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Comparison of dimensional accuracy of lithium disilicate CAD/CAM ceramics

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ABSTRACT

Aim The aim of this *in vitro* study was to evaluate the geometric accuracy of crowns designed by 3D CAD and fabricated with CAD/CAM system.
Materials and methods Accuracy of geometric crown and milling time were tested using three different ceramic blocks available in the market: GC Initial® LiSi Block (GC Corp) (LS), IPS e.max CAD (Vivoclar) (EM) and Cerec Tessera™ (Dentsply Sirona) (TE). All crowns were fabricated using a CAD/CAM milling machine (Cerec MC XL, Dentsply Sirona) by importing the STL file using a CAM software (inLab CAM SW 20.0.1, Dentsply Sirona). Milling time was recorded. Accuracy of the crowns, defined as the percentage of measurement points satisfying the production repeatability of Cerec MC XL (±25 µm), was assessed after glaze firing process by means of an optical precision measuring machine (ATOS Capsule, GOM) superimposing the fabricated crowns and the original STL file (GOM Inspect, GOM). Data were analyzed with one-way ANOVA and Tukey's tests. For each material a prismatic specimen was cut and submitted to thermal expansion: the temperature of maximum linear expansion was set as the dynamic softening temperature.
Results LS showed the best accuracy before and after glaze firing process. TE showed the worst accuracy while EM before crystallization process showed no statistically significant difference with LS, whereas after crystallization there was a statistically significant difference. TE showed the longest milling time (19.5 min), EM the shortest (12.0 min) and LS was processed in 14.6 min, with a statistically significant difference from EM.
Conclusion From the results of this *in vitro* study LS shows high accuracy of margins and acceptable milling time that support its clinical use.

KEYWORDS Geometric accuracy, Lithium disilicate, Crown restoration.

INTRODUCTION

Lithium disilicate materials for crown restorations have been widely used because of their superiority in terms of esthetics and physical properties. Especially, "single-appointment treatment" using CAD/CAM blocks has attracted clinician's attention in recent years (1-3).
The use of chair side procedures to make single unit prosthetic rehabilitations in a reasonable time was well received by practitioners and is still part of daily dentistry (4-5). Chair side procedures require specific esthetic materials in block formulation and a wide range of materials are now available such as resins, reinforced resins, porcelain, lithium disilicate and zirconia (6). Lithium disilicate has become very popular owing to its mechanical and esthetic properties (7-8). Among these blocks, a novel lithium disilicate glass ceramic (Initial LiSi Block, GC Co., Tokyo, Japan), which does not require crystallization process after CAD/CAM fabrication, was developed. Glass ceramics can be treated in a shorter time by polishing to achieve gloss without glaze firing process. Initial LiSi Blocks have already been tested under both *in vitro* (9-12) and *in vivo* conditions showing favorable and promising results (13). The possibility to design at the chair side a crown that can have high accuracy is important as well as the need of a reasonable milling time to fabricate the crown. An important variable is the heat treatment after milling, during which the crown may partially lose accuracy of the margins.
The aim of the present study was to evaluate three different lithium disilicate materials accuracy and milling time when used according to the manufacturers' instructions, to produce crowns. The null hypothesis was that there were no differences among the three materials about: accuracy and grinding time.

MATERIALS AND METHODS

Accuracy of geometric crown and milling time

Three different blocks available in the market were tested (Table 1): GC Initial® LiSi Block (GC Corp) (LS), IPS e.max CAD (Vivoclar) (EM) and Cerec Tessera™ (Dentsply Sirona) (TE). The STL file of the geometric crown was created using a CAD software (Fig. 1). The crowns were

Sample code	Material	Shade	Lot.	Heat treatment after grinding
LS	Initial LiSi Block	A2 LT	2007310	Not Required
EM	IPS e.max CAD	LT A2	Z00FTM	Required
TE	Cerec Tessera	MTLT BL2	16008743	Required

Accuracy of geometric crown and milling time

TABLE 1 The three materials tested.

	Standby temperature (°C)	Closing time (min)	Heating rate (°C/min)	Vacuum	Firing temperature (°C)	Holding time (min)
Initial LiSi Block	480	4:00	45	NO	740	1:00

TABLE 2 Heat treatment program of Initial LiSi Block.

fabricated (production repeatability: ±25 μm) using a CAD/CAM machine (Cerec MC XL, Dentsply Sirona) by importing the STL file using a CAM software (inLab CAM SW 20.0.1, Dentsply Sirona). In addition, the processing time necessary for milling the crown was measured. After fabrication, LS, EM and TE were crystallized or glaze fired using a furnace (Austromat 624, Dekema for LS; Programat EP 5000, Ivoclar Vivadent for EM and TE) according to the manufacturers' instructions (Table 2, 3).
The accuracy of the geometric crown was measured using an optical precision machine (ATOS Capsule, GOM), and was compared by superimposing the crowns and the original STL file (GOM Inspect, GOM) (Fig. 2). The accuracy was defined as the percentage of measurement points satisfying the production repeatability of Cerec MC XL (±25 μm).
Data were analyzed by means of one-way ANOVA and Tukey's tests (* : $p < 0.05$, ** : $p < 0.01$).

