Journal of Dental Sciences 17 (2022) 1151–1159

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-jds.com

Original Article

Clinical esthetic comparison between monolithic high-translucency multilayer zirconia and traditional veneered zirconia for single implant restoration in maxillary esthetic areas: Prosthetic and patient-centered outcomes

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Received 14 December 2021; Final revision received 14 January 2022
Available online 5 February 2022

KEYWORDS
High-translucency multilayer zirconia;
Monolithic crown;
Maxillary esthetic areas;
Dental implants

Abstract *Background/purpose:* Clinical esthetic evidence for the performance of monolithic high-translucency multilayer zirconia is lacking. The aim of this study was to compare monolithic high-translucency multilayer zirconia with traditional veneered zirconia in clinical situation.

Material and methods: A total of 30 participants who were provided with both monolithic zirconia crowns (Group 1) and traditional veneered crowns (Group 2) for single implant restoration in maxillary esthetic areas were enrolled. Patients' subjective outcome (Visual Analog Scale, VAS) were recorded. Photos were taken and then evaluated by 9 evaluators with Pink and White Esthetic Score (WES). Wilcoxon signed rank test was used for comparison between Group 1 and Group 2 in VAS, WES and five variables in WES. Kendall's coefficient of concordance test was used to calculate inter-rater reliability of WES variables. Spearman correlation was used to analyze association between patients' outcome and evaluators' scores.

Results: There was no significant difference in patients' subjective outcome between

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https://doi.org/10.1016/j.jds.2022.01.012

monolithic zirconia and traditional veneered crowns: overall VAS were 9.0 (8.0—9.0) and 9.0 (8.5—9.5), respectively ($P > 0.05$). However, in professional view, significant difference between Group 1 and Group 2 in WES was observed: 7.5 (6.0—8.0) and 8.0 (6.5—8.5), respectively ($P < 0.05$). Kendall's test showed, among WES variables, translucency demonstrated the highest agreement. Professionally reported evaluations did not correlate with patient-reported outcomes (Spearman correlation were 0.246 and 0.224 for Group 1 and Group 2, respectively). *Conclusion:* Within the limitation of this study, it can be concluded that monolithic high-translucency multilayer zirconia restoration might be a treatment modality.

Introduction

Nowadays, the use of ceramic materials for fabrication of implant crowns has become the most common treatment option. The most acknowledged method to restore all ceramic crowns is inner zirconia with veneering glass ceramic, which could provide the best esthetic outcome.[1] However, such bilayer system is costly and has major drawbacks such as chipping, with a complication rate of 9% after 5 years.[2] One of the best way to overcome these drawbacks is to replace with monolithic restorations.

Monolithic zirconia is processed by computer-aided design and computer-aided manufacturing (CAD/CAM) procedure. In recent research, the use of monolithic zirconia has been more and more popular, especially in posterior implant site.[3,4] Monolithic restorations allow to avoid the technique sensitive manual veneering procedure and may therefore result in more efficient laboratory fabrication.[5] Additionally, in some countries, traditional layering procedure is more expensive. Thus, CAD/CAM process with monolithic crowns offers a cost-effective option as well.[6]

High-translucency zirconia has recently gained popularity owing to its esthetic features and high strength. Yttrium-tetragonal zirconia polycrystalline (Y-TZP) with 5% mol yttria is approximately 50% cubic phase zirconia with 3 times more strength than the veneering ceramic.[7] Generally, it was acknowledged that high-translucency zirconia presented with intermediate translucency in between the conventional zirconia and lithium disilicate.[8] However, another study has suggested that the translucency in new zirconia could be better than glass ceramic.[9] Furthermore, an in vitro study stated that monolithic translucent zirconia could be better than veneering traditional zirconia when a more translucent restoration was needed.[10] Recently, one clinical case report of natural teeth restored with monolithic zirconia crowns has represented an esthetic treatment alternative to veneered zirconia.[11] Combined with the information above, it seems that translucent zirconia might provide clinically acceptable translucency. On the other hand, the new high-translucency multilayer zirconia could be precolored, combined gradient shade with incisal layer least stained.[12] Since it could only be modified through external coloring procedure, the use of the new zirconia allowed limited color alteration.[13] One study has raised question about color accuracy of polychromatic zirconia in clinical application.[14] Therefore, it is necessary to investigate whether monolithic high-translucency multilayer zirconia might achieve optimal esthetic outcomes in clinical situation.[15]

