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The Influence of Different Ceramics and Resin Cements on the Color Stability, Marginal Discrepancy and Fracture Resistance of Ceramic Laminate Veneers

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ABSTRACT

Purpose: This study evaluated the influence of different ceramics and resin cements on marginal discrepancy, color stability and fracture resistance of ceramic veneers. **Material and methods:** Sixty sound human maxillary first premolars were prepared for ceramic veneers. Prepared teeth were randomly divided into 3 equal groups according to materials used for construction of laminate veneers. Twenty ceramic veneers were fabricated from Vita Suprinity blocks, other twenty from Vita Enamic blocks and the last from IPS Emprees CAD blocks. Each main group were randomly subdivided equally into two sub groups according to adhesive system used. All samples were subjected to thermo cycling. Marginal discrepancy was measured by stereomicroscope before, after cementation and after thermo cycling and color was measured by digital spectrophotometer before, after cementation then all samples were subjected to fracture. **Results:** Marginal discrepancy in both Vita Suprinity, Empress CAD and Vita Enamic ceramic veneers were less than 100 μ within acceptable value. The highest color changes recorded with V. Enamic followed by Emp CAD while the lowest color changes recorded with V. Suprinity and this was statistically significant. The highest fracture resistance recorded with V. Suprinity followed by Emp CAD while the lowest fracture resistance recorded with V. Enamic and this was statistically significant. **Conclusions:** Ceramic veneers fabricated by Vita Suprinity, Empress CAD and Vita Enamic provided clinically acceptable marginal fit. Vita Suprinity veneers provide more color stability and highest fracture resistance than Empress CAD and Vita Enamic.

KEYWORDS

Thermocycling, Color change, Ceramic laminate veneers.

INTRODUCTION

Laminate veneers are indirect restorations which restore adequate shape, function and harmonize the smile, color of aesthetically

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compromised teeth [1]. The material of choice for laminate veneers is dental ceramic, because of the esthetic advantages of it including improved fluorescence, increased translucency [2] and high capacity to mimic tooth structure. In addition, dental ceramics are inert, biocompatible and resistant to corrosion and have low electrical and temperature conductivity [3, 4].

Feldspathic ceramics are the first introduced of dental ceramics and due to its excellent optical properties, it is widely used until today, but due to its lower flexural strength and brittleness, new ceramic materials had been developed, as IPS Empress 1(glassy matrix containing around 35% leucite crystals) & IPS Empress 2 and E.max (glassy matrix containing around 60% lithium disilicate crystals). Lithium disilicate restorations have long term clinical success due to its color stability, strength and corrosion resistance [5, 6].

A newly introduced material is Vita Enamic. It is a hybrid ceramic which contains 86% of ceramics and 14% of polymer [7]. In the first stage, the pre-sintered porous structured feldspathic ceramics are produced. In the second stage, porous ceramic structure is filled with resin. This hybrid material ensures unique balance between strength and elasticity and provide high absorption of masticatory forces which make it one of potential factor for ultra-thin veneers [8].

Also, another material has been lately developed as anew ceramic material for dental restorations is Vita Suprinity and Celtra Due which consist of a dual microstructure: Glassy matrix containing 10% zirconium oxide and very fine lithium disilicate and metasilicate crystals. It has the strength properties of zirconia and the esthetic properties of lithium disilicate so that it considered as a new group of CAD/CAM ceramics [9].

Color stability and cementation technique are two important factors for the longevity of the ceramic veneers. [10] Resin cements are indicated for bonding of ceramic veneers [11]. Various resin cement types are available [2,11], auto cured, light cured, or dual-polymerizing resin cement and light-cured cement was preferred by many professionals, due to it provided longer clinical working time [10].

Marginal accuracy is one of the most important factors for successful restorations, so the marginal discrepancy between margin of restoration and finish line of prepared teeth should be as small as possible to avoid cement dissolution [12], microleakage [13], secondary caries [14-17], and postoperative hypersensitivity of the teeth [14, 15,18]. It was measured by different techniques as dental probing [19], silicone replica technique [20,21], or direct measurement with a light microscope and stereomicroscope [22 -24].

Color stability of a restoration is important for laminate veneers because of Color changes by time reduce the longevity and quality of restorations. Discoloration of CAD/CAM processed composite resins, and ceramic materials may occur under prolonged exposure to staining solutions [25].