Temperatures for dynamic softening

A prismatic specimen (18.0 mm × 1.5 mm × 1.5 mm) was cut from each material using a precision cutting machine (Isomet 2000, Buehler). The prismatic specimen was polished with waterproof abrasive paper and the bases were precisely adjusted to be parallel. The temperature at which the linear expansion became maximum was set as the temperature at which dynamic softening occurs;

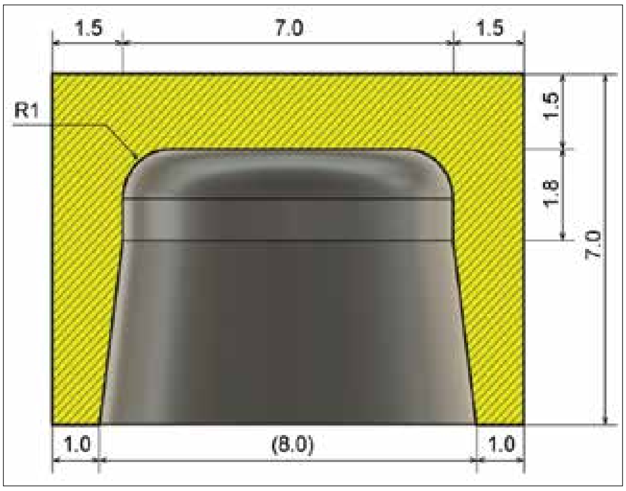

FIG. 1 The geometric crown.

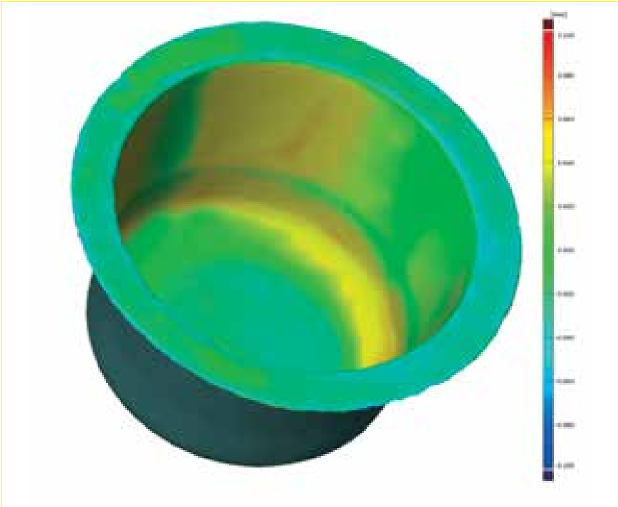

FIG. 2 Superimposition of the fabricated crown and the STL file.

	Standby temperature (°C) B	Closing time (min) S	Heating rate (°C/min) t↑	Heating rate (°C/min) t2↑	Holding temperature (°C) T	Holding temperature (°C) T2	Holding time (min) H	Holding time (min) H2	Vacuum On (°C) V1	Vacuum Off (°C) V2	Long-term cooling (°C) L
IPS e.max CAD	403	6:00	60	30	770	850	0:10	10:00	550	770	700
Cerec Tessera	400	3:30	60	-	760	-	1:30	-	-	-	0

Temperatures for dynamic softening

TABLE 3 Heat treatment program of IPS e.max CAD and CEREC Tessera.

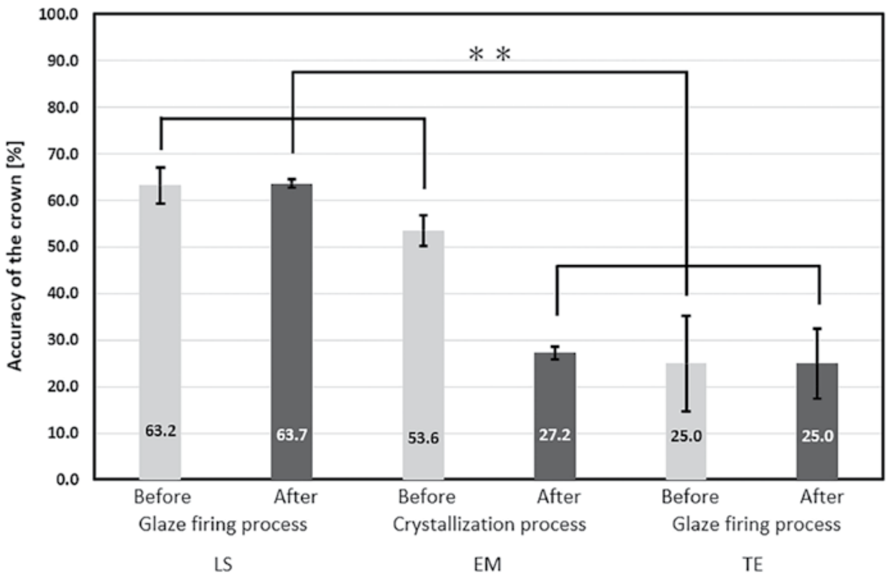

FIG. 3 Accuracy of the crown (accuracy of CAD/CAM machine: ±25 µm) (Tukey's test, **:p<0.01). It shows the accuracy between the crown and STL file for each sample. The accuracy of LS was 63.2%. The difference was observed before and after crystallization process of EM. The accuracy decreased from 53.6% to 27.2%. TE had an accuracy of 25.0% before heat treatment, and the accuracy was equivalent to that of EM after heat treatment.