Thus, the aim of the present clinical study was to test whether high-translucency monolithic multilayer monolithic zirconia implant crowns would show comparable esthetic result compared to traditional veneered zirconia crown in maxillary esthetic areas.

Materials and methods

This clinical study was conducted in accordance with the Declaration of Helsinki on medical protocol and approved by the Shanghai Jiao Tong University Ethical Review Board. The ethical approval number is SH9H-2020-T186-2. The patients who needed single maxillary implant-supported crowns from upper right first premolar to upper left first premolar at the Departments of Implant Dentistry between December in 2020 and September in 2021 were included in this study.

Study baseline was defined as the start of the prosthetic procedure with prospective clinical design. All of the following criteria had to be met for inclusion in the study: (i) subjects must have voluntarily signed the informed consent form before any study related action, (ii) males and females aged at least 18 years old, (iii) single tooth gaps in the anterior maxillary position 14 to 24 (FDI tooth numbering system), (iv) full mouth plaque index (PI) $\leq$ 25%, (v) implant axis compatible with transocclusal screw retention (screw access palatal of incisal edges), (vi) intact contralateral tooth. If any of the following criteria were met, the subject had to be excluded from the study: (i) patients with immediate implant placement, (ii) existing implants or prosthetic crowns in the adjacent or contralateral position, (iii) patients with high smile line, (iv) patients with tooth defect, congenital malformations, tetracycline pigmentation or dental fluorosis in adjacent and contralateral teeth, (v) patients with implant supported provisional restoration prior to final crowns, (vi) patients with contra-indicated general medical or mental status, uncontrolled periodontal disease, and excessive amount of alcohol or tobacco consuming.

All study participants were notified of fabricating two types of implant restorations and informed consent were obtained before impression taking. Detailed differences between two restorations (monolithic zirconia and

veneered zirconia) were not revealed to patients. A silicone (Honigum®, DMG, Hamburg, Germany) impression with putty (soft fast) and light body (light fast) components was taken by using a standard metallic perforated tray (Medesy, Maniago, Italy) with close-tray technique. The impression of the opposite jaw was taken with alginate (Kromopan, Lascod, Sesto Fiorentino, Italy). Afterwards, Vita 3D Master Guide (VITA Toothguide 3D-MASTER with 29 tabs, VITA Zahnfabrik H. Rauter Gmbh & Co. KG, Bad Säckingen, Germany) was used to select the right color and then photos were taken and sent to dental technician.

Monolithic restoration (Group 1) were produced from CAD/CAM technique with high-translucency multilayer zirconia (3D Pro Zir, Aidite, QinHuangDao, China). In this group, precolored zirconia was yttrium-tetragonal zirconia polycrystalline (Y-TZP) with 5% mol yttria (4% mol yttria at cervical region), 0.05wt% Al_2O_3 and grain size of 90 nm. Veneered zirconia (Group 2) were fabricated with 3% mol yttria zirconia core (SuPerfectzir HT, Aidite) and then hand layered with feldspathic veneering ceramic (VITA VMK 95, VITA Zahnfabrik H. Rauter Gmbh & Co. KG). CAD/CAM Tibase for 3Shape was used in this study. The sequence of crown fabrication was alternate. For example, for patient1, the dental technician would fabricate monolithic crown first, but for patient2, traditional veneered crown would be produced first. All implant-supported crowns were fabricated at the same dental laboratory by the same dental technician (G. F).

