Marginal adaptation of CAD/CAM milled lithium disilicate glass ceramic crowns

K. KOJIMA, K. NAGAOKA, Y. MURATA, K. YAMAMOTO, S. AKIYAMA, Y. HOKII, F. FUSEJIMA

R&D Department, GC Corporation, Tokyo, Japan

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ABSTRACT

Aim The purpose of this *in vitro* study was to evaluate the fit of abutment tooth and crown made of lithium disilicate glass-ceramic blocks for CAD/CAM processing submitted or not to glaze firing process.

Materials and methods Sample crowns were fabricated using GC Initial® LiSi Block (GC Corp) (LS), IPS e.max CAD (Ivoclar) (EM) and Cerec Tessera™ (Dentsply Sirona) (TE) by means of a CAM software (inLab CAM SW 20.0.1) and a dental milling machine (Cerec MC XL, Dentsply Sirona) after importing the STL file of the crown. In addition, the duration of the milling process was recorded as well as the temperature at which samples reached maximum linear expansion.

Results LS showed a smaller marginal gap compared to EM and TE; the marginal gap at the crown-abutment tooth interface before and after heat treatment was on average significantly smaller for LS than EM and TE. No change was observed before and after heat treatment in LS, whereas the marginal gap of EM was significantly increased by heat treatment. This may be due to the fact that the temperature was higher than that at which dynamic softening occurs.

Conclusion Since LS showed, in the present study, the best marginal fit before and after heat treatment, it can be considered as a valid lithium disilicate material for clinical use in prosthetic dentistry.

INTRODUCTION

In prosthodontics appropriate fit between the crown and the abutment tooth is an important factor for the longevity of the restoration (1-4). Proper fit of crowns can reduce the risk of post-operative sensitivity, secondary decay, and periodontal problems (5-7).

The amount of marginal discrepancy that can be clinically acceptable is still debated. According to clinical studies, it is generally considered as clinically acceptable a marginal discrepancy of no less than 120 μ that can be detected by a dentist at the chair using the sharp tip of an explorer (7-9).

Recent clinical trials reported on the excellent behavior of lithium disilicate materials in both pressed (10-16) and blocks formulations (17), contributing to increase their popularity among clinicians. Lithium disilicate (LDS) glass-ceramics are materials with high mechanical strength and good aesthetics (18). They were introduced many years ago and since then technological advances have improved their mechanical and esthetic properties (19-20). Lithium disilicates can be fabricated by a pressing procedure and/or in blocks for CAD/CAM (21-23). Usually, the last step of the process to make a lithium disilicate piece is crystallization. A new lithium disilicate glass-ceramic material was developed for CAD/CAM (GC Initial® LiSi Block, GC Corp), which does not require crystallization after milling. In fact, for this material, glazing is optional, and gloss can be easily obtained by polishing. Based on these important characteristics, GC Initial® LiSi Block (GC Corp) preparation requires shorter chair time compared with other commercially available glass ceramics.

The aim of the present study was to evaluate the marginal precision of three lithium disilicate blocks under *in vitro* conditions. The null hypothesis tested was that there were no differences in marginal precision among the three lithium disilicate blocks.

MATERIALS AND METHODS

Measuring the marginal gap

The abutment tooth model of a mandibular left first molar was scanned using D2000 (3Shape) lab scanner, and a crown was designed by CAD Software (3Shape Dental Designer). Three different lithium disilicate blocks were used: GC Initial® LiSi Block (GC Corp)

Code	Materials	Shade	Lot No.	Manufacturer	Main crystal		Firing
					Before heat treatment	After heat treatment	
LS	Initial LiSi Block	A2HT	200903A	GC Corporation	Lithium disilicate	Lithium disilicate	Not required
EM	IPS e.max CAD	HTA2	Z00FTN	Ivoclar Vivadent	Lithium metasilicate	Lithium disilicate	Required
TE	CEREC Tessera	HTA3	16008859	Dentsply-Sirona	Lithium disilicate	Lithium disilicate	Required

TABLE 1 Types of lithium disilicates used and their processing steps.