Assessment of color changes using spectrophotometers and colorimeters have become popular. They offer standardization, numerical expression of color and accuracy. The data is reported in the CIE L*a*b*system where L*measures the brightness of the color, a* measures the red-green content, and b* measures the yellow-blue content. Then L* a* b* used for calculation of ΔE (color changes). Several studies considered color differences greater than 3.5 unit clinically not acceptable [26- 29].

Fracture resistance is important factor for a successful restoration. [30-32]. However, over 15 years period of clinical performance, 67% of the total failures of laminate veneers are fracture. Furthermore, according to literature, debonding or fracture are the most commonly reported failure modes of laminate veneers. [33-35].

The aim of this study was to evaluate the effect of different ceramics and resin cements on the color stability, marginal discrepancy and fracture resistance of ceramic laminate veneers.

MATERIAL AND METHODS

Sixty maxillary first premolars recently extracted for orthodontic reason were used in this study, Teeth were free from abrasion, caries and not endodontically treated. Teeth were selected with similar shape and size then stored in normal saline until the preparation for the study. All teeth samples were mounted in epoxy resin blocks. Occlusal reduction was controlled by guidance grooves and rubber index to give about 1.5mm clearance and preparation extended 2 mm toward palatal cusp. Buccal reduction was controlled by three wheel diamond stones (Bressler, savannah, GA LVS, USA) with radius of 0.5 mm to make guidance grooves and tapered diamond stones with round tip (8459KR, Jota, Ruthi, Switzerland) (12 degree taper angle and 0.5 tip diameter) attached to high speed contra angle to remove tooth structure between guidance grooves and preparation made with the same operator and rubber index used to evaluate the amount of reduction of the buccal surface was 0.7 mm. The proximal area was prepared by round ended tapered stone along the long axis of the tooth. Single operator prepared all the teeth used in the study.

Sample grouping

The sixty samples were randomly divided into 3 equal groups (n=20) of twenty each according to the materials used for construction of the laminate veneers: Group I: 20 veneers constructed from Vita Suprinity (VITA Zahnfabrik, Germany),Group II: 20 veneers constructed form Vita Enamic (VITA Zahnfabrik, Germany) and Group III: 20 veneers constructed from IPS empress CAD (Ivoclar Vivadent AG,Schaan/Liechtenstein). Each group was randomly subdivided into 2 equal subgroups (n=10) of ten each according to the adhesive system used for luting the veneers: Subgroup A: 10 veneers cemented with Etch and wash technique (rely x veneer); Subgroup B: 10 veneers cemented with self-adhesive technique (rely x unicement).

Fabrication of ceramic laminate Veneers

All ceramic laminate veneers (n=60) were fabricated using the Imes- Icore CAD/CAM system. For scanning the prepared tooth, at first the prepared tooth was coated by Shera scan spray, then it was scanned via blue LED 3D dental scanner (Degree of Freedom Scanner, Korean). The prepared tooth was scanned and the virtual image of the prepared tooth appeared on the monitor, the laminate veneers was designed by Exocad system (Exocad GmbH, Germany), When all the adjustments were made laminate veneers saved in a file, then to be milled in the CAD/CAM milling machine after choosing the type of the block. Twenty ceramic laminate veneers were constructed using Vita Suprinity blocks, shade A1 (Group I). After milling, according to manufacturer instructions, the veneers were crystallized in vita programmatic furnace. Twenty ceramic laminate veneers were constructed using Vita Enamic blocks, shade A1 (Group II), after milling, finishing and polishing were done according to manufacturer instructions without any sintering or crystallization. IPS Empress CAD blocks, shade A1 were used to mill twenty laminate veneers (Group III), after milling, the veneers were crystallized in an Ivoclar Vivadent ceramic furnace (Programat P500) according to manufacturer instructions.

