

BACKGROUND

Zirconia ceramic is a high-strength material with excellent corrosion and wear resistance, which makes it suitable for high-stress environments, such as dental applications from implant fixtures to tooth- or implant-borne fixed prostheses.^{1,2,3}

To fabricate accurate dental prostheses with zirconia, subtractive milling (SM) using an optimized tool path has been widely used. However, inherent drawbacks of SM include the possible risk of microscopic cracks on the surface, waste of leftover blocks, and high consumption of milling tools. Additive manufacturing (AM) has been suggested as an alternative method to fabricate zirconia-based dental prostheses to address the drawbacks from SM.^{4,5,6}

Using stereolithography (SLA) or digital light processing (DLP), a solid ceramic body is generated by successive layering, followed by photopolymerization of a resin-based suspension containing ceramic particles. A DLP technique builds an entire object by stacking each layer from a light-mask image, and the light intensity and exposure time are key production parameters, depending on the characteristics of the suspension.^{4,7,8}

The goal of this study was to investigate the association between the exposure energy and quality of DLP-generated zirconia for dental applications. The study contributes the knowledge and its advancement of AM in dental material.

MATERIALS AND METHODS

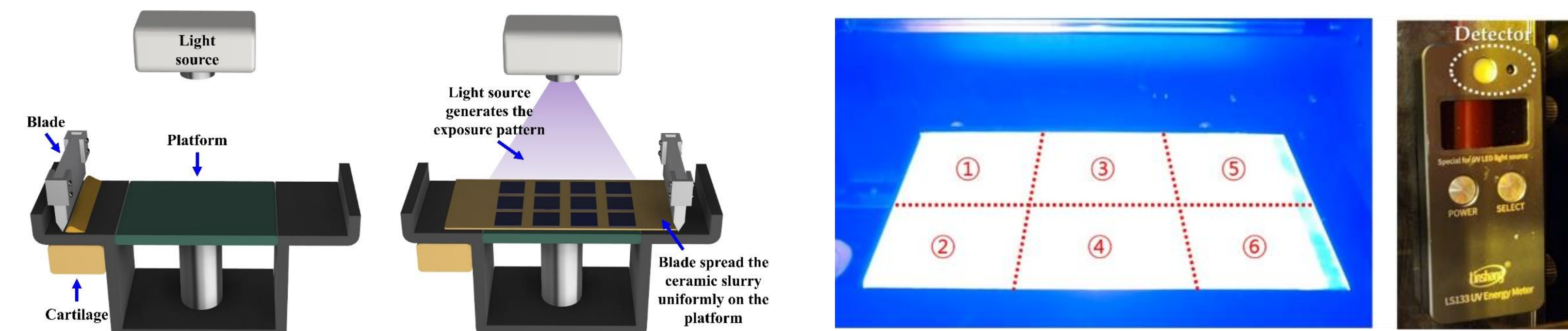


Figure 1: Schematic diagram of the mechanism of a cartridge-based custom printer for digital light processing of dental zirconia suspension with top-down approach.

Figure 2: Uniformity of exposure intensity onto platform was monitored by using an ultraviolet (UV) energy meter. Exposed platform by UV light was divided into six identical areas (1 to 6) and beam irradiation amount for each region was evaluated.

