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INFLUENCE OF ABUTMENT DESIGN ON CLINICAL OUTCOME OF IMPLANT-SUPPORTED MONOLITHIC ZIRCONIA CROWNS

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ABSTRACT

Statement of problem: Longer-term clinical trials with success data are required to validate the current design options of Ti base as viable abutments.

Objective: The aim of this clinical research was to investigate the influence of abutment designs on the clinical outcome of screw- and cement-retained, implant-supported monolithic zirconia crowns.

Material and methods: A total of 28 patients with missing 30 single maxillary premolar areas were implanted (4.1x12mm), and random classified into 3 equal groups (n =10): Group (A) (VC): patients receiving hybrid Ti base abutments (Variobase, Straumann, Switzerland) with cement-retained crowns, Group (B) (VS): patients receiving hybrid Ti base abutments (Variobase) with screw-retained crowns, Group (C) (DS): patients receiving non-segmented screw-retained crown (cemented onto Dess Ti Base). The monolithic zirconia crowns were CAD/CAM fabricated, cemented, and evaluated at baseline, 3, 6, 12 and 18 months clinically and radiographically. All data were collected and statistically analyzed.

Results: All 30 implants remained stable and reached osseointegration (100% cumulative success rate [CSR]). The highest mean average crestal bone level (BL) measured 1.23+0.72mm (median: 1.40mm, range: 0.00-2.25mm) (P=0.09 NS) in group (C) (DS), and the least mean BL measured 1.00+0.55mm (median: 1.10mm, range: 0.00-2.00mm) and (median: 1.00mm, range: 0.10-1.90mm) (P=0.83 NS) and (P=0.52 NS) in the groups (B and A) (VS and VC) respectively.

Conclusions: Under the conditions of this study, using a prefabricated (Variobase or Dess) Ti base as an abutment for an implant-supported zirconia crown is an alternative procedure for FPDs. It promotes healthy and stable hard and soft tissues.

KEYWORDS: Variobase, Ti base, abutment design, clinical evaluation, monolithic zirconia.

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INTRODUCTION

Technical development in the field of digital dental medicine has opened the opportunity for the manufacturing of reconstructions using high-performance materials.[1-3] Recently, the entire prosthetic fabrication process of implant-supported reconstructions has been introduced in a complete digital workflow even without any physical models.[4,5] In addition, the production of the suprastructure can be simplified by the option to connect crowns to prefabricated or individually customized abutments.[6,7]

Single-tooth replacement of sequentially missing teeth is the standard in modern implantology.[8,9] Clinical evaluation of implants is recorded with regard to osseointegration. Implants fulfill the success criteria when: implants showed stable osseointegration, with absence of pain or suppuration, absence of clinically detectable implant mobility, absence of peri-implant radiolucency, a distance between the implant shoulder and the first visible bone-to-implant contact (DIB) ≤ 1.5 mm during the first year followed by 0.2 mm per additional year in function, and absence of prosthetic complications at the implant-abutment interface.[10]

A new prefabricated bonding base Ti abutment (Variobase) has been developed patenting engaging mechanism supposed to allow accurate seating of the coping, crown, bridge, or bar on the abutment thanks to the four precisely engaging cams. The company claimed that it is simple to use, facilitate accurate wax-up, and simple bonding, allow design flexibility for specific prosthetic solutions, and does not need sandblasting. Initial laboratory investigations have demonstrated promising mechanical results for monolithic implant crowns luted to this abutment and revealed constantly high values for stiffness and strength under quasistatic loading.[7,11,12] It revealed more favorable outcome economically and esthetically than the individualized abutment by providing adequate space for the translucent resin nano-ceramic crown material.[13] Anti-rotational abutment features positively affected the marginal fit of single implant-retained crowns. Furthermore, digitizing techniques improved the fit of single-implant restorations.[14]

The monolithic nature of the restoration is supposed to prevent ceramic fractures and chipping. In addition, cementing the components extraorally should reduce the possibility of excess cement and cement-induced peri-implantitis.[15, 16] Zirconia (ZrO2) is a highly attractive ceramic material in prosthodontics. It is widely used to build prosthetic devices because of its good chemical properties, dimensional stability, high mechanical strength, toughness, and a Young's modulus (210 GPa) similar to that of stainless steel alloy (193 GPa).[17, 18]

