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## Original Article

# Zirconia implant abutments supporting single all-ceramic crowns in anterior and premolar regions: A six-year retrospective study

Jo-Yu Chen <sup>a</sup>, Yu-Hwa Pan <sup>a,b,c,\*</sup><sup>a</sup> Department of General Dentistry, Chang Gung Memorial Hospital at Taipei, Taipei, Taiwan<sup>b</sup> College of Medicine, Chang Gung University, Taoyuan, Taiwan<sup>c</sup> School of Dentistry, College of Medicine, China Medical University, Taichung, Taiwan

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## ABSTRACT

**Background:** Clinical studies regarding zirconia implant abutments reported good survival rates in the short-term observation period. The purpose of this study was to assess the six-year clinical performance of zirconia abutments supporting all-ceramic crowns in anterior and premolar regions.

**Methods:** The patients received zirconia implant abutments to support all-ceramic crowns in Chang-Gung Medical Center during the period August 2010 to August 2011 were enrolled. In the following six years of observation period after the implant-crown had finished, the clinical parameters of all of the included patients were registered on a special form. The records regarding the following variables: age, gender, implant location, the condition of edentulous site before implant placement, esthetic performance at baseline, presence or absence of technical complications, and biological outcomes were registered and scrutinized for evaluation.

**Results:** Out of the 32 zirconia implant abutments and 32 all-ceramic crowns that were followed for six years. Neither abutments nor crowns were lost, yielding 100% survival rates for both zirconia abutments and crowns. The esthetic outcomes were excellent except that a score of 2 was given to two restorations. With regard to technical complications, there was one instance of abutment screw loosening, two cases of veneering ceramic chipping, one restoration with occlusal roughness, and three instances of crowns loosening. Overall, the success rates were 96.8% and 81.2% for abutments and crowns respectively. In biological performance, only 1 implant was classified in group II (satisfactory survival) in the Misch classification, while all the others were classified in group I (excellent).

**Conclusions:** Zirconia abutments supporting all-ceramic crowns demonstrated high survival rate, good biological and esthetic results. While some technical complications were frequently observed, the complication-free rates were 96.8% for abutments and 81.2% for crowns in the medium-term observation period.

\* Corresponding author. Department of General Dentistry, Chang Gung Memorial Hospital at Taipei, 199, Tunghua North Rd., Taipei 105, Taiwan.

E-mail address: [Shalom.dc@msa.hinet.net](mailto:Shalom.dc@msa.hinet.net) (Y.-H. Pan).

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## At a glance commentary

### Scientific background on the subject

Zirconia implant abutment supporting all-ceramic crown is an available treatment option used in patient with single implant replacement. With the lack of the metallic property of implant abutment, the esthetic performance is good and commonly used in esthetically demanding regions.

### What this study adds to the field

Zirconia implant abutments supporting all-ceramic crowns demonstrated good clinical performance in the medium-term clinical use.

A single implant in the anterior region is an alternative treatment option to conventional fixed partial denture. Clinical studies and systematic reviews have reported high survival rates and high success rates for anterior single implant replacements, and it is thus regarded as a reliable treatment option [1,2].

The available implant abutment materials include gold, titanium, and high-strength ceramics. Metal abutments, owing to their sufficient mechanical strength, are assumed as the optimal choice for single implant reconstructions. However, one shortcoming of metal abutments is their esthetic performance. Specifically, owing to the metallic properties of metal abutments, grayish discoloration would be revealed surrounding the peri-implant soft tissue, especially in the patients with thin gingival biotypes, compromising the esthetic performance [3,4].

To achieve successful implant esthetics, that is, not only white esthetics, but also pink esthetics, which include the peri-implant gingival contour and the gingival color must be taken into consideration. As a result, high-strength ceramics were developed as alternatives to metal implant abutments in areas with high cosmetic demands. High-strength ceramic zirconia, which was introduced as an abutment material in 1995 and has high fracture toughness and good biocompatibility, has been increasingly applied in clinical use [3,5–7].

