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Marginal chipping factor in machinable zirconia and lithium disilicate ceramic veneer restorations

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Abstract

Background: The marginal edges of the laminate veneer ceramic restorations are very critical areas that play a very determinant role in the success of this type of esthetic restorations.

Aim: To evaluate the marginal chipping factor of laminate veneer restorations prepared from both zirconia lithium disilicate materials.

Materials and methods: Two typodont teeth representing the upper central incisors were used to prepare laminate veneers with an overlapping incisal design. These veneers were fabricated in two thicknesses (0.5 mm and 0.3 mm) using three types of multilayer zirconia materials with varying yttria percentages (3Y, 5Y, and 3Y/5Y) as well as lithium disilicate computer-aided-design (CAD) blocks. The veneers were divided into four groups based on the yttria percentage and further subdivided into two subgroups for the thickness. Top-view images of the veneer margins were captured and imported into the Image Pro Plus software. The average periphery of each veneer margin was 30 mm. The lengths of the chipped margins were measured under a stereomicroscope, and the CF was calculated.

Results: One-way ANOVA suggested significant differences among the ceramics. e.max CAD ceramic veneers exhibited the highest mean CF values (4.72, 5.9), whereas 3Y/5Y zirconia veneers demonstrated the lowest mean CF values (0.74, 1.54) for 0.5 mm and 0.3 mm thicknesses, respectively. Independent t-tests indicated no significant difference in the CF between 0.5 mm and 0.3 mm thicknesses for each ceramic material.

Conclusion: Different ceramic materials exhibited varying levels of marginal chipping, with zirconia ceramics demonstrating lower CF than lithium disilicate ceramics. Reducing the veneer thickness from 0.5 mm to 0.3 mm did not significantly affect the CF.

Keywords: Ceramics, Chipping factor, e.max CAD, Veneer, Zirconia.

1. Introduction

The use of computer-aided-design (CAD)/computer-aided-manufacture (CAM) technologies for producing dental prostheses has led to the development of new processing techniques for numerous materials that cannot be accessed by restorative dentists using traditional processing methods [1]. The use of minimally invasive preparation designs using CAD/CAM technology is an effective treatment option as it facilitates the delivery of accurate and aesthetically pleasing restorations to patients rapidly, especially using thin labial and occlusal ceramic veneers [1-4].

Lithium disilicate is a popular ceramic material used to prepare veneers. It undergoes incomplete crystallization and comprises crystal nuclei of both lithium disilicate ($Li_2Si_2O_5$) and lithium metasilicate (Li_2SiO_3). It adheres to the resin cement, accomplished by silanization after hydrofluoric acid treatment, and exhibits high optical qualities. However, compared with other ceramics, it exhibits inferior mechanical properties [5,6]. Ivoclar Vivadent created IPS e.max CAD, particularly for use in CAD/CAM technologies. The pre-crystallized form of the CAD/CAM block has a flexural strength of 130 MPa to150 MPa, enabling intraoral occlusal correction and easier machining. The final crystallization occurs at 850°C in vacuum after milling. Lithium disilicate glass ceramic that has undergone CAD/CAM processing has a flexural strength of 360 MPa. It is used in inlays, onlays, veneers, implant crowns, and anterior or posterior crowns [7].

Zirconia is a crystalline dioxide composed of zirconium arranged in three different patterns: cubic (C), tetragonal (T), and monoclinic (M). At room temperature, pure zirconia is monoclinic and stable up to 1170°C. It changes to a tetragonal phase above this temperature, which persists until the melting point at 2370°C, after which it transforms to a cubic phase. The tetragonal phase returns to the monoclinic state on cooling between 100°C to 1070°C [8,9]. The addition of yttria is added to stabilize the transformation of the crystalline structure under the conditions of increased temperature and improve the physical properties of zirconia. The amount of yttria affects the mechanical and optical characteristics of zirconia [10]. Owing to the transformation toughening from the tetragonal particles, the 3% yttria partially stabilised zirconia (3Y-PSZ) exhibits good mechanical characteristics. Upon increasing the yttria concentration in 5Y-PSZ to 5%, cubic grains replace the tetragonal grains, which results in ultra translucency and decreased strength. The combination of high-flexural strength 3Y-PSZ and high-translucency 5Y-PSZ in one blank improves the strength and aesthetics [11-13].

Chipping is characterized by a significant loss in the volume of material (chip). In the context of dental prosthesis machining, a parameter called chipping factor (CF) has been established to describe the rate of chipping at the cervical edge. [14,15].