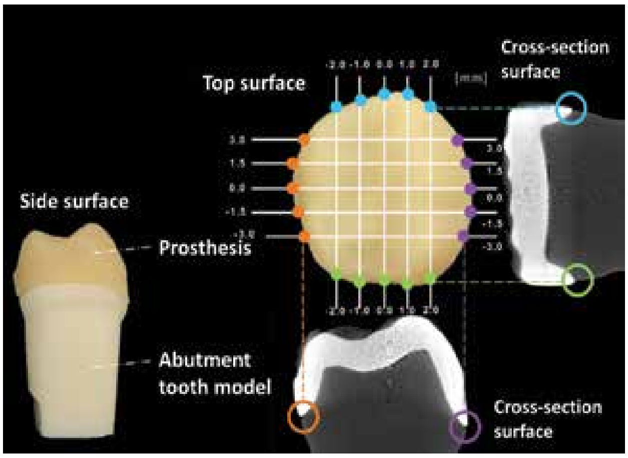

FIG. 1 Position of measured points along the margin.

(LS), IPS e.max CAD (Ivoclar) (EM) and Cerec Tessera™ (Dentsply Sirona) (TE) (Table 1). Then, a crown of each material was fabricated using a CAM software (inLab CAM SW 20.0.1) and a dental milling machine (Cerec MC XL, Dentsply Sirona) after importing the STL file of the crown. In addition, the milling time of each crown was measured. Heat treatment was carried out for EM and TE by using a press furnace (Programat EP5000, Ivoclar Vivadent) according to the manufacturer's instructions. Heat treatment for glaze firing was carried out for LS by using a porcelain furnace (Austromat 624, Dekema) (Table 2). The crown was set on the abutment tooth model after vaseline was applied to the inner surface. Then, the marginal gap between the crown and the abutment tooth model was analyzed using a microfocus X-ray CT system (inspeXio SMX-100CT, Shimadzu). Marginal gaps were measured at 20 points for each sample (Fig. 1) (n=60) with Image J (NIH).

Data were analyzed by means of Tukey-test and T-test ($p<0.01$).

Evaluation of dynamic softening

The prismatic specimen (18.0 mm x 1.5 mm x 1.5 mm) was cut using a table-top precision saw (Isomet 2000, Buehler). The prismatic specimen was polished with waterproof abrasive paper and the bases were precisely adjusted to be parallel. The linear expansion amount of the prismatic specimen under a load of 10 g and heating rate of 10°C/min was measured using a thermal expansion measuring device (TMA8311, Rigaku Co., Ltd.), and the temperature at which maximum linear expansion occurred was set as the temperature of dynamic softening (n=3).

RESULTS

Figure 2 shows the X-ray image of the heat-treated crown attached to the abutment tooth. The images show a smaller margin gap in LS compared to other groups. Figure 3 shows the amount of marginal gap at the crown and abutment tooth interface before and after heat treatment for each material. The average gap distance of LS was significantly smaller than that of EM and TE, and no change was observed before and after heat treatment in LS specimens. On the other hand, the marginal gap of EM was significantly increased by heat treatment. Table 3 shows the temperatures of dynamic softening measured for each sample. Although dynamic softening of EM occurred at 810 °C, the recommended heat treatment temperature was 850 °C. Therefore, it is considered that the material was deformed by heat treatment because the temperature was higher than that of dynamic softening.

	Stand by 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
Initial LiSi Block	480	4:00	45	-	750	-	1:00	-	-	-	-
IPS e.max CAD	550	6:00	60	30	770	850	0:10	10:00	550	770	700
CEREC Tessera	400	3:30	60	-	760	-	1:30	-	-	-	-

TABLE 2 Heat treatment conditions for each block.

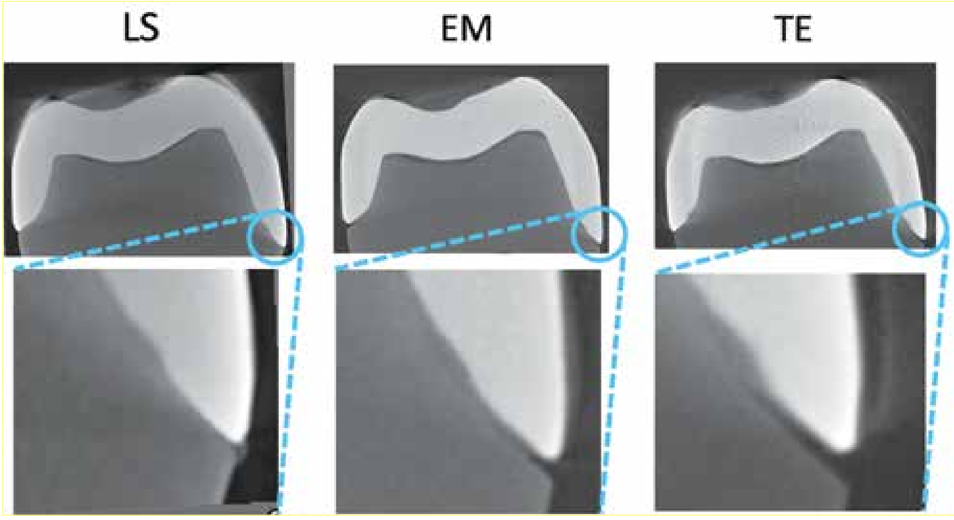

FIG. 2 X-ray CT images of the margins after heat treatment and magnified detail.