In a systemic review, aimed at comparing ceramic abutments with titanium abutments in implant reconstruction, the 5-year survival rates appeared to be similar between ceramic and titanium abutments [8]. Previous studies regarding the use of zirconia abutments to support all-ceramic crowns for single implant replacements, identified good survival rates, technical outcomes and biological outcomes, however, the clinical observation time was relatively short in comparison to the survival period we expected. More specifically, the average observation period ranged from 3 to 5 years of function [8–18]. Thus, the aim of this study was to assess the six-year clinical performance of zirconia implant abutments supporting all-ceramic restorations in anterior and premolar regions.

## Materials and methods

This retrospective investigation was conducted in Chang Gung Medical Center. The study design and protocol were

approved by the institutional review board of the Chang Gung Medical Foundation (protocol number: 201801678B0).

### Patient selection

Patients in need of single implant restorations, who were treated consecutively from August 2010 to August 2011 and met the following inclusion criteria were enrolled in the study.

Inclusion criteria were:

1. Patients with a missing tooth in anterior esthetically demanding area (that is, maxillary or mandibular incisor, canine, or first premolar)
2. Males and females aged at least 18 years old
3. Patients who received two-piece zirconia abutments to support all-ceramic crowns in consideration of individual local factors, which included thin biotype of gingiva, patients with high smile lines, patients with high esthetic demands and high esthetic expectations [19–21].

If any of the following exclusion criteria were met, the patients had to be excluded from the study:

1. Patients with systemic diseases (such as heart, coagulation, and leukocyte diseases or metabolic disorders)
2. Physically or mentally handicapped patients who have difficulty in maintaining adequate oral hygiene
3. Patients with inadequate oral hygiene
4. Patients with smoking habit (more than 15 cigarettes per day)
5. Patients with teeth adjacent to the implant site with a pocket probing depth of  $\geq 4$  mm
6. Patients with a lack of primary stability of the implant
7. Patients with severe bruxism and clenching habits
8. Patients who received extensive bone augmentation due to inadequate vertical bone volume during stage I implant surgery (The edentulous site was classified as Garber Class V [22,23] [Table 1]).
9. Patients with insufficient soft tissue volume around implant site
10. Patients with deep bite occlusion

**Table 1 Implant placement in edentulous sites Garber classification [22,23].**

Class I	Favorable horizontal and vertical levels of both soft tissue and bone
Class II	Sites with no vertical bone loss and slight horizontal bone deficiency measuring about 1–2 mm narrower than normal
Class III	Sites with no vertical bone loss and horizontal bone loss greater than Class II
Class IV	Sites with no vertical bone loss but significant horizontal loss
Class V	Sites with extensive apicocoronal bone loss present

**Table 2 Gender and age distribution of patients.**

Age	Gender	
	Male	Female
20–30 years	4	6
30–40 years	6	8
40–50 years	3	2
50–60 years	1	2
total	14	18

**Table 3 Distribution of all 32 implants by region.**

Region	Maxilla	Mandible	Total
Central incisor	12	2	14
Lateral incisor	7	1	8
Canine	3	1	4
First premolar	4	2	6

A total of 32 patients were included in this study. 14 female patients and 18 male patients with good general health were evaluated. The median age of the patients was 36.2 years old, with a range from 20 to 58 years old [Table 2]. The 32 implants in 32 patients were divided into subgroups according to the missing tooth location in the anterior and premolar regions [Table 3].

The data were collected from patient's records in the 6-year observation period regarding the following variables: age, gender, implant location, the condition of edentulous site before implant placement, esthetic performance at baseline, presence or absence of technical complications, and biological outcomes. All of the records were registered on a special form for each patient and the data were scrutinized for evaluation.