The marginal edges of the laminate veneer ceramic restorations are important for the success of this type of esthetic restoration [4]. Edge quality is measured by its smoothness and lack of discrepancies and irregularities in the form of chipping fractures; it significantly influences the clinical lifetimes, in addition to the accuracy of the fitness of these margins, either vertically or horizontally. In addition, small chipping fractures of the restoration margins are responsible for late clinical failures of ceramic restorations [2,16].

The term "chipping factor" (CF) was first used by Tsitrou in 2007. It is an estimation of the degree of marginal chipping and is calculated by estimating the ratio of overall marginal chipping to the total marginal circumference of the restoration multiplied by 100 to obtain the percentage of chipping [1,4,17,18].

Minimally invasive veneer preparations have become increasingly popular. They include thinner porcelain and reduced tooth reduction. The thickness of minimally invasive veneers is 0.3 mm, compared with the typical range of 0.3 mm to 1.0 mm for traditional porcelain veneers. The outcomes of minimally invasive veneers with a thickness of 0.3 mm have not been extensively studied [19].

The durability of restoration during its clinical service is known to be influenced by margin quality, and improving margin integrity can lower the risk of biological and technical complications. Further, defects in the margin are also related to the thickness of the restoration, the material composition, and the manufacturing process used [20,21]. The present study focused on comparing the material type and restoration thickness.

Therefore, this study aimed to evaluate the marginal chipping of laminate veneer restorations prepared with zirconia and lithium disilicate laminate veneer ceramic materials with different thicknesses by calculating the chipping factor. The null hypothesis was that the chipping factor does not differ among the tested materials or between the two different ceramic veneer thicknesses.

2. Materials and methods

Forty laminate veneer restorations were fabricated using four different ceramic materials, with 10 in each. Table 1 presents the types of ceramic materials and grouping of samples according to their yttria content (ceramic type) and veneer thickness.

Table 1. study samples divided into groups according to their yttria content (ceramic type) and veneer thickness

Ceramic material type	N	Number of samples\Veneer thickness	Manufacturer
3Y zirconia (copra supreme symphon)	10	5 samples of 0.5mm	Whitepeaks Langeheide Essen-Germany
		5 samples of 0.3mm	
5Y zirconia (DDcubex2 ML)	10	5 samples of 0.5mm	Dental direct, Spenge Germany
		5 samples of 0.3mm	
Combined 3Y and 5Y zirconia (IPS e.max ZirCAD prime)	10	5 samples of 0.5mm	Ivoclar Vivadent, Germany
		5 samples of 0.3mm	
Lithium disilicate (IPS e.max CAD)	10	5 samples of 0.5mm	Ivoclar Vivadent, Germany
		5 samples of 0.3mm	

Laminate veneer restorations with a thickness of 0.5 mm and 0.3 mm were prepared on typodont teeth using 0.5mm and 0.3 mm self-limiting depth-cutting burs. A silicone index with a heavy-body rubber-based silicone impression material (Zhermack S.P.A., Badia Polesine, Italy) was made to ensure consistency. A palatal overlap of 1.0 mm was present beneath the 1.5 mm reduction in the incisal area, based on the diameter of the diamond bur and confirmed using a veneer preparation kit (DiaTessin, Switzerland). A chamfer-finishing line was made 1 mm above the cement enamel junction. The amount of incisal reduction was calculated as 1.5 mm using a veneer preparation kit (DiaTessin, Switzerland) based on the diameter of the diamond bur [22,23].

The prepared typodont teeth were scanned digitally to construct 40 laminate veneers. They were divided into eight groups with five in each (n=5) according to the material type and veneer thickness (Table 1).

A digital camera (China/Nikon/COOLPIX P520) and Adobe Photoshop v.5 acquisition software (Adobe Inc. system V5.0. Ltd. Europe) were used to obtain a top-view photograph of the margins of each veneer to estimate the peripheral circumference (Figure 1). The photos were loaded into the Image Pro Plus software (version 4.01, Media Cybernetics, USA). Each image was calibrated with a steel rule (Figure 2), and the average perimeter of all the veneer margins was calculated to be 30 mm ± 0.02 mm. Each veneer edge was divided into eight sections to ensure a straight line between any two spots on the perimeter when viewed axially. Images of each section of the veneer perimeter were captured. The length of the chipped margins of each veneer was measured using a stereomicroscope at a magnification of 25X, and the total amount of each sample was calculated in microns (Figures 3 and 4) [1,4,15]. The chipping factor (CF) was calculated using the following equation, CF=[L/P] x 100.
Where, L is the amount of marginal chipping in mm, and P is the marginal circumference of each veneer in mm.