Calderon et al.,[19] tested 60 3-unit monolithic zirconia iFDPs produced onto conical and cylindrical Ti base abutments. A higher percentage of debonding and micromovement was recorded in group C (conical Ti base abutment for the prosthesis and cylindrical Ti base abutment for the crown). The conical Ti base abutments had a higher debonding and a higher macromovement rate.[19]

A review performed by Al-Thobity[15] reporting that several studies investigated the effect of introducing Ti base abutments into implant-supported restorations. Zirconia abutments with Ti inserts were found to have a remarkable increase in fracture resistance compared with the one-piece zirconia. The fracture of one-piece anatomic contour zirconia abutments occurred either at the coronal part of the abutments or at the hexagon connection part.[15]

While these developments and concepts appear to be quite promising, clinical evidence is needed to validate their performance.[16] The null hypothesis was that no difference exists in the clinical and radiographic outcomes of the implant-supported monolithic zirconia crowns screw- and cement-retained to the new prefabricated bonding base Ti abutments (Variobase, Institut Straumann, Switzerland) and the non-segmented zirconia implant crowns (Dess Ti Base, Spain).

MATERIAL AND METHODS

A total of 28 patients, with missing 30 single maxillary premolar indicated for single implants, were selected according to certain inclusion and exclusion criteria.[5,20] Two patients presented with missing right and left maxillary premolars. For the purpose of standardization, all the steps in this in vivo study were carried out by one clinician and one experienced master dental technician according to the manufacturers' instructions. Primary result measure was peri-implant bone level change following 1 year of loading; clinical significance was set at >0.25 mm difference and a 0.3 mm standard deviation was estimated. A power calculation was done by using G*Power24 (Version 3.1.9.2) and exposed that 10 implants in each group would be required (80% power, normal distribution, 2 tailed).[21]

The treatment planning and CBCT (cone beam computed tomography) were performed to visualize and measure the thicknesses of both hard and soft tissues.[22] Partially-guided 3D-printed surgical guide stents were fabricated using an additive manufacturing by using the CBCT.[23] All individuals received single implants using a two-stage surgical technique. The surgical stage-1 involved "closed flap" technique as the stent and universal surgical kit were used (In2Guid Universal kit Cybermed Inc.). A Regular Tissue Punch (R 4 mm diameter) was used until touching the bone to reflect a full thickness mucoperiosteal flap by using a mucoperiosteal elevator. The osteotomy was initiated using a pilot drill of 2 mm diameter through the stent, followed by sequential drilling to prepare the site according to the selected implant size (4.1mm diameter).

The 3D-Printed surgical drills were used in series (2, 2.5, 2.8, 3, 3.3, and 3.5 mm diameter) with the guided keys. The final drill was 3.5 mm in diameter (surgical drill, Institut Straumann AG, Basel, Switzerland), as the stent was partially-guided. The Ti implant (RC Bone Level Tapered Ti Implant SLA RN, 4.1 x 12 mm, Institute Straumann AG, Switzerland) was positioned in the osteotomy site with the help of a Ratchet and Torque control device (Institut Straumann AG, Switzerland) at 35 Ncm of torque. A digital periapical radiograph was taken immediately after the fixture placement. The long-cone parallel technique was used with a prefabricated film holder (The posterior Hanshin film holder, Japan), to standardize the film positioning.

In the surgical stage-2, 3-6 months after implant placement, the site was found to be healed well. A digital periapical radiograph was taken. The surgical re-entry was performed by a short vertical incision, and a gingival former (RC Healing Abutment 3.5/4.0, Institute Straumann AG, Switzerland) was inserted. After 1-2 weeks, a closed-tray (indirect) impression was taken for each patient on implant level using a Vinyl Polysiloxane (VPS) impression material with a transfer type of impression coping with a polymer rectangular cap (RC Closed-tray impression posts, Straumann AG, Switzerland). The impression was made with an addition silicone impression material (Ghenesyl addition curing silicone impression material, LASCOD Spa, Italy) using a 1-step (one phase) (putty-wash) impression technique. The RC implant analog (Institute Straumann AG, Switzerland) was attached to the impression coping, and then was accurately seated into its corresponding location in the set impression. A soft tissue cast was poured producing a final cast with the implant position and soft tissue representing the intra oral conditions.