### Follow-up and maintenance

One week after the date of crown cementation was considered the baseline. The follow-up visits took place at 1 month after the baseline, 6 months after the baseline, and annual follow-up visits thereafter. The clinical parameters registered in this study included the following items:

1. Esthetic outcomes: All of the implant-supported prostheses were evaluated at baseline according to a four-point scale (1 = excellent, 4 = very poor) by a blinded prosthodontic examiner, who was independent and not involved in the treatment course. The evaluation scale used in this study was modified on the basis of current proposed implant esthetics indices [24–27], and classified the esthetic performance into four classes regarding following parameters: crown morphology, shade matching, harmony of the gingival color and contour.
2. Technical outcomes: The technical complications registered in this study included following factors: fracture of the abutment, fracture of the abutment screw, loosening of the abutment screw, fracture of the crown framework, fracture of the veneering ceramic, loosening of the crown (decementation), and occlusal wear.
3. Biological outcomes: Standardized periapical radiographs were taken at the implant sites by means of the paralleling

method at the base line visit and follow-up visits. The peri-implant tissue status was measured according to the Misch implant classification system [28,29] [Table 4], which uses a combination of qualitative and quantitative criteria to classify the status in 1 of 4 classes.

### Surgical procedures

The implants (Biomet 3i Certain R implant system, Palm Beach, USA) were placed according to a standard two-stage protocol by oral surgeons for submerged healing and early implant placement protocol were followed [30,31]. The three-dimensional placement of the implant followed surgical guideline by Bashutski and Wang [32], the implant was placed in a position with at least 2 mm of buccal bone, approximately 3 mm apical to the cemento-enamel junction of the adjacent teeth, and about 1.5 mm from the adjacent tooth root.

The 32 edentulous sites in 32 patients were thoroughly evaluated before implant placement, including soft and hard tissue quality and quantity, and the necessity of reconstruction to get good positioning of the implant followed Garber classification [22,23] [Table 1]. The 9 cases of edentulous sites were classified as Garber Class II and Class III, where the edentulous sites were with different degree of insufficient horizontal bone volume and bone regenerations were implemented simultaneously during implant insertion. The other 23 edentulous sites were classified as Garber Class I, where the sites were with favorable soft and hard tissue and ideal implant placement procedures were performed. With regard to soft tissue condition, the 32 edentulous sites were with sufficient keratinized gingiva and the tissue biotypes of all the 32 patients were thin biotypes, which measured by probe

**Table 4 Health Scale for Dental Implants by Misch classification [28].**

Implant quality scale (Group)	Clinical conditions
Group I. Success (optimum health)	A. No pain or tenderness upon function B. No mobility C. <2 mm radiographic bone loss from initial surgery D. No exudates history
Group II. Satisfactory survival	A. No pain on function B. No mobility C. 2–4 mm radiographic bone loss D. No exudates history
Group III. Compromised survival	A. May have sensitivity on function B. No mobility C. Radiographic bone loss >4 mm (less than 1/2 of implant body) D. Probing depth >7 mm E. May have exudates history
Group IV. Failure (clinical or absolute failure)	Any of the following: A. Pain on function B. Mobility C. Radiographic bone loss >1/2 length of implant D. Uncontrolled exudate E. No longer in mouth

transparency. No soft tissue augmentation was performed prior to implant placement in the 32 edentulous sites.

During the healing period, the edentulous areas were restored with interim removable partial dentures or provisional fixed prostheses.

### Prosthetic procedures

After up to 6 months of healing, the implants were uncovered, and transmucosal healing abutments were inserted. The prosthetic treatments were conducted by an experienced prosthodontist. Each provisional crown was fabricated according to the condition the given patient's peri-implant soft tissue in order to achieve a harmonious gingival contour and emergence profile before the final impression was taken. Subsequently, a final impression was taken at the implant level, using a silicone impression material (Aquisil Ultra LV, Dentsply Sirona, USA) and customized impression coping (Cerec, Dentsply Sirona, Germany).

Two-piece zirconia abutment was used, which consisted of a titanium insert (Ti-Base, Sirona Dental Systems) and a transmucosal zirconia part. The zirconia part was customized by using a CAD/CAM system (Cerec, Dentsply Sirona, Germany). The individually zirconia part was connected to the titanium insert by way of cement.

All the zirconia abutments were tightened to 20N according to the manufacturer's recommendation. The all-ceramic crowns (LAVA™ All Ceramic System, 3M, ESPE, Germany) were fabricated and cemented to the zirconia abutments with Hy-Bond™ polycarboxylate cement (Shofu Dental Corporation, California, USA).