During crown seating, both prosthesis were presented and tried in at the same time. Sequence of two crowns seating was randomly assigned using the envelope technique. Subjective patient satisfaction with implant esthetics was evaluated using a Visual Analog Scale (VAS) representing the spectrum of satisfaction between 0 (total discontent) and 10 (total satisfaction). After evaluation, patients could choose the favorite one to wear and take the other one away as a gift for participating in this study. VAS scores for both crowns were recorded for each patient based on their answers to the following questions: (i) how do you feel about the shape of your new implant tooth (sVAS) ? (ii) how do you feel about the color of your new implant tooth (cVAS) ? (iii) what is your overall satisfaction with the new implant tooth (oVAS) ?

While seating, both crowns were photographed with a digital camera (D90, Nikon, Tokyo, Japan) and a 105 mm lens (AF-S VR Micro-Nikkor 105 mm f/2.8G IF-ED, Nikon) with a ring flash (MR18-MACRO, Nissin, Tokyo, Japan). Photographs were taken at or slightly superior to the occlusal plane, centered at the contact region. For assessing anterior tooth replacements, the reference tooth had to be visible enough to ensure comparability. Standard clinical photographs were taken at each implant site (occlusal view, restoration centered view and frontal view). The implant-supported restorations at the region of the canine were photographed to ensure comparison with the first premolar. At the region of the first premolar, standardized photographs had to include a full representation of the second premolar (Fig. 1). Contralateral and adjacent teeth were served as reference.

Photographs were transferred to a computer and assessed in one screen (13.3 inch MacBook Pro, Apple Inc, Cupertino, CA, USA) at a resolution of 2560*1600 pixels, using Preview under macOS version 11.4 by 9 examiners (3 implantologists, 3 prosthodontists, 3 general dentists) who were not involved in treating the patients. Room lighting was also standardized. The clinical photographs were primarily used to assess the two types of implant restorations and peri-implant soft tissue. Objectively, evaluation were performed with PES/WES scoring system. The Pink Esthetic Score (PES) awards a total of seven variables (mesial papilla, distal papilla, level of soft tissue margin, soft tissue contour, alveolar process deficiency, soft tissue color, and soft tissue texture) with a score of 0, 1, or 2.[16] The White Esthetic Score (WES) index according to Belser are tooth form, tooth volume, surface texture, tooth color, translucency and characterization.[17] As translucency is one

Figure 1 Standard clinical photographs (from up to bottom: occlusal view, restoration centered view and frontal view).

of the most significant parameters in evaluating monolithic zirconia, we singled translucency as one independent variable. Furthermore, to better evaluate the individualized feature of restorations, characteristics were combined with surface texture as one variable, as they are both complex and vary greatly from one person to another. The thresholds of PES and WES for a clinically acceptable score are set at 6 and 9, respectively. Intra-evaluator reliability and calibration of all 9 evaluators was performed on the basis of 20 photos that were scored twice with an interval of 1 week. Intra-class correlation coefficient were 0.701—0.931 for WES and 0.711—1.000 for PES. Afterwards, all evaluators scored all cases twice at an interval of 4 weeks.

The sample size was estimated based on the reported comparison between zirconia and glass ceramic (White Esthetic Score: 6.73 ± 0.73 vs 8.21 ± 1.65, respectively) from a previous study (De Angelis P et al., 2020).[18] PASS software (version 15.0.3, NCSS, Kaysville, UT, USA) was used to calculate the sample size. 26 participants were needed to achieve 80% power with a significance level of 5%. A total of 30 subjects were recruited allowing 15% of missing or incomplete data. All other calculations were performed with the SPSS statistical software program (Version 26.0, SPSS Inc., Chicago, IL, USA). Results are presented as median (IQR) for PES, WES and VAS. The Wilcoxon signed rank test was used as a nonparametric methodology to detect differences in WES and VAS and in each pair of five WES variables comparison between two groups. Inter-rater reliability of five WES variables were calculated with Kendall's coefficient of concordance (W) test. Final inter-rater reliability was averaged score of WES1 and WES2 in five WES variables. The association between patients' evaluation (aVAS, averaged sVAS and cVAS) and dentists' scores (WES) was measured by the Spearman correlation coefficient in two restorations, respectively. Results were considered significant at the 5% level ($P < 0.05$).