Sealed, sequentially numbered, envelopes comprising the randomized allocation were organized via an external source prior to the beginning of the restorative phase (www.sealedenvelope.com). The thirty implants were random classified for comparative evaluation into 3 equal groups (n =10)[5,18] according to the design of Ti base abutment, and the retention type of monolithic zirconia crown as follows:

1. **Group (A) (VC)**: patients receiving hybrid (prefabricated bonding bases) Ti abutments (Variobase, Straumann, Switzerland) with cement-retained crowns.

2. **Group (B) (VS)**: patients receiving hybrid (prefabricated bonding bases) Ti abutments (Variobase) with screw-retained crowns.
3. **Group (C) (DS)**: patients receiving non-segmented screw-retained crowns (cemented onto Dess Ti Base).

In the restorative phase, the CAD/CAM technology (Ceramill map200 Units, AmannGirrbach North America, LP, USA) was used to create all zirconia crowns in the 3 groups from the partially-sintered highly translucent monolithic zirconia blanks (Ceramill zolid ht+ preshades, AmannGirrbach North America, LP, USA). The monolithic zirconia crowns were fabricated by CAD/CAM scanning, designing, milling, sintering, finishing and polishing, wax try-in, staining, and glazing. The edentulous ridge, adjacent teeth, and Ti base were sprayed with a thin layer of an antireflection scan powder (CAD/CAM Telescan Spray, White 75 ml, DFS Diamon GmbH, Riedenburg, Germany). A scanbody (CARES® RC Mono ScanBody RN (D 4.1mm, H 10mm), Institut Straumann AG, Basel,) was used in the scanning to allow the fabrication of a screw channel in group (B).

The surface treatment of the crown was performed by air-abrasion of the intaglio surface using alumina particles (Al_2O_3) (50 μm). The internal surfaces of the crown, and the Ti abutment were covered with a slight coat of a specialized primer (Z-PRIME plus, BISCO, Inc. Schaumburg, IL 60193, USA). The crowns of each group were cemented to the respective Ti bases (abutments) with a dual-cured, self-adhesive, resin cement (PANAVIA SA Cement Universal, Kuraray Noritake Dental Inc., Japan) following the Variobase and cement manufacturers' instructions.[23]

The crowns were cemented intraorally in group (A) and cemented extraorally in the groups (B) and (C), to remove the excess cement. The screw channel of the abutment was filled using a wax for maintenance, then sealed with a resin composite (A2 Tetric N-Ceram, ivoclar vivadent) from the top of abutment to occlusal surface in the groups (B) and (C). The implant-supported crowns were evaluated at the baseline (Time 0) (Figure 1), 3, 6, 12, and 18 months clinically and radiographically. A single, calibrated examiner, blinded to the experimental procedures, assessed all the clinical results of the study both at the baseline and at the follow-up evaluations. All data were collected and statistically analyzed.

Statistical analysis

All data were collected, tabulated, coded, and then statistically analyzed using a statistical software program (SAS, (2004). SAS/STAT user's guide: Version 9.1.3. SAS Inst., Cary, NC.) using the general linear models (GLM).

The descriptive statistics for quantitative data were calculated in the form of mean ± standard deviation (SD), median, range (minimum and maximum), and frequency (Number-percent) values. The groups were compared by two-way analysis of variance (ANOVA) and the significance of the mean difference between the groups were done by Tukey's multiple comparison test after ascertaining the normality by Shapiro–Wilk test. For comparisons of periodontal parameters, the Kruskal-Wallis test was used. The Wilcoxon matched-pairs signed-rank test was applied for comparisons of crestal bone level changes. Furthermore, global P-values were computed for changes in BL, modPI, BoP, and PPD over time at sequential follow-up dates from baseline to 18 months. The statistical significance of the obtained results was set at ≤0.05 level.

RESULTS

All patients were satisfied with the esthetic and functional outcome at all examination. No implant was lost (100% overall survival rate). All 30 implants remained stable and reached osseointegration (100% cumulative success rate [CSR]) after 18 months follow up.