This study was thus based on data from 32 patients, all of whom completed the 6 years follow-up. Survival was defined as the zirconia abutments and crowns existing for the entire observation period. Success was defined as there being none of the above-mentioned technical complications. The survival rate and success rate were calculated.

## Results

All of the 32 patients had completed the 6 years follow-up. Neither zirconia abutments nor all-ceramic crowns were lost during the observation period, yielding 100% survival rates for both zirconia abutments and crowns.

The esthetic performance results are displayed in [Table 5]. Two of the restorations were evaluated as acceptable, while all of the others were evaluated as excellent. With regard to technical outcomes, detailed results are displayed in [Table 6]. There was one instance of abutment screw loosening, two cases of veneering ceramic chipping, one restoration with occlusal roughness, and three instances of crowns loosening. Other than those issues, no more complications occurred. In seven technical complications, 3 cases occurred in anterior region and the others occurred in premolar region. The success rates were 96.8% for abutments and 81.2% for crowns.

The biological outcomes of the implants, abutments and crowns were excellent with no biological complications at the implant sites. Only one implant resulted in 2.1 mm of bone loss at one year follow-up visit, and that implant was still

**Table 5 Esthetic performance of implant-supported restorations at baseline (n = 32).**

Evaluation results (four-point scale)			
1 = Excellent	2 = Acceptable	3 = Poor	4 = Very poor
30	2	0	0

classified in group II (satisfactory survival) in the Misch classification, while all the others were classified in group I (excellent). All the associated data are shown in [Table 7].

## Discussion

The esthetic outcomes of zirconia abutments have generally been found to be pleasing, including exhibiting less mucosa shine-through and less discoloration of peri-implant tissues [4,9,10,16]. In a systemic review, which assessed the influence of zirconia implant abutment and titanium abutment on peri-implant soft tissue, the results revealed that there was a significant tendency in zirconia abutments evoking better color response of peri-implant mucosa and superior esthetic outcome measured by Pink Esthetic Score [10]. In the present study, only two prostheses were evaluated as having a score of 2 (acceptable) in the esthetic evaluations, with each of those scores being due to the shade of the restoration was not as the same as that of adjacent natural teeth. However, with regard to the prosthesis morphology, gingival contours and gingival colors were all in harmony with adjacent teeth.

The evaluation of implant esthetics can be performed either by using subjective Visual Analog Scale or other objective assessments using proposed implant esthetic indices. There were few indices to clinically evaluate implant esthetics, Pink Esthetic Score/White Esthetic Score index were widely used due to PES/WES index were more reproducible and were not influenced by different observers [33]. According to the literature survey, esthetic parameters regarding the zirconia abutments were included in prospective designed studies, however, the information regarding esthetic performance in the retrospective design was rare [10,13,17,18]. The 4-point scale was used in present investigation and aimed to simplify the difficulty of esthetic evaluation due to restricted study design. Future research projects to perform a prospective designed study and more reliable esthetic indices may be needed in the future.

**Table 6 Technical complications in 6-year follow up period.**

	Anterior region	Premolar region
Abutment fracture	0	0
Abutment screw loosening	0	1 (3.1%)
Abutment screw fracture	0	0
Fracture of crown framework	0	0
Fracture of veneering porcelain (chipping)	0	2 (6.2%)
Crown loosening (decementation)	3 (9.3%)	0
Occlusal wear	0	1 (3.1%)

**Table 7 Biological performance of dental implants according to Misch classification [25] (n = 32).**

Evaluation results			
Group I. Success (optimum health)	Group II. Satisfactory survival	Group III. Compromised survival	Group IV. Failure (clinical or absolute failure)
31	1	0	0

In general, technical complications are frequently reported for single implant replacements, with the common technical issues including abutment screw fracture, screw loosening, ceramic chipping, framework fracture, and crown loosening [9]. Abutment screw loosening was the most frequent technical complication in single-implant restorations [34]. The type of connection was reported to be a primary factor in screw loosening, and which more frequently occurred in external connections in comparison of internal connected abutments [9,34]. Similar findings were reported by Fabbri et al. [35], evaluating the influence of implant connection type on the reliability of zirconia abutments and concluding that internal connections with secondary metallic components reduced the incidence of complications. The results revealed screw loosening was more frequently occurred in external connection zirconia abutment (1.2%) than internal connection with metal components (0.4%), followed by full-zirconia conical connection (0%). In the present study, the zirconia abutments were internal connection with metal components and the relatively low rate of abutment screw loosening can be explained.

