Future Dental Journal

Volume 4 | Issue 2 Article 29

2018

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Recommended Citation

El-Agwany, Mohamed; Wahsh, Marwa Mohamed; and Morsi, Tarek Salah (2018) "Effect of veneering techniques and subsequent aging on translucency of bilayered zirconia," *Future Dental Journal*: Vol. 4 : Iss. 2 , PP 274-278.
Available at: https://digitalcommons.aaru.edu.jo/fdj/vol4/iss2/29

Future Dental Journal 4 (2018) 274–278

Contents lists available at ScienceDirect

Future Dental Journal

journal homepage: www.elsevier.com/locate/fdj

Effect of veneering techniques and subsequent aging on translucency of bilayered zirconia

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ARTICLE INFO

Keywords:
Veneering techniques
Translucency
Aging
Zirconia

ABSTRACT

Purpose: this study compared the translucency of zirconia specimens veneered with different veneering techniques, and compared the change in translucency after aging.

Materials and methods: Fifty slice specimens (0.50 ± 0.01 mm thick) were fabricated of IPS e.maxZirCAD core material, and ZL1 IPS e.maxZirLiner (0.10-mm thick) was layered. The specimens were randomly divided into five groups (n = 10/group). Group I (traditional layering technique) was veneered (0.60 mm) by condensing and sintering IPS e.max Ceram low-fusing nano-fluorapatite veneering porcelain; Group II (High translucency press on technique) was veneered (0.60 mm) by heat-pressing HT IPS e.maxZirPressfluorapatite glass-ceramic ingots; Group III (Low translucency press on technique) was veneered (0.60 mm) by heat-pressing LT IPS e.maxZirPressfluorapatite glass-ceramic ingots; Group IV (High translucency CAD-ON technique) was veneered (0.60 mm) by HT IPS e.max CAD lithium disilicate glass ceramic blocks and GroupV (Low translucency CAD-ON technique) was veneered (0.60 mm) by LT IPS e.max CAD lithium disilicate glass ceramic blocks. CIE (L*, a*, b*) parameters were measured and translucency was calculated for each veneering technique before and after aging according to the following equation: $TP = [(L^*_B\text{-}L^*_W)^2 + (a^*_B\text{-}a^*_W)^2 + (b^*_B\text{-}b^*_W)^2]^{1/2}$. One-way analysis of variance (ANOVA) combined with Bonferroni's post-hoc test and Paired *t*-test were used to analyze the data ($\alpha = 0.05$).

Results: Statistical analysis utilizing One-way ANOVA showed that, pressing technique had higher translucency than build-up and CAD on techniques. There was a significant difference between the three techniques except for the low translucency Pressing and CAD on techniques when compared with the build up after aging. Using Paired-t test to determine the effect of aging, a significant decrease of translucency was found in all techniques after aging except for the low translucency Pressing and CAD on techniques.

Conclusion: Veneering zirconia with both layering and pressing techniques produced more translucent samples than with CAD-ON veneering technique. Aging caused a decrease in translucency of all samples.

1. Introduction

Making the visual recognition of the inserted restoration a difficult task even for well-trained eyes is one of the most difficult challenges in esthetic dentistry [1]. The achievement of an all-ceramic esthetic restoration which matches perfectly with adjacent teeth is the result of the interplay between two critical optical factors: on one hand, the masking capacity of ceramics to block the background color, and on the other hand, the amount of translucency of the ceramic that will let the natural background color shine throughout a translucent material and show the most natural appearance [2]. Recent developments in ceramic technology and evolutionary treatment methods have all increased the predictability of all-ceramic restorations. The introduction of partially stabilized zirconium dioxide to the dental field opened new design and application limits of all-ceramic restorations allowing a minimum thickness of framework of 0.5 mm with the remaining thickness of the restoration used for building the ceramic veneer [3]. Veneering zirconia core can be done by three types of procedures: the traditional layering technique (veneered by condensing and sintering veneering porcelain), press-on technique (veneered by heat-pressing ceramic ingots), and CAD-ON technique. However, the best zirconia veneering technique that provides optimum esthetics is yet to be evaluated [4,5]. The conventional layering technique was selected as it is preferred by most clinicians due to its great optical properties and its ability to create depth notion and to nicely mimic tooth structure. Dentin porcelain for layering technique contains nanofluorapatite crystals similar to those of