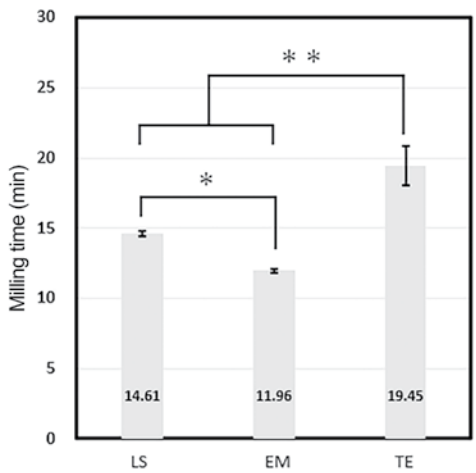

FIG. 4 Milling time of the geometric crown using CEREC MX XL (Tukey's test,*; p<0.05,**: p<0.01).

Sample	Dynamic softening temperature [°C]
LS	792.8 ± 4.7
EM	809.8 ± 2.4
TE	788.4 ± 2.6

TABLE 4 Temperature at which dynamic softening occurred in the samples before crystallization and glaze firing.

for this procedure a thermal expansion measurement device (TMA 8311, Rigaku Corp.) was used with 10 g load, 10 °C/min temperature rise (Table 4).

RESULTS

The results of crowns accuracy are reported in Figure 3. LS showed the best accuracy before and after glaze firing process. TE showed the worst accuracy while EM before crystallization process showed no statistically significant difference with LS, while after crystallization process the data was statistically different. When milling time of the geometric crown using Cerec MX XL (Tukey's test,*; p<0.05,**: p<0.01) was tested, it resulted that TE had the longest milling time (19.5 min). On the contrary, EM had the shortest processing time (12.0 min). LS was processed for 14.6 min and there is a statistically significant difference from EM.

Figure 4 shows the milling time required to process a geometric crown. TE had the longest milling time (19.5 min), whereas EM the shortest (12.0 min); LS was processed for 14.6 min and there is a significant difference from EM.

The dynamic softening temperature of all samples was about 800 °C (Table 4). Only EM is treated at a temperature (850 °C) higher than that at which dynamic softening occurs (809.8 °C).

DISCUSSION

The variety of available esthetic materials has increased in recent years. CAD/CAM can be used not only for porcelain and resin, but for lithium disilicate and zirconia as well. Their use has different clinical indications, such as single partial and full crowns and small bridges.

In the last years, lithium disilicate materials have become more and more popular and often used by practitioners. It has been reported that survival of lithium disilicate crowns is between 85.5% and 100% after 5 and 10 years (14-17). Different lithium disilicate materials are available in the market and are produced in two formulations: pressed and milled. From the mechanical point of view, pressed lithium disilicate materials are stronger than milled ones (9), although it is not clear yet if this affects clinical outcomes. Pressed lithium disilicates are generally superior to CAD/CAM materials, in terms of flexural strength, abrasion resistance, and marginal/material discolorations (4-6). Not only the materials themselves are different, but also the manufacturing methods are (pressed vs CAD/CAM), and the latter can influence both mechanical and optical properties of the materials (7, 18).

It is still debated if indirect CAD/CAM resin composite restorations perform clinically better than CAD/CAM lithium disilicate restorations. However, no long term clinical data are available neither for indirect CAD/CAM resin composite restorations (19-21) nor for lithium disilicates (13). The clinical performances of the material can be predicted by its mechanical properties and it can be expected that LS and EM perform clinically better than TE. Marginal accuracy is a very important clinical parameter because a wide marginal gap can determine postoperative sensitivity, secondary decay, discoloration of margins, unesthetic appearance and mechanical failure. Marginal accuracy can be affected by fabrication process. EM requires heat treatment at high temperature (max 850 °C) for crystallization after fabrication, therefore, it is thought that dimensions are deformed during the process of transformation of lithium metasilicate into lithium disilicate. TE requires longer processing time, which means it is more difficult to mill and this may affect marginal accuracy. Therefore, it is considered that TE could not be milled accurately with respect to the STL file, and lower accuracy values were obtained. It was suggested that with LS accurate crowns can be obtained owing to its good milling properties using CAD/CAM machines and does not require crystallization process.

CONCLUSIONS

From the results of this *in vitro* study it can be concluded that LS has good marginal accuracy and an adequate milling time which are strong indications for its clinical use.

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