The frequency of veneering porcelain chipping in the present study was 6.2%. A recent systemic review on all-ceramic crowns supported by zirconia abutments revealed an estimated 3.2% of chipping rate [9], which was relatively low in comparison with the result in the present study. However, the factors influencing porcelain chipping are multifactorial, such as insufficient zirconia cooling time, and the cement type used, and these factors might have contributed to the relatively high chipping rates [36].

Three crown decementations were observed (9.3%) in the present study, which was a relatively high rate in comparison to the estimated 5-year rate of crown decementation of 5.5% reported in a systemic review by Pjetursson et al. [1]. The cement type used is a factor that contributes to this complication. In consideration of crown retrievability, in the present study, semi-permanent cement was used in all of the crowns.

The biological performance of the zirconia abutments used in this study was excellent. Only one implant was reported with 2.1 mm of bone loss at one year follow-up visit, and that implant was still classified as having satisfactory survival according to the Misch classification. Although the bone loss > 2 mm, no probing pocket depth was greater than 5 mm and no bleeding on probing or suppuration was detected, and the bone level of this implant was near the 2.1 mm in the following annual follow-up visits, no further advanced bone loss was observed. The other 31 implants demonstrated low amounts of bone loss and no peri-implant tissue inflammation. These results were in accordance with those of multiple previous studies, which collectively indicated that zirconia is biocompatible materials that is prone to less inflammation and less plaque accumulation in comparison with titanium [37,38].

Zirconia abutments were commonly used in esthetically demanding regions. In the present study, the implants existing in the anterior and premolar regions were enrolled. The results revealed there were no clinically relevant differences between anterior and premolar regions in esthetic and biological performance. However, technical complications were detected primarily in the premolar regions, except crown decementation, which probably due to provisional cementation. The results were in accordance with a systemic review, which compared the incidence of complications of different abutment materials in anterior and posterior regions. The results revealed the increased incidence of technical complications occurred in the posterior region due to high functional loading [39].

The information on long-term performance of zirconia abutments supporting all ceramic crowns is still scarce, this clinical study is a 6 years results and it is part of an ongoing long-term evaluation of zirconia implant abutments supporting all ceramic crowns. Further update results (>7 years ≤ 12) with greater number of patients may be required to confirm the medium-term findings.

## Conclusions

Zirconia abutments supporting all-ceramic crowns in anterior and premolar single implant replacements constitute a promising treatment option in the medium-term observation period. Overall, a high implant survival rate, good biological intergration and excellent esthetic performance can be expected. Moreover, while some technical complications were frequently observed, the rates of complication-free were 96.8% for abutments and 81.2% for crowns respectively.

## Conflicts of interest

The authors declare no conflicts of interest.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.bj.2019.05.001>.