Cementation of ceramic laminate veneers

The fitting surface of all ceramic laminate veneers of groups I was etched with 9% hydrofluoric acid etch (Dentobond,ITENA, France) for 20 seconds, group II,III was etched with 9% hydrofluoric acid etch for 60 seconds, rinsed off then cleaned in ultrasonic bath for three minutes and dried with air. Silane coupling agent (Dentobond, ITENA, and France) was applied to the fitting surface of the veneer and allowed to dry for 60 seconds then dispersed to obtain a thin coat. Subgroup A of each ceramic group was cemented with total etch resin cement (Rely X veneer, 3M ESPE, St. Paul, United states). Subgroup B of each ceramic group was cemented with self-adhesive resin cement (Rely X unicement, 3M ESPE, Deutschland GmbH carl-schurz-str.1 41453Neuss-German). ceramic laminate veneers seated on the prepared tooth using applicator then use ready-made loading device with fixed pressure of 250 g for one minute before any light curing is carried out according to manufacturing instructions, the excess cement was trimmed away after light curing for 2 seconds, then light curing for 20 seconds for each surface. All samples were subjected to 5000 thermal cycle equivalents to 5 years of oral service. The high temperature point was 55 ºC and the low-temperature point was 5°C.

Marginal discrepancy measurement

Marginal discrepancy was evaluated before, after cementation and after thermocycling by measuring gap between finish line of prepared teeth and laminate veneer margin by stereomicroscope device and integrated digital camera using a fixed magnification of 45X and analysis software. During gap evaluation, a specially designed device used for specimen holding. The measurements were determined at three points at the middle of each surface, at each point, readings were recorded to give total of twelve readings for each sample. The mean marginal discrepancy value for each veneer was calculated from the mean values of circumferential measuring locations. Statistical analysis should be done after the final data obtained, collected and tabulated.

Color measurement

Color of samples was measured before, after cementation using digital spectrophotometer (Model RM200QC, X-Rite, Neu- Isenburg, Germany). The change in color (ΔE) values was evaluated through calculation of the difference in color measurements of all samples pre and post cementation by using the formula:

$$\Delta E = [(L^*1 - L^*2)2 + (a^*1 - a^*2)2 + (b^*1 - b^*2)2]^{1/2}$$

Fracture resistance evaluation

All samples were individually mounted on a computer-controlled material testing machine with a load of 5 KN was applied on occlusal surface of restoration and data were recorded using computer software (Figure 1). Statistical analysis should be done after the final data obtained, collected and tabulated.

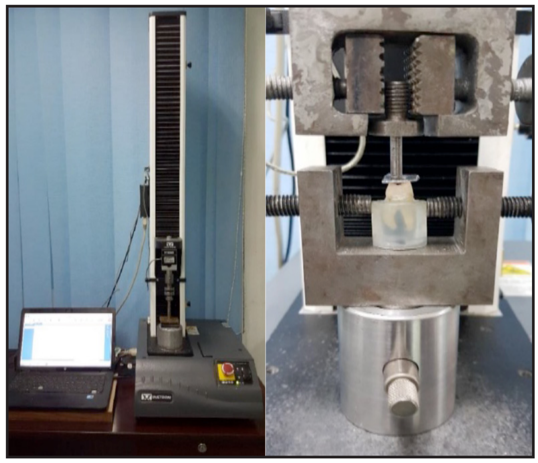

Figure (1): Universal testing machine (Instron device)

RESULTS

The results were analyzed using Graph Pad Instat software for windows. A value of $P < 0.05$ was statistically significant. Continuous variables were expressed as the mean and standard deviation. After homogeneity of variance and normal distribution of errors had been confirmed, three-way analysis of variance was performed for each factor. One-way ANOVA was used to compare stages. Student t-test was done for compared pairs. Sample size (n=10) was large enough to detect large effect sizes for main effects and pair-wise comparisons, with the satisfactory level of power set at 80% and a 95% confidence level.

Marginal discrepancy measurement

The mean values and standard deviation for all groups with both cementation approaches before and after cementation and after thermal aging are summarized in table (1).

Table (1): *Marginal discrepancy reading (Mean values± SDs).*

Variables		Total			Self		
		Before cem	After cem	After thermocycle	Before cem	After cem	After thermocycle
V Suprinity	Mean	48.45	53.01	55.41	44.03	54.59	59.85
	SD	±3.12	±3.633	13.57	±11.53	±1.994	±5.505
Emp CAD	Mean	44.94	54.3	70.5	46.15	53.77	60.73
	SD	±9.245	±3.203	±18.03	±7.874	±3.664	±4.468
V. Enamic	Mean	41.37	53.15	64.61	44.1	57.14	63.82

Total effect of material type on marginal discrepancy

Regardless to measurement stage or cementation approach, it was found totally that the highest marginal discrepancy recorded with Emp CAD (55.07±7.75μm) followed by V. Enamic (54.03±7.67μm) while the lowest marginal discrepancy recorded by V. Suprinity (52.56±6.56μm) and this was non-significant statistically as indicated by three-way ANOVA test (P=0.4712> 0.05).