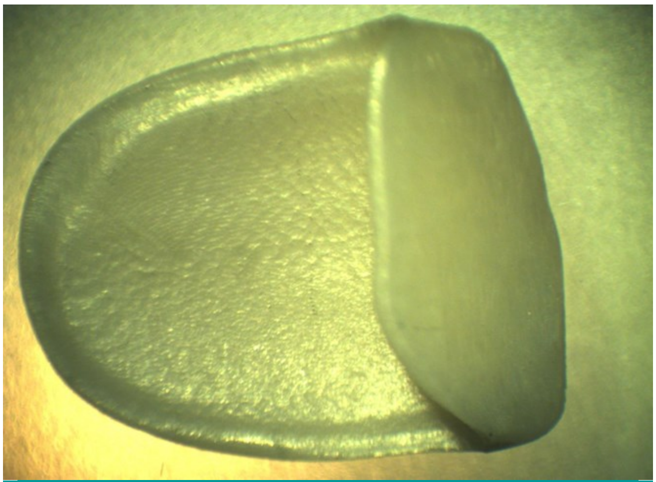

Figure 1. Top view image for the periphery of one tested ceramic veneer

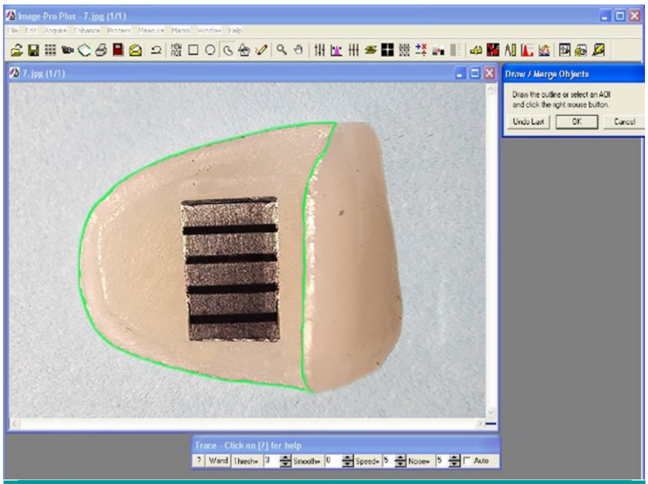

Figure 2. The measurement of the average periphery of all the veneer margins was calculated and found to be (30±0.02 mm). A steel ruler was used to calibrate the image (green line).

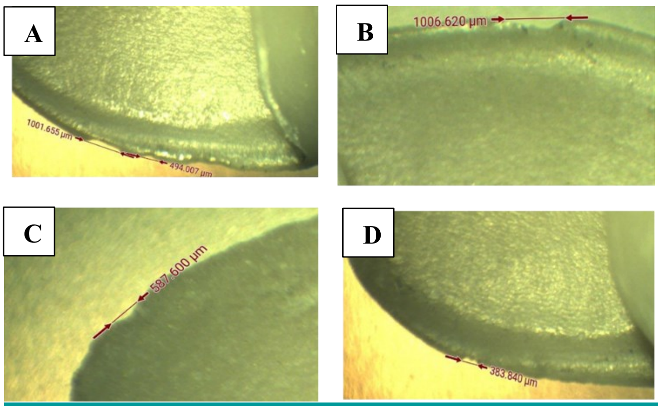

Figure 3. Microscopic images (25X) showing the peripheral marginal chippings of the four different ceramic veneers A: e.max CAD /0.3mm thickness. B: 5 Y zirconia /0.3mm thickness. C: 3 Y zirconia /0.3mm thickness. D:3Y/ 5 Y zirconia /0.3mm thickness.

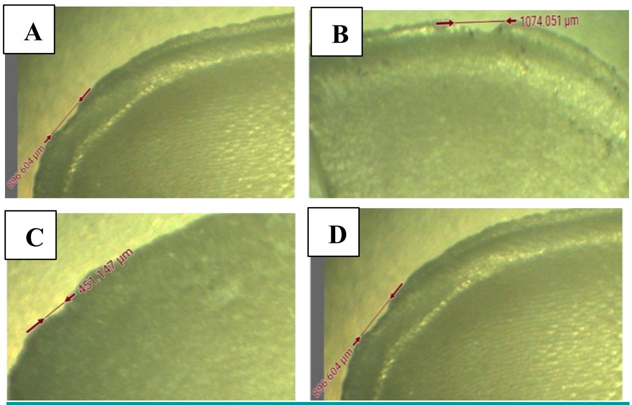

Figure 4. Microscopic images (25X) showing the peripheral marginal chippings of the four different ceramic veneers A: e.max CAD /0.5mm thickness. B: 5 Y zirconia /0.5mm thickness. C: 3 Y zirconia /0.5mm thickness. D:3Y/ 5 Y zirconia /0.5mm thickness.