Peer review under responsibility of Faculty of Oral & Dental Medicine, Future University.
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https://doi.org/10.1016/j.fdj.2018.05.009
Received 12 December 2017; Received in revised form 27 May 2018; Accepted 28 May 2018
Available online 29 May 2018

vital teeth, which ensure the restorations match natural tooth accurately in terms of color, surface texture, and translucency [6] However, it is a time-consuming process and structural defects, as micro-gaps and air bubbles at the core-veneer interface was a common finding, These structural defects act as stress concentration sites where crack initiation and propagation are highly anticipated, with the risk of chipping or delamination [6]. Heat pressing technique presents the advantages of good color production, superior marginal fit, quickness, simplicity, defect free structures, superior interface quality, higher bond strength with zirconia frameworks [7] and reduction of intrinsic defects [8]. However, the main drawbacks of press on technique are the lower esthetic and optical qualities as compared with the layering technique [9]. CAD-ON technique is a one visit procedure that provides higher mechanical strength [10] and better control over core-veneer thickness ratio and hence a better color match [11,12].

Translucency happens when a light beam passing through a material is scattered partly, reflected and transmitted through the object. The greater the quantity of light passing through the object, the higher the translucency. Scattering of light is generated by many factors, such as refractive indices among ceramic phases, voids and porosities, high crystalline content and crystal number and size, especially when the crystal particles are slightly larger than the wavelength of the incident light [13]. Many authors consider translucency as a key component for ceramic restorations [14,15].

In the oral environment, all-ceramic materials are prone to aging [16]. Aging can lead all-ceramic materials to change color and translucency. Accelerated aging simulates the effects of long-term exposure to environmental conditions through an artificial weathering process that involves temperature, light exposure and humidity [17,18].

The purpose of this study is to compare the change in translucency of zirconia specimens with different veneering techniques before and after aging.

2. Materials and methods

IPS e.max® all-ceramic system (Ivoclar Vivadent, Schaan, Liechtenstein) was selected to fabricate the specimens. IPS e.max ZirCAD block (partially sintered zirconium oxide stabilized with yttrium oxide) was the core material, while A2 (HT and LT) IPS e.max ZirPress (fluorapatite glass-ceramic ingot) for heat-pressing, A2 IPS e.max Ceram (low-fusing nano-fluorapatite dentin porcelain) for layering and A2(HT and LT) IPS e.max CAD (lithium disilicate glass ceramic blocks) for CAD-On, were veneering materials. ZL1 IPS e.max ZirLiner was used as bonding ceramic for specimens veneered by pressing and build up technique, while low fusion glass-ceramic IPS e.max Crystall./connect. was used as bonding ceramic for Specimens veneered by CAD-On technique. Fifty slices (n = 50) of IPS emax ZirCad of thickness (0.5 ± 0.01 mm thick) were used for this study and veneered with porcelain Layer of thickness (0.6 ± 0.01 mm thick). The slices were randomly divided into five groups (n = 10/group) (Table 1).

Using CNC milling machine (Centroid™, USA), IPS emaxzirCAD blocks of size C15L of shade MO2 were cut into slices of thickness 0.6 mm to have 50 slices of diameter 14.5 mm × 15.5 mm and to reach the required 0.5 mm thickness after sintering. The entire surface of the substructure was well supported to avoid deformation. The sintering program was then started to run automatically and the sintering temperature was 1570 °C. After sintering, slices thickness was checked using an electronic digital caliper (Globaltronics GnbH& Co KG, Hamburg, Germany), to assure the required final thickness.

For group B (veneered by layering technique) Zirconia slices were placed in prefabricated mold with a total depth of 1.1 mm and with dimensions of 15 mm × 16 mm. The remaining depth after placing zirconia slices was 0.6 mm to accommodate the thickness of veneering porcelain. IPS emaxZirliner was mixed with the respective liquid to a creamy consistency and applied to zirconia slices after cleaning from any dirt and grease, and then fired in a porcelain furnace. IPS emax Ceram was mixed with the corresponding liquid and applied in drop-shaped increments and condensed properly until all the space over the zirconia slice in the mold was completely filled. Veneered slices were carefully removed from the mold and were put in the ceramic firing furnace for firing cycles. Verification and determination of thickness was achieved, using electronic digital caliber and a total thickness of 1.1 was assured. IPS emax glaze powder was mixed with IPS emax glaze liquid and was painted lightly onto the surface in an even layer, then Glaze firing is accomplished.