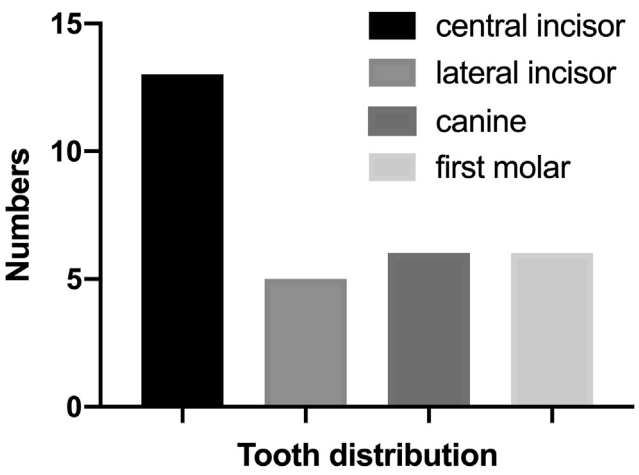

Figure 2 Implant site distribution.

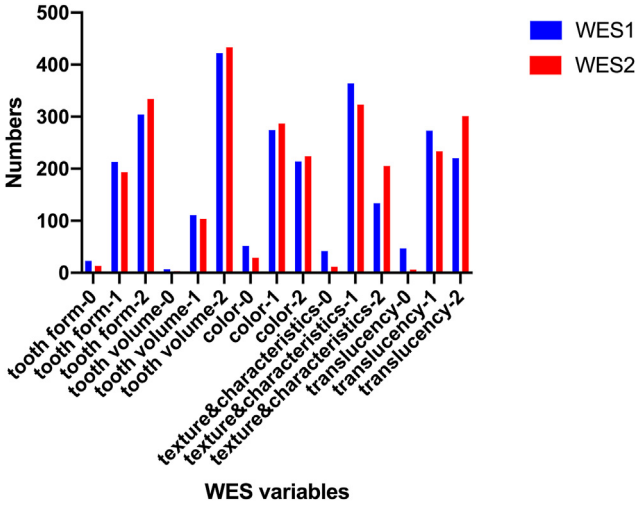

Figure 3 Subscores distribution in White Esthetic Score (WES) variables.

Results

A total of 30 participants were enrolled, including 13 central incisors, 5 lateral incisors, 6 canines and 6 premolars (Fig. 2). Patient demographics were as follows: mean age, 36.3 years old; sex ratio, 56.67% women to 43.33% men. The implants used were SIC (SIC invent AG, Basel, Switzerland). All implants osseointegrated successfully in prosthetic ideal position with or without bone grafting during surgery.

Frequency distribution of variables in the PES/WES index was presented in Fig. 3. For PES, the variable with the largest percentage of score 2 was soft tissue texture, followed by soft tissue color. For WES, most score of 2 was assigned in the tooth volume. The variable of surface texture and characteristics presented with the lowest score in the ratings of WES.

The summarized mean total PES and WES scores with all variables of the 60 examined single-tooth implant restorations in 9 evaluators are presented in Tables 1 and 2, respectively. The mean total PES was 9.75 (8.0—11.0). The mean WES1 and WES2 among all 9 evaluators were 7.5 (6.0—8.0) and 8.0 (6.5—8.5), respectively. The percentage of clinical acceptance of PES, WES1 and WES2 were 81.48%, 80.74% and 88.89%, respectively. When comparing between the WES1 and WES2 in 5 variables separately, the variable color was a marked difference in the evaluation of those two restorations, followed by translucency, surface texture and characteristics and tooth form (Table 3).

Inter-rater reliability of 5 variables in WES were performed to further explore the evaluation consistency. Translucency showed the highest score (0.545), while tooth form demonstrated the lowest agreement (Table 4).