Total effect of cement type on marginal discrepancy

Irrespective of measurement stage or material types, it was found totally that self-adhesive cement recorded higher vertical marginal discrepancy (54.00±8.51μm) than total etch cement type mean value(53.79±9.91μm). This was non-significant statistically as demonstrated by three- factors ANOVA test (P=0.929> 0.05).

Total effect of measurement stages on marginal discrepancy

Regardless to material types or cementation approach, it was found totally that the highest marginal discrepancy recorded after thermal aging stage (62.49±11.01μm) followed by after cementation stage (54.33±3.89μm) while the lowest marginal discrepancy recorded before cementation stage (44.84±7.06μm) and this was significant statistically as indicated by three-way ANOVA test (P=<0.0001 < 0.05).

Color measurement

Color change results (Mean±SD) for both groups after cementation are found in (table 2 and table 3)

Effect of material group on color changes

Irrespective to cementation approach, it was found totally that the highest color changes mean value recorded with V. Enamic group (3.78±0.01 ΔE) followed by Emp CAD group (3.42±0.22 ΔE) while the lowest color changes mean value recorded V. Suprinity group (3.05±0.34 ΔE) and this was significant statistically as indicated by two-way ANOVA test (P=0.0178< 0.05). Pair-wise Tukey's post-hoc test showed non-significant (p>0.05) difference between (V. Suprinity and Emp CAD) and (Emp CAD and V. Enamic) as shown in (table 2)

Table (2): *Total color changes results of all groups (Mean values ±SDs).*

Variable	Material type			Statistics
	V. Suprinity	Emp CAD	V. Enamic	P value
Mean	3.05	3.42	3.78	0.018*
SD	0.34	0.22	0.01	

**; significant (p<0.05) non-significant (p>0.05)*

Effect of cementation approach on color changes

Irrespective of material groups, totally it was found that self-adhesive cement recorded higher color changes mean value (3.61±0.36 ΔE) than total etch cement type mean value (3.23±0.14 ΔE). This was non-significant statistically as demonstrated by three-factors ANOVA test (P=0.0634 > 0.05) (table 3).

Table (3): *Total color changes results (Mean values ±SDs) of both cementation approaches.*

Variables		Mean± SD	Statistics
			P value
Cementation approach	Total	3.23±0.36	0.0634 ns
	Self	3.61±0.14	

**; significant (p<0.05) non-significant (p>0.05)*

Fracture resistance

Fracture resistance (N) results showing mean, standard deviation (SD) values for all groups with both cementation approaches after thermal aging are summarized in (table 4 and table 5)

Effect of material group on fracture resistance

Irrespective to cementation approach, it was found totally that the highest fracture resistance mean value recorded with V. Suprinity group (707.14 N) followed by Emp CAD group (645.20 N) while the lowest fracture resistance mean value recorded for V. Enamic group (589.18 N) and this was significant statistically as indicated by two-way ANOVA test (P=0.0006< 0.05). Pair-wise Tukey's post-hoc test showed non-significant (p>0.05) difference between (Emp CAD and V. Enamic) as shown in (table 4)

Effect of cementation approach on fracture resistance

Irrespective of material groups, totally it was found that ***self-adhesive*** cement recorded higher fracture resistance mean value (672.91±62.26 N) than ***total etch*** cement type mean value (621.44±53.36 N). This was non-significant statistically as demonstrated by two- factors ANOVA test (P=0.0626 > 0.05) as shown in (table 5)

Table (4): *Comparison of total fracture resistance results (Mean values ±SDs) between all groups*

Variable	Material type			Statistics
	V. Suprinity	Emp CAD	V. Enamic	P value
Mean	707.14	645.20	589.18	0.0006*
SD	±26.68	±90.11	±41.58	