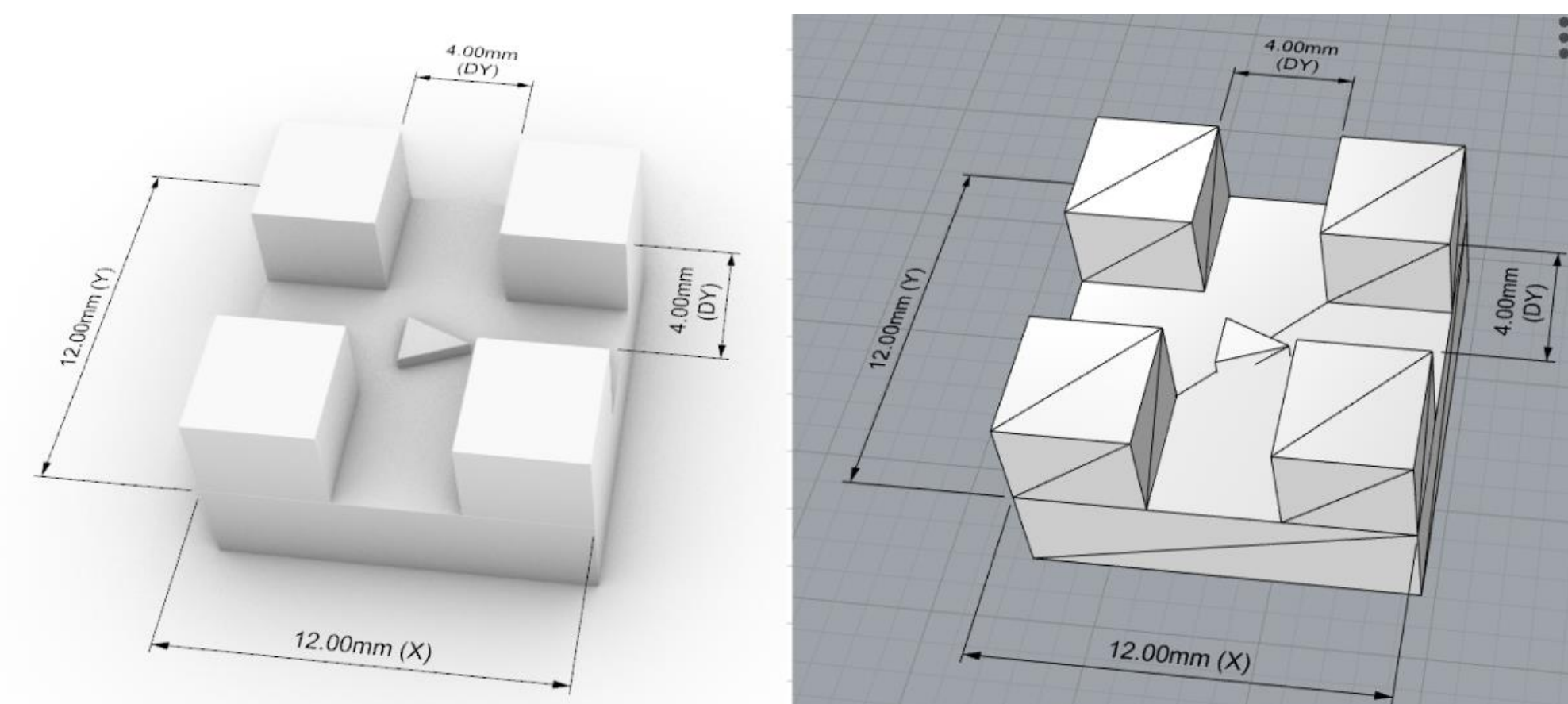


Figure 3: A geometric cubic shape stacked in the simplified four-cusped molar form to measure lateral resolution of zirconia green body.

MATERIALS AND METHODS CONT.

Lateral Resolution of Green Body of Dental Zirconia

- Two different outcomes were evaluated for each energy group:
 - 1) The outline width (X_o and Y_o) in the horizontal plane (x -and y -axis) of the cubic shape, originally designed as 12.0mm in the reference model.
 - 2) The isthmus width (X_i and Y_i) in each axis of the cubic shape, originally set as 4.0 mm in the reference model.
- Four different widths (X_o , Y_o , X_i , and Y_i) of each cubic-shaped green body fabricated under each exposure energy-dose condition were measured using a digital caliper.
- The width measurements were compared with the setting values of the reference model.