For both groups PHT and PLT (veneered by pressing technique), IPS emaxzirliner was applied and fired as described previously, in construction of IPS emaxCeram. Wax pattern (Renfert, Hilzingen, Germany) was built over zirconia substrate in the mold to completely fill the space over zirconia slice. Sprues were placed over the center of each slice with the thickest portion of it toward the wax pattern to assure continuous flow of pressed ceramic and all specimens were collected onto a crucible former. Investing was carried out using IPS investment material. The corresponding IPS Silicone Ring with the matching IPS Ring Gauge (Ivoclar Vivadent, Schaan, Liechtenstein) was used for investment. Preheating of investing ring was done in burn-out furnace (Ney, Dentsply, USA) at 850 °C for 40 min. Cold IPS emaxZirpress ingot was placed into hot investment ring, and IPS plunger (Ivoclar Vivadent, Schaan, Liechtenstein) was placed over the ingot. Completed investment ring was placed at the center of the furnace, and the selected press program was started. After completion of the cycle, investment ring was removed from the furnace and was placed on a cooling grid to cool. Specimens were divested from the ring using abrasive disks carefully, and successive sandblasting were done for fine divestment. The specimens were cleaned under running water for 2 min and dried. The specimens were then glazed. Verification and determination of thickness was achieved.

For both groups CHT and CLT (veneered by CAD-On technique), Using CNC milling machine, IPS emax CAD blocks of size C14 LT and HT were cut into slices of thickness 0.6 mm. Through the specially developed low fusion glass-ceramic IPS e.maxCrystall./connect. a homogenous bond was created between the zirconia slices and the IPS e.max CAD veneering structure. Crystallization of IPS e.max CAD veneer took place during the same firing cycle. IPS e,maxCrystall./Connect of shade 2 was selected as recommended by the manufacturer to match the required A2 shade of specimens.

Each sample was measured against both black and white backgrounds using Vita EasyShade Compact. where in each time, CIE lab values were calculated. Translucency of each sample was calculated according to the following equation: $TP = [(L^*_B\text{-}L^*_W)2 + (a^*_B\text{-}a^*_W)2 + (b^*_B\text{-}b^*_W)2]1/2$ where *TP*: translucency, *l,a,b*: CIElab measurements, *B,w*: measurements against black and white backgrounds respectively.

All the 25 slices were subjected to hydrothermal aging in autoclave at 134 °C and 2 MPa for Five hours, to mimic one year of oral conditions [19] according to ISO standards 13356 and translucency of all specimens was re-calculated after hydrothermal aging.

Numerical data were explored for normality by checking the data

Table 1
Samples grouping.

Group B	IPSe.maxzirCAD slices coated with IPSe.maxzirLiner and veneered with traditional build up technique using IPSe.maxceram.
Group PHT	IPSe.maxzirCAD slices coated with IPSe.maxzirLiner and veneered with heat pressing technique using IPSe.maxzirPressHT.
Group PLT:	IPSe.maxzirCAD slices coated with IPSe.max and veneered with heat pressing technique using IPSe.maxzirPressLT.
Group CHT:	IPSe.maxzirCAD slices veneered with CAD-ON technique using IPSe.max CAD HT, via low fusing glass.
Group CLT:	IPSe.maxzirCAD slices veneered with CAD-ON technique using IPSe.max CAD LT, via low fusing glass.

distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. One-way ANOVA test was used to compare between the three techniques. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. Paired *t*-test was used to study the effect of aging.

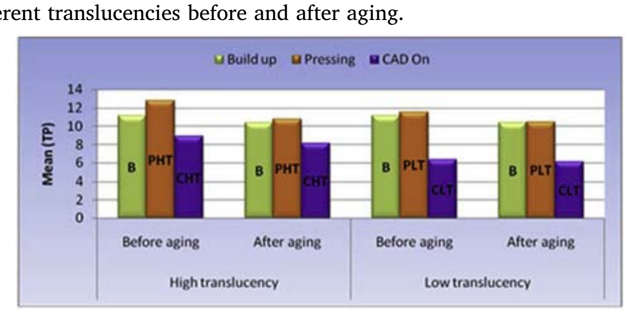
The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics Version 20 for Windows.