Considering the hard tissues (radiographic) evaluation, the present study revealed that the highest mean average crestal bone level (BL)

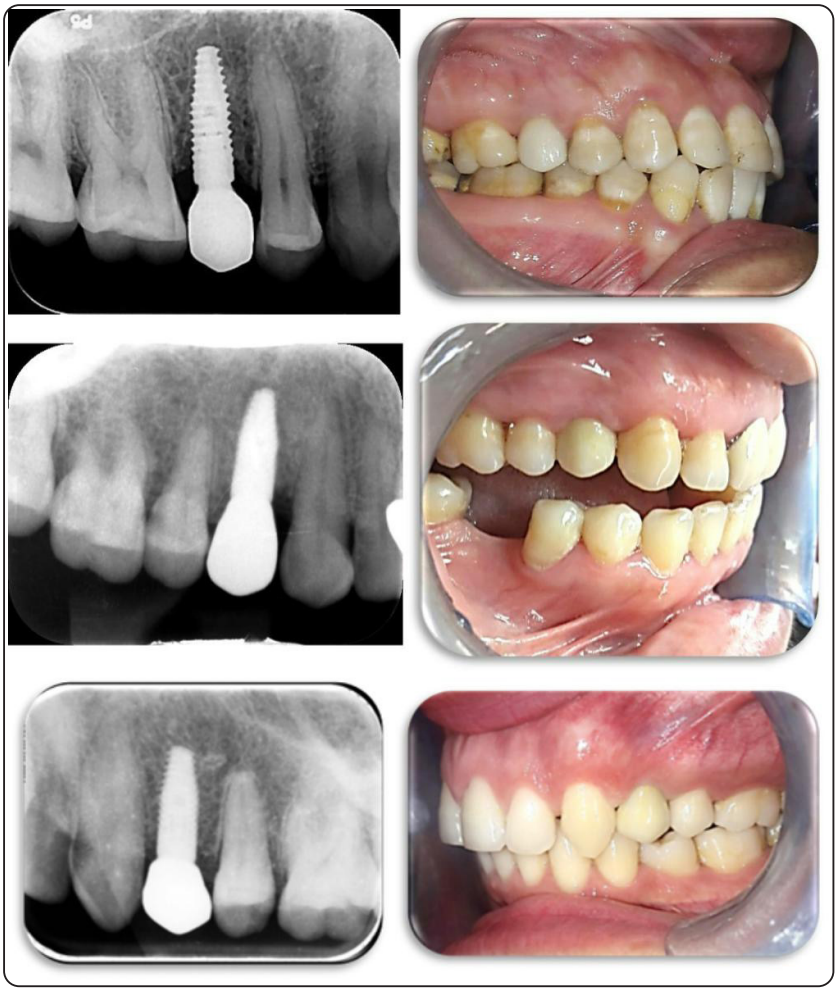

Fig. (1) Clinical photographs and periapical radiographs of maxillary premolars replaced with implant-supported monolithic zirconia crowns at the baseline in the three groups A, B &C

measured 1.23±0.72mm (median: 1.40mm, range: 0.00-2.25mm) (P=0.09 NS) in group (C) (DS), and the least mean BL measured 1.00±0.55mm (median: 1.10mm, range: 0.00-2.00mm) and (median: 1.00mm, range: 0.10-1.90mm) (P=0.83 NS) and (P=0.52 NS) in the groups (B and A) (VS and VC) respectively. There was a statistically significant difference between group (C) and the groups (B and A). While there was a statistically non-significant difference between group (B) and (A). Therefore, the null hypothesis was rejected.

Regarding the soft tissues (biological) evaluation, the highest plaque index (PI) and mean modified plaque index (modPI) values measured 48.0% and 0.44±0.50 in group (A) (VC), followed by 36.0% and 0.36±0.49 in group (B) (VS), and the least values measured 14.0% and 0.10±0.30 in group (C) (DS) (P= 0.05 S). For the gingival index (GI), The highest mean GI value (0.60±0.50) was recorded in group (B), followed by (0.50±0.61) group (C), and the least mean value (0.48±0.51) was recorded in group (A). There were statistically insignificant differences among the groups. For the bleeding on probing (BoP), The highest bleeding on probing (BoP) and mean modified bleeding index (MBI) values measured 52.0% and 0.52±0.51 in group (B), followed by 42.0% and 0.48±0.65 in group (A), and the least BoP value measured 28.0% and 0.32±0.55 in group (C) (P= 0.68 NS) (Table 1).