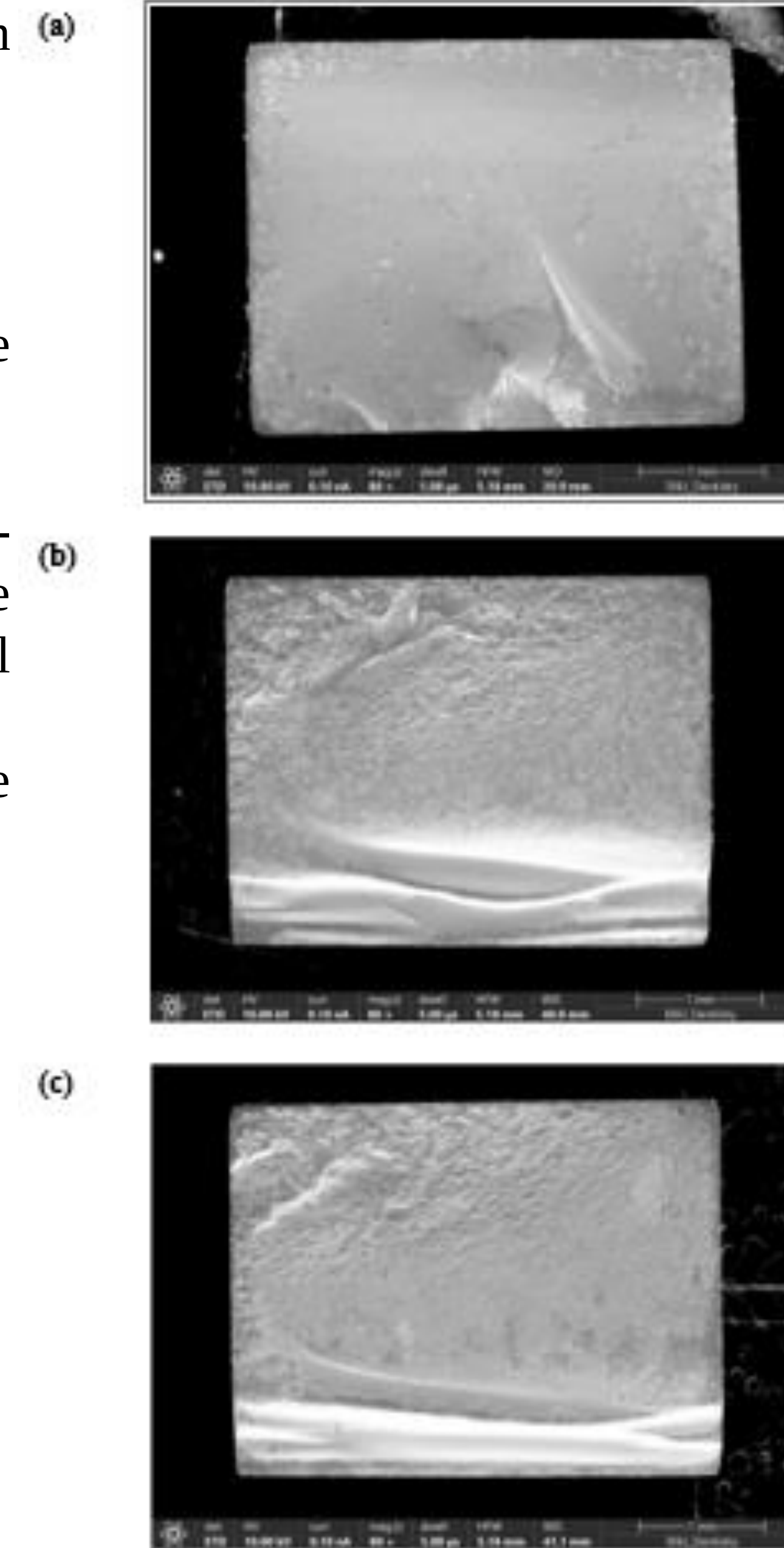


Figure 4: Representative microscopic image of fractured dental zirconia specimens. (a) Low-energy group, (b) Medium-energy group, (c) High-energy group. The LE group showed several micro-sized interlayer porosities and numerous agglomerates, while the ME and HE groups showed less agglomerates on the fractured surface than those of LE group, and no distinctive interlayer pores or surface defects.