3. Results

For both types of translucencies before and after aging, pressing technique had the highest mean value followed by build up then CAD On technique and there was a significant difference between the three techniques. Pairwise comparisons for the high translucency groups before aging showed all the groups' pairings to have a significant difference. For all other comparisons, there was no significant difference between pressing and build up techniques, while they were both significantly different from CAD On technique. All groups with different types of translucencies showed a lower mean value after aging. The difference between before and after aging values for the low translucency CAD On technique was not significant while for all other techniques and types of translucencies the difference was significant (see Table 2).

Table 3 shows the mean values and corresponding standard deviations (SDs) of translucency (TP) before and after aging. With buildup technique, there was a statistically significant decrease in mean (TP) after aging. With Pressing as well as CAD On techniques and high translucency; there was a statistically significant decrease in mean (TP) after aging. While with low translucency, there was no statistically significant change in mean (TP) after aging.

Bar chart representing mean (TP) of the three techniques and different translucencies before and after aging.



Bar chart representing mean (TP) of high and low translucency.

Table 2
Means and standard deviation (SD) values of translucency (TP) of the three techniques and different translucencies before and after aging.

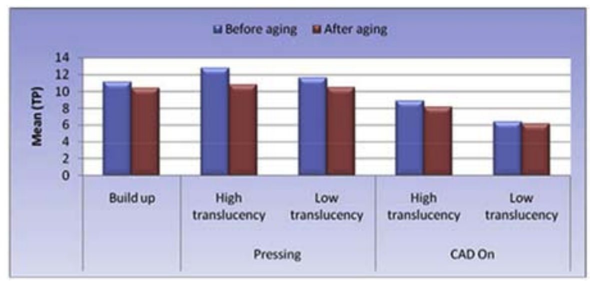
Aging	Build up			Pressing		CAD On		*P*-value
	Mean	SD		Mean	SD	Mean	SD	
Before aging	11.12^A	0.71	HT	12.76^B	0.35	8.86^C	2.37	0.004*
			LT	11.56^A	1.23	6.34^B	2.13	0.001*
After aging	10.36^A	0.59	HT	10.76^A	0.89	8.1^B	2.63	0.023*
			LT	10.46^A	0.53	6.1^B	2.51	< 0.001*

Different superscript letters within the same row indicates a statistically significant difference *; significant ($p \leq 0.05$) ns; non-significant ($p > 0.05$).

Table 3
Mean and standard deviation (SD) values of translucency (TP) before and after aging.

Technique	Translucency	Before aging		After aging		*P*-value
		Mean	SD	Mean	SD	
Build up		11.12	0.71	10.36	0.59	0.002*
Pressing	High	12.76	0.35	10.76	0.89	0.004*
	Low	11.56	1.23	10.46	0.53	0.018*
CAD On	High	8.86	2.37	8.10	2.63	0.005*
	Low	6.34	2.13	6.10	2.51	0.394ns

* Significant ($p \leq 0.05$) ns; non-significant ($p > 0.05$).



4. Discussion

The esthetic value of dental restorations is partially controlled by their translucency and color. Since natural enamel has inherent translucency, it is important that ceramic restorations reproduce the translucency and color of the natural teeth [20].

Color and its elements, such as hue, value, chroma, translucency, opacity, light transmission and scattering, metamerism, and fluorescence, influence the esthetics of a dental restoration [21].

White-colored core of high strength Y-TZP based systems needs veneering to ensure the esthetic effect [21,22].

For purpose of standardization, a specially constructed mold was constructed for the core samples as well as the core and veneer samples as used by different authors [23–26].

To provide the required thickness of zirconia slices of 0.5 mm, IPS emaxzirCAD blocks were cut into 0.6 mm slices, to compensate sintering shrinkage which is about 18.6–23.2% [27].