3. Results

The mean and standard deviation of CF are presented in Table 2.

Table 2. Means and standard deviation for chipping factor of different groups of ceramic materials

Groups	N	Mean	SD*
0.3 mm dental direct zirconia (5Y zirconia of 0.3 mm veneer)	5	3.82	2.11
0.5 mm dental direct zirconia (5Y zirconia of 0.5 mm veneer)	5	2.18	1.43
0.3 mm white peaks zirconia (3Y zirconia of 0.3 mm veneer)	5	2.76	3.45
0.5 mm white peaks zirconia (3Y zirconia of 0.5 mm veneer)	5	2.38	1.53
0.3 mm zircad prime zirconia (3Y/5Y zirconia of 0.3 mm veneer)	5	1.54	0.64
0.5 mm zircad prime zirconia (3Y/5Y zirconia of 0.5 mm veneer)	5	0.74	0.14
0.3 mm e.max lithium disilicate ceramic (e.max CAD 0.3 mm)	5	5.90	3.47
0.5 mm emax lithium disilicate ceramic (e.max CAD 0.5 mm)	5	4.72	1.06

*Standard deviation.

3.1 Effect of ceramic material type

We performed the one-way analysis of variance (ANOVA) to analyze the impact of 0.5- and 0.3-mm thickness veneer restorations on the CF and observed a significant difference among different ceramic materials (Table 3 and Table 4).

Table 3. One way analysis of variance (ANOVA) for the chipping factor of 0.5-mm-thick ceramic veneer materials

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	40.714	3	13.571	7.932	0.002
Within Groups	27.376	16	1.711		

Table 4. One way analysis of variance (ANOVA) for the chipping factor of 0.3-mm-thich ceramic veneer materials

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	51.258	3	17.086	2.065	0.005
Within Groups	132.372	16	8.273		

To determine the level of significance among the ceramic materials, a post hoc Duncan multiple range test was conducted that demonstrated significantly different CF, where the IPS e.max group reported the highest CF of 4.72 and the 3Y/5Y zirconia group reported the lowest CF of 0.74 and also significant difference between the combined 3Y/5Ywith the 3Y zirconia and 5Y zirconia materials but no significant difference between the 3Y and 5Y zirconia ceramics (Figure 5) for 0.5 mm thickness veneer restorations where the CF was:(2.18, 2.38, 0.74) for 3Y, 5Y and combined 3Y/5Y, respectively.

Also, the post hoc Duncan multiple range test has demonstrated significantly different CF between the tested ceramics, where the IPS e.max group reported the highest CF of 5.9 and the 3Y/5Y zirconia group reported the lowest CF of 1.54. Moreover, we observed a significant difference between the combined 3Y/5Ywith the 3Y zirconia and 5Y zirconia materials but no significant difference between the 3Y and 5Y zirconia ceramics (Figure 6) for 0.3 mm thickness veneer restorations where the CF was:(3.82, 2.76, 1.54) for 3Y, 5Y and combined 3Y/5Y, respectively.

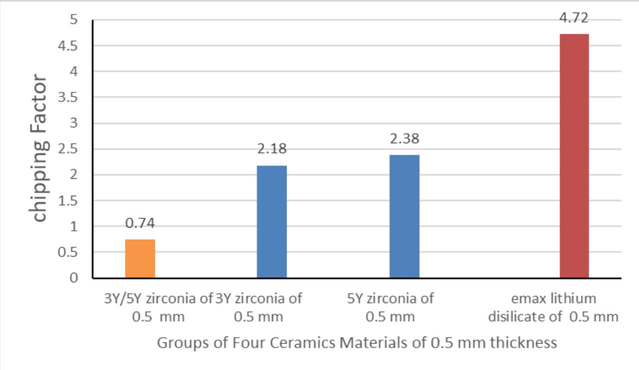

Figure 5. Column graph for Duncan multiple range test for the four different ceramic veneers of 0.5 mm thickness where Same colours mean no significant difference and different colours mean significant difference.

