smaller than the size of alumina. During the first step of drying process, the water in mixture was quickly absorbed by plaster plate, so that the smaller zirconia particles were flowing more easily to the bottom in the slip mixture.

The observed variation of zirconia concentration profile in the In-Ceram Zirconia restoration is considered to be one of the determining factors for the physical properties of different layers in the restoration. This information will help identifying the initiation of failures in In-Ceram Zirconia dental restorations.

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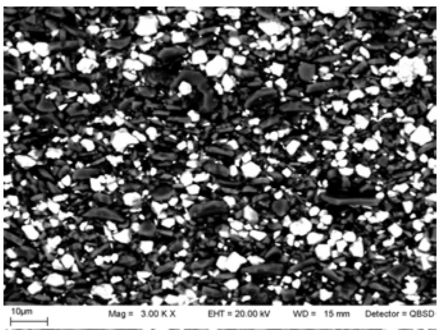

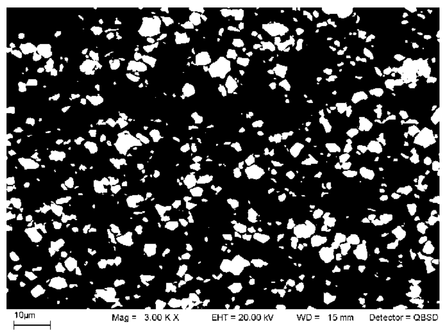

FIG. 1. (A) Backscattered electron image of Vita In-Ceram Zirconia and (B) the image processed with AnalySIS Pro.

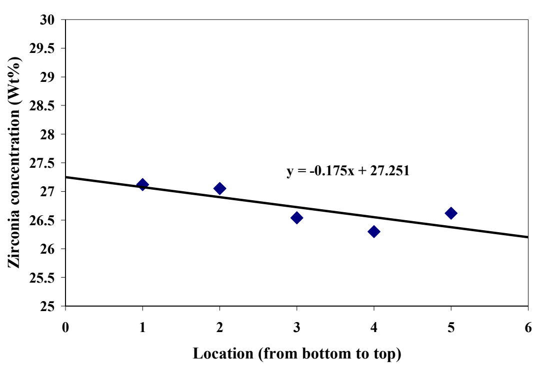

FIG. 2. Concentration profile of zirconia in Vita In-Ceram Zirconia

TABLE 1. Mean concentration (Wt%) of zirconia by imaging analysis

Layers	sample 1	sample 2	sample 3	sample 4	Avg
1	29.36	26.55	25.95	26.62	27.12
2	28.88	26.85	26.22	26.27	27.05
3	28.02	26.47	26.83	24.84	26.54
4	26.75	25.73	26.48	26.22	26.30
5	27.71	27.16	26.53	25.10	26.62

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