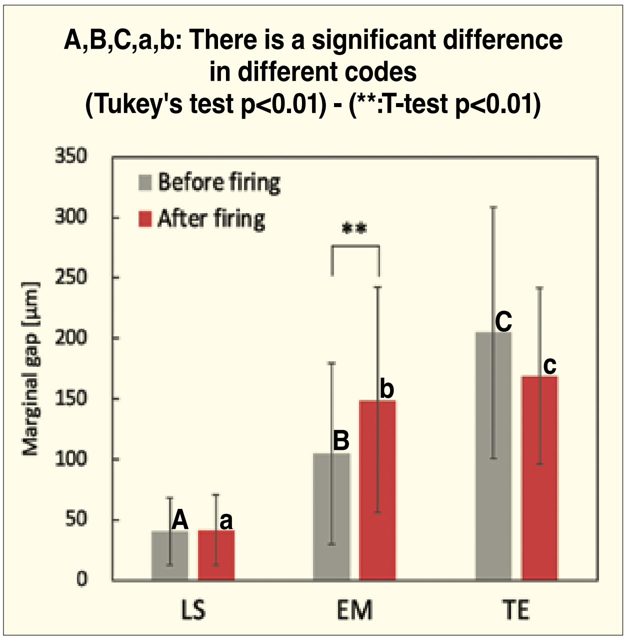

FIG. 3 Amount of marginal gap between prosthesis and abutment tooth before and after firing.

	LS	EM	TE
Dynamic softening temperature (°C)	793±5	810±2	788±3
Heat treatment temperature (°C)	750	850	760

TABLE 3 Temperature of dynamic softening.

	LS	EM	TE
Milling time	15 min 17 sec	14 min 4 sec	18 min 31 sec

TABLE 4 Milling time with the machine used (CEREC MC XL).

Furthermore, TE showed the largest marginal gap (Fig. 2) and longest milling time using Cerec MC XL (Table 4). Thus, we consider that the accuracy of TE was affected by its milling difficulty. On the other hand, the small crystal size of LS resulted in easier milling procedure which led to higher accuracy.
Figure 2 shows the X-ray image of the heat-treated crown attached to the abutment tooth. When the margin of each sample was analyzed, LS showed the smallest marginal gap compared to the other two groups.

DISCUSSION

In the present study three different CAD-CAM lithium disilicate blocks were tested to compare their mechanical properties and marginal precision.
All the three materials showed good milling properties; however, in LS the marginal gap was significantly lower than in the other two ceramics. Therefore, the null hypothesis that there were no differences among the three lithium disilicate blocks on marginal precision was rejected.
The clinical reports available in the literature on these three materials showed that their behavior under normal function is acceptable at least in the short-medium term. The clinical reports also covered both partial and full crowns. However, the possibility to have a small marginal gap, below 50 µ, is highly desirable in order to prevent possible endodontic and periodontal complications (Martignoni, Sorensen). Only LS showed a marginal gap below 50 microns, both before and after glaze firing and therefore it can be suggested that it is expected to have long-term durability under clinical conditions. For these reasons, LS can have strong indications for clinical use.
Also, it was reported that EM performed very well after 10 years of clinical service and that suggests that also the other products, which have similar mechanical properties, can have similar behavior.
LS was launched into the market some years ago and

has been extensively tested, in both pressed and CAD-CAM blocks (10, 17), with excellent clinical results both in the short and medium term; the same results were obtained also using EM (12,15n). However, there is also a strong need for RCTs with a observation time longer than 3 years and testing both full and partial crowns made with different prosthodontic materials in patients with different types of occlusion. mechanical properties of lithium disilicate are well known, in particular its resistance to functional occlusal forces (21-22), but there is little information about its clinical behavior when used in patients with parafunctions.
Ultimately, the results of this study clearly show that LS is an operator friendly material and can achieve high marginal precision.

CONCLUSION

Based on the results of this study the following conclusions can be drawn.
1. LS showed the best marginal fit before and after heat treatment.
2. LS can be considered a valid lithium disilicate material for clinical use.

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