All patients answered the VAS questionnaire. 15 out of 30 patients could not tell the difference between the two restorations. However, among those 15 patients, there was 1 patient whose averaged WES1 score of all evaluators was higher than WES2. Four patients preferred the monolithic zirconia restorations, though no difference was observed in professional evaluation. The rest 11 patients preferred traditional veneered zirconia restorations. For monolithic zirconia restorations, aVAS and oVAS were 9 (8.375—10) and

Table 1 Median (IQR) of each WES variables in all evaluators for Group 1 and Group 2.

	I1	I2	I3	P1	P2	P3	G1	G2	G3
Form 1	2 (1–2)	2 (1–2)	2 (2–2)	1 (1–2)	1 (1–2)	2 (1–2)	2 (1–2)	2 (1–2)	1 (1–2)
Volume 1	2 (2–2)	2 (2–2)	2 (2–2)	2 (2–2)	2 (1–2)	2 (1–2)	2 (1–2)	2 (1–2)	2 (2–2)
Texture & characteristics 1	1 (1–2)	1 (1–1)	2 (2–2)	1 (1–2)	1 (0–1)	1.5 (1–2)	1.5 (1–2)	1 (0–1)	2 (1–2)
Color 1	1 (1–1)	1 (1–1)	1 (1–2)	1 (1–2)	1 (0–1)	1 (1–1)	1 (1–2)	1 (1–1)	1 (1–1)
Translucency 1	2 (1–2)	1 (1–1)	2 (2–2)	1 (1–2)	0 (0–1)	1 (1–1)	1.5 (1–2)	1 (1–2)	2 (1–2)
Sum 1	7.5 (7–8)	7 (6–8)	9 (8–10)	7 (6–8)	4 (2.75–6)	7 (5.25–8)	8 (7–9)	7 (5–8)	8 (7–8)
Form 2	2 (1–2)	2 (1–2)	2 (2–2)	2 (1–2)	1 (1–2)	1 (1–2)	2 (1–2)	2 (2–2)	2 (1–2)
Volume 2	2 (2–2)	2 (2–2)	2 (2–2)	2 (2–2)	1 (1–2)	2 (1–2)	2 (1–2)	2 (2–2)	2 (2–2)
Texture & characteristics 2	1 (1–2)	1 (1–1)	2 (2–2)	1 (1–2)	1 (1–1)	2 (1–2)	1 (1–2)	1 (1–1)	2 (1–2)
Color 2	2 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–1)	1 (1–2)	1 (1–2)	1 (1–2)
Translucency 2	2 (2–2)	1 (1–2)	2 (2–2)	2 (2–2)	1 (1–1)	1 (1–1)	2 (1–2)	1.5 (1–2)	2 (2–2)
Sum 2	8 (8–9)	8 (7–8)	9 (8–10)	8 (7–9)	6 (5–8)	7 (6–8)	8 (7–8.75)	7.5 (6–9)	8 (8–9)

Table 2 Median (IQR) of each PES variables for all evaluators.

	I1	I2	I3	P1	P2	P3	G1	G2	G3
Mesial papilla	1 (1–1)	1 (1–2)	1 (1–1)	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–1)
Distal papilla	1 (1–1)	1 (1–2)	1 (0–2)	1 (1–2)	1 (1–1)	1 (1–1)	1 (1–2)	1 (1–2)	1 (1–1)
Gingival height	2 (1–2)	2 (1–2)	2 (1–2)	2 (1–2)	1 (1–2)	1 (1–2)	2 (1–2)	1 (1–1)	2 (1–2)
Gingival contour	2 (1–2)	1 (1–1)	1 (1–2)	1 (1–1)	1 (1–2)	1 (1–2)	1 (1–2)	1 (1–1)	1 (1–2)
Bone defect	1 (1–1)	2 (1–2)	1 (1–1)	2 (1–2)	1 (1–2)	1 (1–1)	2 (2–2)	1 (1–2)	1 (1–2)
Gingival color	2 (1–2)	1 (1–2)	2 (2–2)	1 (1–2)	1 (1–2)	1 (1–2)	2 (2–2)	1 (1–2)	1 (1–2)
Gingival texture	2 (2–2)	1 (1–2)	2 (2–2)	2 (2–2)	1 (1–2)	1 (1–1)	2 (2–2)	2 (1–2)	2 (1–2)
Sum	10 (9–10)	10 (7.25–11)	10 (8–11)	10 (9–11)	8.5 (7–11)	9 (7–9)	11 (10–12)	9 (7–11)	10 (8–11)