Statistical Analysis

- Descriptive statistics were calculated using the means and standard deviations of the lateral resolution and flexural strength values.
- Shapiro-Wilk and Levene tests for normality.
- Kruskal-Wallis test was conducted to compare the calculated lateral resolution and 1-way analysis of variance (ANOVA).
- Post hoc pairwise comparison was performed adjusted using the Bonferroni method.

RESULTS

For lateral resolution, there was a significant difference seen between the three groups with the ME group displaying the least error when compared to the original design. For flexural strength, the ME group displayed the highest mean strength, yet not a statistically significant difference from HE group.

Group	Outline width		Isthmus width	
	X_o	Y_o	X_i	Y_i
Low	(-) 0.103 ± 0.016*	(-) 0.062 ± 0.019*	(-) 0.114 ± 0.030*	(-) 0.127 ± 0.024*
Medium	(-) 0.040 ± 0.021*	(-) 0.014 ± 0.015*	(-) 0.024 ± 0.028*	0.000 ± 0.024*
High	(+) 0.112 ± 0.046*	(+) 0.152 ± 0.046*	(+) 0.052 ± 0.041*	(+) 0.037 ± 0.012*

Table 1: Means and standard deviations of lateral resolution of printed zirconia green body.

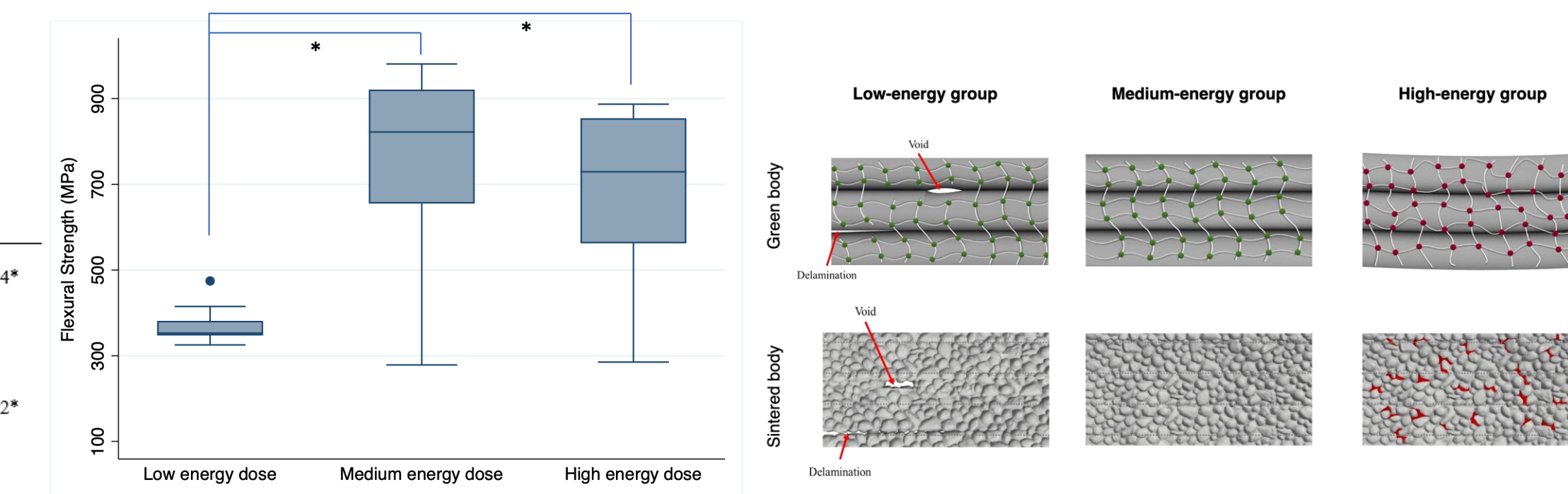


Figure 5: Measurements and standard deviations of the flexural strength under three different exposure energy conditions.

Figure 6: Schematic diagram of association between overall exposure energy dose and flexural strength of dental zirconia fabricated.

CONCLUSIONS

We can conclude the exposure energy dose of in-office manufacturing can affect the lateral resolution of the green body, as well as the flexural strength of the sintered body of zirconia for dental applications.

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