## REFERENCES

- [1] Jung RE, Zembic A, Pjetursson BE. Systematic review of the survival rate and the incidence of biological, technical, and aesthetic complications of single crowns on implants reported in longitudinal studies with a mean follow-up of 5 years. *Clin Oral Implants Res* 2012;23:2–21.
- [2] Pjetursson BE, Bragger U, Lang NP. Comparison of survival and complication rates of tooth-supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). *Clin Oral Implants Res* 2007;18:97–113.
- [3] Yildirim M, Edelhoff D, Hanisch O. Ceramic abutments—a new era in achieving optimal esthetics in implant dentistry. *Int J Periodontics Restor Dent* 2000;20:81–91.
- [4] Jung RE, Sailer I, Hammerle CH. In vitro color changes of soft tissues caused by restorative materials. *Int J Periodontics Restor Dent* 2007;27:251–7.
- [5] Ormianer Z, Schirotti G. Maxillary single-tooth replacement utilizing a novel ceramic restorative system: results to 30 months. *J Oral Implantol* 2006;32:190–9.
- [6] Scarano A, Piattelli M, Caputi S. Bacterial adhesion on commercially pure titanium and zirconium oxide disks: an in vivo human study. *J Periodontol* 2004;75:292–6.
- [7] Piconi C, Maccauro G. Zirconia as a ceramic biomaterial. *Biomaterials* 1999;20:1–25.
- [8] Sailer I, Philipp A, Zembic A. A systematic review of the performance of ceramic and metal implant abutments supporting fixed implant reconstructions. *Clin Oral Implants Res* 2009;20:4–31.
- [9] Zembic A, Kim S, Zwahlen M, Kelly R. Systematic review of the survival rate and incidence of biologic, technical, and esthetic complications of single implant abutments supporting fixed prostheses. *Int J Oral Maxillofac Implants* 2014;29:99–116.
- [10] Linkevicius T, Vaitelis J. The effect of zirconia or titanium as abutment material on soft peri-implant tissues: a systematic review and meta-analysis. *Clin Oral Implants Res* 2015;26:139–47.
- [11] Zembic A, Sailer I, Jung RE, Hammerle CH. Randomized-controlled clinical trial of customized zirconia and titanium implant abutments for single-tooth implants in canine and posterior regions: 3-year results. *Clin Oral Implants Res* 2009;20:802–8.
- [12] Canullo L. Clinical outcome study of customized zirconia abutments for single-implant restorations. *Int J Prosthodont* 2007;20:489–93.
- [13] Ekfeldt A, Furst B, Carlsson GE. Zirconia abutments for single-tooth implant restorations: a retrospective and clinical follow-up study. *Clin Oral Implants Res* 2011;22:1308–14.
- [14] Lops D, Bressan E, Chiapasco M, Rossi A, Romeo E. Zirconia and titanium implant abutments for single-tooth implant prostheses after 5 years of function in posterior regions. *Int J Oral Maxillofac Implants* 2013;28:281–7.
- [15] Nothdurft F, Pospiech P. Prefabricated zirconium dioxide implant abutments for single-tooth replacement in the posterior region: evaluation of peri-implant tissues and superstructures after 12 months of function. *Clin Oral Implants Res* 2010;21:857–65.
- [16] Sailer I, Zembic A, Jung RE, Siegenthaler D, Holderegger C, Hammerle CH. Randomized controlled clinical trial of customized zirconia and titanium implant abutments for canine and posterior single-tooth implant reconstructions: preliminary results at 1 year of function. *Clin Oral Implants Res* 2009;20:219–25.
- [17] Zembic A, Bosch A, Jung RE, Hammerle CH, Sailer I. Five-year results of a randomized controlled clinical trial comparing zirconia and titanium abutments supporting single-implant crowns in canine and posterior regions. *Clin Oral Implants Res* 2013;24:384–90.
- [18] Wittneben JG, Gavric J, Belser UC. Esthetic and clinical performance of implant-supported all-ceramic crowns made with prefabricated or CAD/CAM zirconia abutments: a randomized, multicenter clinical trial. *J Dent Res* 2017;96:163–70.
- [19] Sailer L, Zembic A, Jung RE, Hammerle CH, Mattiola A. Single-tooth implant reconstructions: esthetic factors influencing the decision between titanium and zirconia abutments in anterior regions. *Eur J Esthet Dent* 2007;2:2296–310.
- [20] Park SE, Da Silva JD, Weber HP, Ishikawa-Nagai S. Optical phenomenon of peri-implant soft tissue. Part I. Spectrophotometric assessment of natural tooth gingiva and peri-implant mucosa. *Clin Oral Implant Res* 2007;18:569–74.
- [21] Zucchelli G, Mazzotti C, Mounssif I, Mele M, Stefanini M, Montebugnoli L. A novel surgical-prosthetic approach for soft tissue dehiscence coverage around single implant. *Clin Oral Implant Res* 2013;24:957–62.
- [22] Garber DA, Rosenberg ES. The edentulous ridge in fixed prosthodontics. *Compend Contin Educ Dent* 1981;2:212–23.
- [23] Al-Sabbagh M. Implants in the esthetic zone. *Dent Clin N Am* 2006;50:391–407.
- [24] Belser U, Grutter L, Vailati F, Bornstein MM, Weber HP, Buser D. Outcome evaluation of early placed maxillary anterior single-tooth implants using objective esthetic criteria: a cross-sectional, retrospective study in 45 patients with a 2- to 4-year follow-up using pink and white esthetic scores. *J Periodontol* 2009;80:140–51.
- [25] Buser D, Chappuis V, Bornstein MM, Wittneben JG, Frei M, Belser UC. Long-term stability of contour augmentation with early implant placement following single tooth extraction in the esthetic zone: a prospective, cross-sectional study in 41 patients with a 5- to 9-year follow-up. *J Periodontol* 2013;84:1517–27.
- [26] Fürhauser R, Florescu D, Benesch T, Haas R, Mailath G, Watzek G. Evaluation of soft tissue around single-tooth implant crowns: the pink esthetic score. *Clin Oral Impl Res* 2005;16:639–44.
- [27] Hof M, Umar N, Budas N, Seemann R, Pommer B, Zechner W. Evaluation of implant esthetics using eight objective indices—comparative analysis of reliability and validity. *Clin Oral Impl Res* 2018;29:697–706.
- [28] Misch CE, Perel ML, Wang HL, Sammartino G, Moreno PG, Trisi P, et al. Implant success, survival, and failure: the international congress of oral implantologists (ICOI) pisa consensus conference. *Implant Dent* 2008;17:5–15.
- [29] Abrishami MR, Sabour S, Nasiri M. Comparison of the reproducibility of results of a new peri-implantitis assessment system (implant success index) with the Misch classification. *J Korean Assoc Oral Maxillofac Surg* 2014;40:61–7.
- [30] Adell R, Lekholm U, Rockler B, Branemark PI, Lindhe J, Eriksson B, et al. Marginal tissue reactions at osseointegrated titanium fixtures(I). A 3-year longitudinal prospective study. *Int J Oral Maxillofac Surg* 1986;15:39–52.
- [31] Chen ST, Wilson Jr TG, Hammerle CH. Immediate or early placement of implants following tooth extraction: review of biologic basis, clinical procedures, and outcomes. *Int J Oral Maxillofac Implants* 2004;19:12–25.
- [32] Bashutski JD, Wang HL. Common implant esthetic complications. *Implant Dent* 2007;16:340–8.
- [33] Tettamanti S, Millen C, Gavric J, Buser D, Belser U, Brägger U, et al. Esthetic evaluation of implant crowns and peri-implant soft tissue in the anterior maxilla: comparison and reproducibility of three different indices. *Clin Implant Dent Relat Res* 2016;18:517–26.