Table 3 Wilcoxon signed rank test result of WES variables comparison between Group 1 and Group 2 (*P* value).

	I1	I2	I3	P1	P2	P3	G1	G2	G3	Overall
Form	0.206	0.317	0.317	0.004[a]	0.144	0.157	0.637	0.008[a]	0.004[a]	0.000[a]
Volume	0.317	0.248	0.317	0.317	1.000	0.046[a]	0.166	0.034[a]	0.317	0.079
Texture + characteristics	0.035[a]	0.617	0.705	0.808	0.000[a]	0.683	0.782	0.014[a]	0.134	0.012[a]
Color	0.000[a]	0.011[a]	0.593	0.275	0.000[a]	0.206	0.827	0.033[a]	0.007[a]	0.000[a]
Translucency	0.001[a]	0.050	0.109	0.000[a]	0.000[a]	0.366	0.433	0.453	0.001[a]	0.000[a]

[a] $P < 0.05$.

Table 4 Kendall's coefficient of concordance for inter-rater reliability in different WES indices.

	Form	Volume	Texture and characteristics	Color	Translucency
Coefficient	0.191	0.261	0.312	0.199	0.545

Table 5 Wilcoxon signed rank test result for comparison between Group 1 and Group 2 in VAS and WES.

	Wilcoxon *P* value
aVAS1 versus aVAS2	0.072
oVAS1 versus oVAS2	0.054
WES1 versus WES2	0.000[a]

VAS, Visual Analog Scale; WES, White Esthetic Score; aVAS, averaged VAS-shape and VAS-color; oVAS, overall VAS.
[a] $P < 0.05$.

9 (8.0–9.0), respectively. While for traditional veneered restorations, aVAS and oVAS were 9 (8.5–10.0) and 9 (8.375–9.5), respectively. There was no significant difference in aVAS and oVAS between two groups. On the contrary, significant difference in WES scores was observed between the two restorations ($P < 0.05$) (Table 5). Spearman correlation revealed no significant correlation between aVAS scores and WES results (Table 6).

Discussion

Due to its better mechanical properties and more efficient CAD/CAM procedures, monolithic zirconia has overtaken traditional veneering zirconia as the preferred restoration

Table 6 Correlation between WES and patient-centered outcome.

	Spearman correlation
WES1 versus aVAS1	0.246
WES2 versus aVAS2	0.224

VAS, Visual Analog Scale; WES, White Esthetic Score; aVAS, averaged VAS-shape and VAS-color.

modality. As we know, this is the first clinical study comparing the clinical performance of monolithic high-translucency multilayer zirconia crowns and traditional veneered zirconia crowns in esthetic area. According to the findings of this investigation, high-translucency multilayer monolithic zirconia in maxillary esthetic areas could be a treatment modality for achieving acceptable patient-centered outcomes.

The grand means of PES, WES1 and WES2 were 9.75 (8.0—11.0), 7.5 (6.0—8.0) and 8.0 (6.5—8.5), respectively. In order to classify esthetic outcome, Cosyn J and colleagues set the thresholds for clinical acceptance at values of 8/14 for the PES and 6/10 for the WES.[19] The percentage of clinical acceptance in previous studies ranged from 84% to 94% for the PES and 79%—100% for WES.[20—22] In this study, the percentage of clinical acceptance of PES, WES1 and WES2 were 81.48%, 80.74% and 88.89%, respectively. The percentage of clinical acceptance for PES were lower than previous results. As we can see from Arora's study in 2017 and 2018,[20,21] the PES scored less in delayed implantation and restoration, when compared to immediate implantation and provisional restoration. Notably, in our study, neither immediate implantation nor provisional crowns were performed, which might explain the relatively lower PES score.