TABLE (1) The plaque index (PI) and modifies plaque index (modPI), and gingival index (GI), the probing pocket depth (PPD), and the width of the keratinized mucosa (KM):

PI	**Group (A) (VC)**		**Group (B) (VS)**		**Group (C) (DS)**		**Groups**	
Time	**Mean**	**P**	**Mean**	**P**	**Mean**	**P**	**Mean**	**P**
Baseline (Time 0)	40.0%		00.0%		30.0%		23.3%	0.07 NS
18 months	60.0%		40.0%		20.0%		40.0%	0.20 NS
Group	48.0%	0.77 NS	36.0%	0.01S	14.0%	0.21NS	32.7%	0.07 NS
modPI	**Group (A) (VC)**		**Group (B) (VS)**		**Group (C) (DS)**		**Groups**	
Time	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean± SD**	**P**
Baseline (Time 0)	0.40	0.50	0.00	0.00	0.30	0.48	0.23±0.43	0.07 NS
18 months	0.60	0.52	0.40	0.52	0.20	0.42	0.40±0.50	0.20 NS
Group	0.44	0.50	0.36	0.49	0.10	0.30	0.30±0.46	0.07 NS
P	0.88 NS		0.01 S		0.06 NS			
GI	**Group (A) (VC)**		**Group (B) (VS)**		**Group (C) (DS)**		**Groups**	
Time	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**P**
Baseline (Time 0)	0.40	0.50	0.20	0.42	0.80	0.92	0.47±0.68	0.10 NS
18 months	0.60	0.52	0.80	0.42	0.40	0.52	0.60±0.50	0.20 NS
Group	0.48	0.51	0.60	0.50	0.50	0.61	0.53±0.54	0.10 NS
P	0.77 NS		0.01 S		0.18 NS			
PPD	**Group (A) (VC)**		**Group (B) (VS)**		**Group (C) (DS)**		**Groups**	
Time	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**P**
Baseline (Time 0)	2.80	0.34	2.60	0.39	2.20	0.59	2.50	0.51	0.00 S
18 months	3.15	1.03	2.50	0.33	3.00	0.78	2.88	0.80	0.16 NS
Group	2.93	0.50	2.52	0.37	2.60 0.03	0.58	2.68	0.53	0.00 S
P	0.54 NS		0.92 NS		S		0.00 S		
KM	**Group (A) (VC)**		**Group (B) (VS)**		**Group (C) (DS)**		**Groups**		
Time	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**P**
Baseline (Time 0)	3.15	0.95	3.75	0.59	4.00	1.05	3.62	0.96	0.04 S
18 months	3.50	0.75	3.60	0.57	3.80	0.48	3.63	0.60	0.54 NS
Group	3.33 0.83 NS	0.89	3.67	0.58	3.89	0.76	3.63	0.77	0.00 S
P			0.95 NS		0.97 NS				

NS: non-significant difference (P > 0.05). S: significant difference (P < 0.05).

DISCUSSION

The present study assessed the clinical, technical, radiographic, biological, esthetical outcomes as well as patient satisfaction of monolithic zirconia implant-supported restorations cemented on Ti base abutments over 18 months predominantly revealed that: (1) the abutment design influenced the implant-supported monolithic zirconia crown clinically, radiographically, and esthetically, (2) a low rate of prosthetic complications and technical failures were noted within ≥ 4 years follow up that included a screw loosening in the group (A) (VC) in 2 cases, and in the group (B) (VS) in 1 case (10%), and screw fracture in the group (A) (VC) in 1 case (3%), mainly within the first year, (3) 2 patients had

mucositis and 1 patient had periimplantitis in group (C), (4) stable mean crestal bone levels with a high heterogeneity among different sites, (5) insignificant changes in the biological parameters, except that a significant increase in GI, BoP, and MBI values in group (B), and a significant increase in PPD values in group (C), (6) good esthetics and high PES/WES scores, (7) excellent patients` satisfaction.

Unfortunately, a comparison between the present technical outcomes with other clinical datasets is not feasible, as there is no long-term clinical data available for all-ceramic implant-supported single crowns on Ti bases (Pjetursson et al in 2021).[25, 26]

Considering the hard tissues evaluation, the present study revealed that, in group (A) (VC), the mean average BL amounted to 1.12±0.69mm (median: 0.49mm, range: 0.25-1.80 mm) at the baseline, and to 0.81±0.84mm (median: 0.63mm, range: 0.10-1.90 mm) (P<0.05) (=bone gain 0.31±0.15mm) at 24 months follow up. In group (B) (VS), the mean average BL amounted to 0.82±0.84mm (median: 0.77mm, range: 0.00-2.00 mm) at the baseline, and to 1.09±0.69mm (median: 1.20mm, range: 0.00-1.60 mm) (=bone loss 0.27±0.15mm) (P>0.05) at 24 months follow up. In group (C) (DS), the mean average BL amounted to 0.82±0.84mm (median: 0.60mm, range: 0.00-2.00mm) at the baseline, and to 1.60±0.82mm (median: 1.88mm, range: 0.15-2.25 mm) (P<0.05) (=bone loss 0.78±0.02mm) at 18 months follow up.