**; significant (p<0.05) non - significant (p>0.05)*

Table (5) *Comparison of total fracture resistance results (Mean values ±SDs) between both cementation approaches*

Variables		Mean± SD	Statistics
			P value
Cementation approach	Total	621.4±53.3	0.0626 ns
	Self	672.9±62.2	

**; significant (p<0.05) non - significant (p>0.05)*

DISCUSSION

Ceramic laminate veneers can be considered as one of the best treatment options used to change shape and color of anterior teeth with poor esthetics as discolored, fractured, or misaligned teeth. Ceramic veneers preparations are very conservative which remain within the enamel and thus being more conservative and allow better bond strength to tooth structure than when bonding to dentine. This implies using ceramic materials with minimum thickness and increased translucency; however, they have to mask the underlying discolored tooth structure without increasing their thickness that is why our study was conducted to evaluate the effect of veneer material, degree of veneer translucency, and shade of luting cement on masking the underlying dark substrate color. [36,37].

The materials used in our study included IPS Empress CAD is aleucite reinforced glass ceramic. It was chosen due to its shade natural appearance, fluorescence and translucency [38]. Vita Suprinity is zirconia-reinforced lithium silicate glass-ceramic has improved strength and reliability which are made by addition of 10wt% of zirconium oxide and very fine lithium disilicate and metasilicate crystals. It was also chosen due to its better mechanical properties; it has the strength properties of zirconia and the esthetic properties of lithium disilicate [39]. Vita Enamic is hybrid ceramic material with dual structure. This hybrid material has the characteristics of a ceramic and a composite. It is composed of a porous ceramic matrix (86% by wt.) with the pores filled with resin (14 % by wt.). In addition to a high degree of elasticity, this hybrid ceramic ensures high strength after adhesive bonding, therefore enabling the reduction of wall thicknesses for minimally-invasive restorations [40].

In the present study, human maxillary first premolars were selected to provide microstructure to resin cement that is similar to the clinical condition in addition to strength and modulus of elasticity of natural teeth is better than plastic or animal teeth. Sixty maxillary first premolars were collected and prepared to receive laminate veneers. For standardization, silicone index was made of all teeth before reduction. Standardized tooth preparation was done to overcome variables of preparation dimensions[41]. Types of finish line which is recommended for optimal marginal fit are chamfer, shoulder-bevel and shoulder. In previous studies showed no difference between marginal fit of shoulder and chamfer margins, but chamfer design has clinical advantages over the shoulder design [42-44]. Ceramic laminate veneers seated on prepared tooth using readymade loading device with fixed pressure of 250 g for one minute. The excess cement was trimmed away after light curing for 2 seconds, then light curing was carried out for 20 seconds for each surface. Studies that used finger pressure technique does not ensure standardization [45-47].

The present study examined the effect of three CAD/CAM ceramic materials and two types of resin cements on marginal discrepancy, color stability and fracture resistance of ceramic veneers before, after cementation and after thermo cycling by using one preparation design. Thermal cycling procedure is a method to simulate intraoral conditions. It is performed as clinical trials are costly and time consuming [48].

Regarding marginal discrepancy, the three ceramic materials showed an acceptable value (40-120 ums). It was found, regardless to measurement stage or cementation approach, totally it was found that the highest marginal discrepancy recorded with Emp CAD group (55.07±7.75μm) followed by V. Enamic group (54.03±7.67μm) while the lowest marginal discrepancy recorded by V. Suprinity group (52.56±6.56μm) and this was statistically non-significant and irrespective of measurement stage or material types, totally it was found that self-adhesive cement recorded higher vertical marginal discrepancy(54.00±8.51μm) than total etch cement type(53.79±9.91μm), This was statistically non-significant, but regardless to material types or cementation approach, there was significant difference with the highest marginal gap recorded after thermal aging stage (62.4 μm) followed by after cementation stage (54.3 μm) while the lowest marginal gap mean value recorded before cementation stage (44.8 μm)[49-51].

Our results are in agreement with a study evaluated the effect of artificially accelerated aging on marginal fit and color stability of laminate veneers fabricated from Lava Ultimate, IPS E.max CAD and IPS Empress CAD showed a statistically significant change in the marginal discrepancy before and after thermal aging due to effect of aging [52].