The differences between WES1 and WES2 were noted by most of evaluators (6 out of 9), which indicated the employment of monolithic zirconia in esthetically critical regions is still questionable. As we can see from the results, color and translucency were the major controversial parts, which were in concert with previous study.[7] In fact, pre-colored multilayer zirconia have been introduced as a solution for the color enhancement and gradation of monolithic zirconia restorations. It could make incisal part of restoration least stained, then growing in chroma and opacity towards the gingival region. With zirconia pre-shaded with A2 in our study, externally shading technique was also performed when needed. However, in most cases, the color differences were still perceptible and under clinical acceptability. It is understandable that without traditional multiple layering process, final color might be under expectation in complicated cases.[23] Moreover, the color that the human eyes see is most strongly determined by value. Value indicates the degree of lightness and darkness of an object. Due to a relatively higher opacity with monolithic zirconia, it is no wonder that most evaluators considered the restorations were ivory.

It is well acknowledged that apart from color, translucency is the most significant parameters in evaluating monolithic zirconia. Thus, we singled translucency as one independent variable. Translucency of zirconia is brand dependent and is greatly affected by yttria content, amount of impurities and grain size.[15] In our study, yttrium-tetragonal zirconia polycrystalline (Y-TZP) was used with 5% mol yttria (4% mol yttria at cervical region) with 50% cubic phase content, 0.05wt% Al_2O_3 and grain size of 90 nm. However, most evaluators were not satisfied with the translucency of monolithic restorations in our study, especially for the incisal part. As we can see from photos, incisal translucency was acceptable for some patients. However, for other patients with high incisal translucency, monolithic restoration could not achieve the best esthetic outcome in comparison to traditional veneering zirconia. It is somewhat different from the study conducted by Baldissara et al., in 2018,[9] which stated that ultra-translucent zirconia showed significantly higher translucency than lithium disilicate. In fact, 100% percent cubic grain zirconia in Baldissara's study with reduced content of alumina and porosities would result in more translucent zirconia. On the other hand, zirconia thickness also affects translucency.[24] Thinner translucent zirconia should be preferred when a more translucent part was intended.[25] In our study, in order to achieve the best translucency, thickness of incisal part has been adjusted to around 1 mm when needed. However, the translucency was still under expectation. Thus, in the future, more studies are needed by using different kinds of translucent zirconia.

Surface texture and characteristics was the next controversial parameter in comparing WES1 and WES2. As we can see from the study conducted by Buser in 2009, characteristics was one of WES variables. However, in previous studies, characteristics was either absent or combined with translucency as the last variable. To better evaluate the individualized feature of restorations, in our study, characteristics was combined with surface texture as one variable, as they are both complex and vary greatly from one person to another. As we can see from the result, the score of this combined variable was lower than previous studies.[26] Integration of surface texture and characteristics might be the reason as we all know that individualization in restoration was the most difficult to achieve. In fact, in the study conducted by Li et al., characteristics scored lower when compared to other parameters.[27] On the other hand, surface texture and characteristics scored higher in traditional restorations. By using traditional layering technique, the mixed ceramic powder and its liquid were directly applied on the sintered zirconia core, which could contribute to better surface texture and characteristics. However, characteristics might differ from one dental technician to another depending on their experience or skill.[28,29]