For veneering with CAD-ON technique, IPS e.max CAD Crystall./Connect; low fusing ceramic was used to create a homogenous bond between the zirconia slices and the IPS e.max CAD veneering slice due to its thixotropic behavior, its sintering temperature that has been adjusted to the crystallization temperature of IPS e.max CAD (840–850 °C) and its thermal expansion coefficient of 9.2×10^{-6}/k that matches both Y-TZP and IPS e.max CAD [28].

For veneering with buildup and pressing techniques, IPS e.maxZirliner was used to enable a good bond with the zirconium oxide framework and to demonstrate high light transmitting capability coupled with high fluorescence. And thus they made the white and highly opaque zirconium oxide frameworks look as if they have been shaded and permitted the adjustment of the basic zirconium oxide shade of the framework to the shade of the IPS e.max Press and IPS e.max Ceram [29,30].

All specimens were finished and glazed to simulate clinical situation and to produce smooth glossy surface needed for color measurements, as the surface texture influences the color of ceramic restorations [31].

4.1. Effect of veneering technique on (TP)

The results of the current study revealed that mean (TP) values was highest with pressing veneering technique followed by buildup veneering technique and lowest (TP) values was shown with CAD-ON veneering technique either before or after aging.

The results were in conflict with Clarke [32] who stated that materials composed of small particles are less opaque when visible light passes through, with less refraction and absorption in spite of greater scattering from increased number of particles. On the contrary, large particles cause surface reflection as light strikes, refraction as light passes through and absorption. So, the anticipated translucency of layering technique is higher than that of pressing technique as Nano-flourapatite particles of IPS emax Ceram is smaller than fluorapatite particles of IPS emaxZirPress, a situation that was not found in this study, and this may be due to porosity of layering porcelain. This porosity could be due to incorporated voids during porcelain manipulation that wasn't eliminated during condensation process [33–35]. However, the translucency of CAD-on technique was lesser than that of layering technique, as lithium disilicate of IPS emax CAD particle size is larger than both flourapatite and nanofluorapatite, the results were in accordance with Clarke [32].

With high translucency before aging, translucency (TP) values of pressing technique was significantly higher than that of CAD-ON technique while higher than that of layering technique, but the results were statistically insignificant, while after aging, (TP) values of pressing technique was higher than that of both layering and CAD-ON techniques, but the results were statistically insignificant, whereas (TP) values of layering techniques was higher than that of CAD-ON technique, but the results were statistically insignificant.

With low translucency, either before or after aging, CAD-ON technique showed the significantly lowest mean (TP) values, whereas there was no significant difference between pressing and layering techniques.

4.2. *Effect of degree of translucency of veneering material on (TP)*

When translucency (TP) values is measured between different translucencies of the same veneering technique, it was found that high translucency veneer shows higher (TP) values than low translucency veneer either before or after aging but these differences was not significant.

The higher translucency levels for the HT groups were probably due to higher transmission of light through the high translucency veneer compared to the low translucency one.

4.3. *Effect of aging on translucency (TP)*

To evaluate the effect of aging on translucency, mean (TP) values of each group was measured before and after aging, and this measurement reveals that mean (TP) values decreased with aging for all groups. This decrease was significant with buildup, high translucency pressing and high translucency CAD-ON techniques while with low translucency pressing and CAD-ON techniques, the decrease in mean (TP) values after aging were statistically insignificant.

This can be explained according to the findings of Heffernan et al [2] who stated that the translucency depends on the absorption and scattering of light within the ceramic crystals. They found that chemical composition, the amount of crystals, the volume and size of pores, and the sintered density determine the amount of absorbed, reflected, and transmitted light, thus influence the optical property of core ceramics [36]. When zirconia substrate exposed to thermo-cycling aging, crystalline transformation from tetragonal to larger monoclinic phase occurred. Monoclinic crystalline phase interferes with light transmission thus decreasing the translucency of zirconia.

5. Conclusion

Based on the limitations of this study, it is concluded that Veneering zirconia with both buildup and pressing techniques produced more translucent samples than with CAD-ON veneering technique. Also aging of all samples caused a decrease in translucency of all samples.

Acknowledgement

This project was supported by Dr. Tarek Salah Morsi, Dr. Marwa Mohamed Wahsh and Dr. Amr El-etriby. Dr. Heba Mohamed Kamal helped in editing and formatting of this document.

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