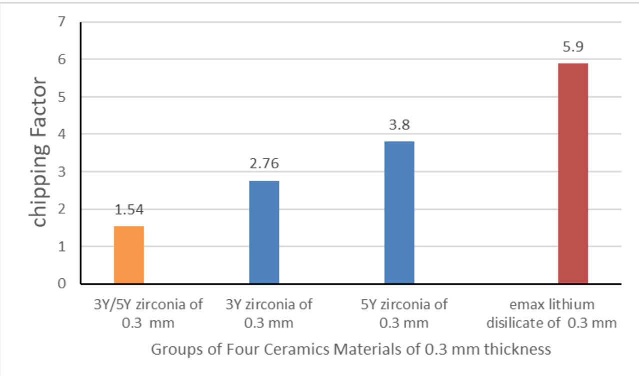

Figure 6. Column graph for Duncan multiple range test for the four different ceramic veneers of 0.3 mm thickness where the Same colours mean no significant difference and the different colours mean significant difference

3.2 Effect of thickness on chipping factor of each ceramic material

The four independent t-tests demonstrated no significant difference between 0.5-mm-thickness and 0.3-mm-thickness ceramic materials for each type (Table 5).

4. Discussion

In this study, CF was used to measure the marginal chipping of the materials. The null hypothesis had to be partially rejected regarding the effect of ceramic type on veneer marginal chipping regardless of the veneer thickness. This is because we observed statistically significant differences in the mean CF between glass ceramics lithium disilicate and zirconia ceramics and between the combined 3Y/5Y with the 3Y zirconia and 5Y zirconia materials. However, no significant difference was observed between the 3Y and 5Y zirconia ceramics. The e.max CAD ceramic veneers exhibited the highest mean CF of 4.72 and 5.9 for 0.5 mm and 0.3 mm thicknesses, respectively. The 3Y/5Y zirconia veneers exhibited the lowest mean CF of 0.74 and 1.54 for 0.5 mm and 0.3 mm thicknesses, respectively. The decreased CF may be explained by its method of manufacturing using cold isostatic pressing resulting in more dense zirconia that is less prone to chipping during the machining process. This finding may be in agreement with others that glass ceramic is more prone to marginal chipping than zirconia and other materials [24]. The susceptibility for marginal chippings increases with the brittleness index (BI) of a material. This finding was confirmed with studies that have found the highest BI values as well as Vickers hardness may contribute to the highest CF mean values [1,4,18,24,25].

Table 5. Four independent sample t-tests for the chipping factor between 0.3 mm and 0.5 mm thicknesses for each ceramic veneer material

	Mean Difference	Std. Error Difference	Sig. (2-tailed)
Chipping factor of 0.3 mm and 0.5 mm dental direct zirconia (5Y zirconia)	1.64	1.14	0.189
Chipping factor of 0.3 mm and 0.5 mm white peaks zirconia (3Y zirconia)	0.38	1.69	0.828
Chipping factor of 0.3 mm and 0.5 mm zircadprime zirconia (3Y/5Y zirconia)	0.80	1.08	0.483
Chipping factor of 0.3 mm and 0.5 mm emax lithium disilicate ceramic (e.max CAD)	1.18	1.62	0.489

For different zirconia ceramics, we observed significant differences in the CF for either thickness between the combined 3Y/5Ywith the 3Y zirconia and 5Y zirconia materials, but no significant difference between the 3Y and 5Y zirconia ceramics as shown in (Figures 5 and 6). This result was consistent with prior studies that showed ultra-translucent zirconia's (5mol% yttria) are more prone to transportation or machining damage than 3Y-TZP (3mol%) [20,26-28]. This could be caused by variations in the crystal structures of the tested materials, as well as variations in composition, grain size, manufacturing processes, and the tested zirconia materials' varying fracture toughness, hardness, and BI. [1,18,25,28].

We accepted the second part of the null hypothesis that there was no statistically significant difference between the two thicknesses of the ceramic materials. This is because we observed no significant difference between 0.5 mm and 0.3 mm thicknesses for the marginal CF (Table 5). This finding disagrees with a previous result that the CF decreases with increased thickness of the ceramic [19]. Another study has shown that large-margin defects are more likely to occur when manufacturing specimens with thin structures [29].

6. Conclusion

In conclusion, different ceramic materials have different marginal CF, which in turn affects the longevity of the restorations. Zirconia ceramics exhibit lower CF than lithium disilicate ceramic with the combined zirconia having the least chipping factor. Reducing the veneer thickness to 0.3 mm does not significantly affect the CF of the four tested ceramic materials.

Conflicts of interest: Authors declared no conflicts of interest.

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