The high patient satisfaction observed in the current study is in line with findings from previous studies.[21,30] In the present sample, aVAS for Group 1 and Group 2 were 9.0 (8.375—10.0) and 9.0 (8.5—10.0), respectively. Moreover, there were 4 patients who rated monolithic zirconia restorations higher. In authors' opinion, this is the most interesting finding in our study. Among these 4 patients, 2 patients (a central incisor and a premolar) told us they would prefer whiter teeth, though veneering restorations scored higher and were more natural for most evaluators. Two patients (a central incisor and a canine) thought monolithic zirconia restorations were more natural, whose

contralateral and adjacent teeth also presented overall opacity without obvious translucent incisal part. Monolithic restorations were also rated higher in professional view, though not reaching statistically significance. On the other hand, there was 1 patient with missing incisor who rated monolithic crown the same with veneered zirconia crown. However, professional difference between two crowns has reached statistically significance ($P < 0.05$). Notably, this patient is 58 years old without obvious transparent incisal part owing to tooth wear. Thus, considered together, monolithic high-translucency multilayer zirconia restoration could be used in certain patients (Fig. 4).

Figure 4 A and B were the patients who prefer whiter restorations; C and D were the patients who thought monolithic zirconia were more natural; Patient E was the patient whose professional score for monolithic restoration was higher and reached statistically significance. 1 and 2 represented monolithic restorations and veneered zirconia, respectively.

Professionally reported esthetic outcomes (PES/WES results) were not significantly correlated with patient-reported outcomes in our study. In fact, it is well established that the opinions of dentists and patients often differ, as demonstrated on numerous occasions.[31,32] For example, as in Altay's study,[33] no significant relationship between PES/WES and VAS score was found. Notably, one study stated that professional opinions might correlate with patients' assessments. However, the correlation coefficient was 0.35 and they have used modified ICAI (Implant Crown Aesthetics Index) score system.[34] In general, patients were less critical than clinicians. Moreover, owing to the subjective nature of esthetics, the opinions of different people, whether patients or professions, often vary. Therefore, it is understandable that the outcomes from objective evaluations may not always fall in line with the patients' satisfaction levels.

Objective and subjective indices have been developed to document and understand the esthetic result of single implant crown and patient satisfaction. In fact, PES/WES is not the only professional indices to evaluate objective esthetic outcomes. There are many other indices such as PICI (Peri-implant and Crown Index) and IAS (Implant Crown Aesthetic Index). However, most indices are more detailed in soft tissue rather than crown. For example, in PICI, it has only 3 indices for crown evaluation, while IAS is just for peri-implant soft tissue evaluation. In our view, WES variables also need to be refined. One study stated that one of the lowest reliability in WES was translucency and characteristics, which demonstrated the worst intra- and inter-reliability.[35] In our study, we singled translucency as an independent parameter, which resulted in the highest inter-rater reliability. Meanwhile, reliability in characteristics also improved, which indicated that combined with surface texture might be better for evaluation. However, reproducibility of WES variables still needs improvement, as we can see from results that inter-rater reliability of other WES variables were generally low with tooth form demonstrating the lowest agreement. There is a need to develop a comprehensive and practical index to assess the esthetic outcomes for single tooth implant restorations that is more detailed to clinicians and technicians. For example, in order to be more objective, tooth form could be divided into shape, crown position, incisal edge position, and mesio-distal dimension. Moreover, color and translucency could be divided into cervical, body and incisal part to evaluate separately.

The limitation of this study are as follows. First, as we focused mainly on white esthetics, patient-centered evaluation of soft tissue was not performed. Second, longer follow-ups are required to thoroughly assess clinical effect of monolithic zirconia restorations. Despite these limitations, the findings of this study could provide an additional insight to application of monolithic high-translucency multilayer zirconia restoration in esthetic area.

Within the limitation of this study, it can be concluded that monolithic high-translucency multilayer zirconia restoration might be a viable treatment modality for certain patients.

Declaration of competing interest

The authors have no conflict of interest to declare.

Acknowledgements

This work was financially supported by the Research Discipline fund No. KQYJXK2020 from Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, and College of Stomatology, Shanghai Jiao Tong University. The authors are sincerely grateful for all the work fabricated by the technician Guo Fu.

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