Our findings are also in agreement with a study evaluated the influence of different resin cements on marginal discrepancy of crowns fabricated from lithium disilicate. Significant statistically differences were found between groups. No significant statistically differences were found between groups Rely x & Harved premium flow or between Rely x and Enamel plus preheated composite [53].

Our results are not in agreement with a study that evaluated the marginal and internal adaptation of all ceramic crowns fabricated from Vita Suprinity, Lava Ultimate,Vita Enamic, IPS e.max CAD, GC Cerasmart and Incoris TZI. The marginal discrepancy was measured by silicone replicas. This study reported that the marginal gap after thermocycling was not within clinically acceptable value (more than 120 μm). Marginal gap of Vita Enamic, Vita Suprinity, and Lava Ultimate were similar where larger gap observed in Incoris TZI and GC Cerasmart followed by IPS e.max[54] .

The explanation of our results could be attributed to the newly released version of the designing software (3D) has automatic detection of the margins of the restorations which improve final fit of the milled restorations. This improvement is due to recent advancements of software, scanning technology and advanced milling strategy.[55,56]

Regarding color stability in this study, irrespective to cementation approach, it was found totally that the highest color changes mean value recorded with V. Enamic group followed by Emp CAD group while the lowest color changes mean value recorded V. Suprinity group and this was statistically significant. Irrespective of material groups, totally it was found that self-adhesive cement recorded higher color changes mean value than total etch cement type mean value and this was statistically non-significant.

Our results are in agreement with a study that evaluated the influence of coffee on the stainability of CAD/CAM ceramic materials (VITA Suprinity, VITA Enamic and Vitablocs Mark II), it was found that Vita Enamic exhibits statistically significant highest color change followed by Vitablocs mark II and Vita Suprinity in the polished groups compared with the controlled glazed groups [57].

The explanation of our results that color change of Vita Enamic could attributed to their composition where the pores of the structured sintered ceramic matrix were filled with a polymer material rendering it a hybrid material which has dual network structure. Not only the filler/resin ratio is better in Vita Enamic but also the type of the resin that may contribute to the color change, as some resin monomers can be classified as stain resistant and others as non-stain resistant. UDMA is a hydrophobic monomer rendering it more stain resistant whereas TGDMA exhibits a degree of water absorption thus allows the hydrophilic colorant to penetrate into resin matrix [58].

Regarding fracture resistance in our study, irrespective to cementation approach, it was found totally that the highest fracture resistance mean value recorded with V. Suprinity group followed by Emp CAD group while the lowest fracture resistance mean value recorded for V. Enamic group and this was statistically significant. Irrespective of material groups, totally it was found that self-adhesive cement recorded higher fracture resistance mean value than total etch cement type mean value and this was statistically non-significant.

Our results are in agreement with a study evaluated the effect of thermodynamic loading on the durability and fracture resistance of occlusal veneers fabricated from Vita Suprinity,Vita Enamic, e.max CAD and Telio CAD.It was found that after thermodynamic loading, Vita Suprinity demonstrated significantly higher fracture resistance than Vita Enamic and Telio CAD ($P \leq 0.021$). In addition, E.max CAD showed statistically significantly higher fracture strengths than Vita Enamic ($P \leq 0.045$). But, no significant statistically difference was found between Vita Suprinity - E.max CAD and E.max CAD - Vita Enamic ($P \leq 0.291$) [59].

The explanation of our results that the highest fracture resistance of Vita Suprinity veneers due to the glass matrix of Vita Suprinity contain completely dissolved zirconium oxide (10%), which lead to enhancing both fracture resistance and flexural strength of the material[60], where the lowest fracture resistance of Vita Enamic veneers due to low mechanical properties of this material including low fracture toughness (1.5 MPa m1/2) and low flexural strength (150-160 MPa). Another cause that the polymer in polymer infiltrated ceramic represents weak point of the microstructure from which failure could be initiated [61.62].

CONCLUSION

Ceramic veneers fabricated by Vita Suprinity, IPS Empress CAD and Vita Enamic provided clinically acceptable marginal discrepancy and the cement type has no effect on marginal discrepancy but marginal discrepancy after thermo cycling recorded statistically significant increased compared to after cementation and before cementation stages. Vita Suprinity veneers recorded high color stability and fracture resistance better than IPS Empress CAD and Vita Enamic veneers.

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