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- [34] Gracis S, Michalakis K, Vigolo P, Vult von Steyern P, Zwahlen M, Sailer I. Internal vs. external connections for abutment/reconstructions: a systematic review. *Clin Oral Implants Res* 2012;23:202–16.
- [35] Fabbri G, Fradeani M, Dellificorelli G, De Lorenzi M, Zarone F, Sorrentino R. Clinical evaluation of the influence of connection type and restoration height on the reliability of zirconia abutments: a retrospective study on 965 abutments with a mean 6-year follow-up. *Int J Periodontics Restor Dent* 2016;36:19–31.
- [36] Tholey MJ, Swain MV, Thiel N. Thermal gradients and residual stresses in veneered Y-TZP frameworks. *Dent Mater* 2011;27:1102–10.
- [37] Degidi M, Artese L, Scarano A. Inflammatory infiltrate, microvessel density, nitric oxide synthase expression, vascular endothelial growth factor expression, and proliferative activity in peri-implant soft tissues around titanium and zirconium oxide healing caps. *J Periodontol* 2006;77:73–80.
- [38] Rimondini L, Cerroni L, Carrassi A. Bacterial colonization of zirconia ceramic surfaces: an in vitro and in vivo study. *Int J Oral Maxillofac Implants* 2002;17:793–8.
- [39] Influence of implant location on the clinical outcomes of implant abutments: a systematic review and meta-analysis. *Clin Cosmet Investig Dent* 2018;10:19–35.