The plausible explanation for the observed crestal bone loss in group (C) is the possible micromovement at the implant/abutment interface due to the use of non-original Dess Ti base abutments. It was used as it is compatible with Straumann implant. As speculated in the 18-months data, the design of the abutment might serve as another more likely explanation for this significant bone loss (0.78±0.02mm).

In general, the mean plaque index (PI) values increased statistically insignificantly from 23.3% at the baseline to 40.0% at 24 months (P=0.07 NS). The mean modifies plaque index (modPI) increased statistically insignificantly from 0.23±0.43 at the baseline to 0.40±0.50 at 18 months (P=0.07 NS). The mean gingival index (GI) values increased statistically insignificantly from 0.47±0.68 at the baseline to 0.60±0.50 at 24 months (P=0.10 NS). There were statistically insignificant differences among the groups. The mean bleeding on probing (BoP) values increased statistically insignificantly from 30.0% at the baseline to 40.0% at 24 months (P=0.02 S). The mean modified bleeding index (MBI) measured 0.43±0.73 at the baseline and 0.40±0.50 at 24 months (P=0.06 NS). The mean probing pocket depth (PPD) values increased statistically insignificantly from 2.50±0.51mm at the baseline to 2.88±0.80mm at the 24 months (P=0.00 S). The mean keratinized mucosa (KM) measured 3.62±0.96mm at the baseline, and 3.63±0.60mm at the 18 months follow up appointments (P=0.00 S).

Substantially, there were insignificant changes in the biological parameters, except that a significant increase in the mean GI, BoP, and MBI values (0.60±0.00, 60.0%, 0.60±0.52, respectively) in group (B), and a significant increase in the mean PPD value (0.80±0.19mm) in group (C). The PI and modPI did not increase significantly over the same observation period, thereby demonstrating that parameters other than oral hygiene influenced these significant changes. As the same abutment was used in group (A) and (B), the design of the abutment might not serve as an explanation for these increases. Moreover, using the cement-retained crown over the Ti base abutment in group (A) (VC) is recommended, as it did not increase the risk of peri-mucositis and peri-implantitis. However, the significant increase in PPD in group (C) might be related to that the used Dess Ti base abutment is nonoriginal or its special design.

Al-Thobity[15] reached comparable results and reported that some manufacturers provide Ti base abutments with different sulcular heights to compensate for implant placement in different depth levels and variation of soft tissue heights. Multiple

clinical reports have demonstrated the ability to design and fabricate ceramic abutments and crowns using Ti base to achieve the optimum emergence profile and improve the esthetic outcomes. Similarly, Strauss et al.,[25] emphasized that all 22 patients were entirely satisfied with their screw-retained veneered zirconia restorations cemented extraorally on a non-original Ti base abutment at 5 years.

This was inconsistent with the study done by Asgeirsson et al.,[27] who resulted in that the papilla index at all sites was ≤2 at the baseline, and 8 of the mesial and 6 of the distal papillae (from 24 tested patients) had values of 3 at 1 year. The mean height of the reconstructions at baseline was 8.7±1.2mm and 8.6±1.5mm at 1 year. The mean soft tissue thickness was 2.5±1.0mm at baseline and 2.6±1.5mm at 1 year.

CONCLUSIONS

Within the limitations of this study, the following conclusions could be drawn:

Using a prefabricated Ti base (Variobase or Dess Ti base) as an abutment for an implant-supported cement- or screw-retained zirconia crown is an alternative procedure for FPDs. It promotes healthy and stable hard and soft tissues and achieves good esthetic results. Very few mechanical complications have been observed using these abutments over ≥ 2 years follow up. The prosthetic procedures presented in this study might be taken into consideration as a further option in the implant-supported monolithic zirconia crown. The monolithic zirconia crown supported by Variobase abutment could be recommended for daily clinical practice, especially in the limited interocclusal distance, due to high survival and success rates, clinical, radiographic, and esthetical outcomes, and a very low rate of prosthetic complications and technical failures. While these developments and concepts appear to be quite promising, nevertheless, longer term clinical studies are needed to confirm these results and to validate their performance.

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