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Five-year outcomes of a randomized controlled clinical trial comparing single-tooth implant-supported restoration with either zirconia or titanium abutments.

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Conflict of interest – Source of Founding:

The authors declare that they have no conflict of interests regarding the present manuscript. This research was partially supported with an unrestricted grant from Thommen Medical AG, Grenchen, Switzerland. The authors were fully independent in preparing the protocol, conducting the research whilst interpreting the results, and preparing the manuscript.

Author contribution

All authors have actively contributed to the conception and design of this work, in the acquisition, analysis and interpretation of data and in drafting the work and revising it critically

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Clinical relevance

Scientific Rationale for Study: There is controversy regarding the influence of the abutment material (metal vs. ceramic) on the long-term aesthetic result and the stability of the peri-implant tissues.

Principal findings: The use of zirconia abutments during a 5-year follow-up provided better aesthetic results when compared to titanium abutments, similar clinical behaviour, and no additional mechanical complications from 1-5 years.

Practical implications: In aesthetically demanding areas, the use of standard zirconia abutments showed better matching than titanium abutments in the long term.

Abstract

Aims: To evaluate the influence of the abutment material (zirconia vs. titanium) on the long-term aesthetic and clinical outcomes of implant-supported restorations.

Materials and methods: In 30 patients, a single implant-supported restoration with either a zirconia or a titanium abutment was placed in the anterior maxilla (incisors, canines, and bicuspids). Aesthetic (Implant Crown Aesthetic Index-ICAI), clinical, radiographic and patient-centred outcomes were recorded at baseline (1-month after final restoration), 1 year and 5 years of follow-up. This study was registered in ClinicalTrials.gov (NCT02315794).

Results: 25 subjects completed the follow-up visits at 1 and 5 years. Using ICAI values demonstrated statistically significant better aesthetic outcomes when zirconia abutments were used compared to titanium abutments. Between 1 to 5 years, the aesthetic sub-analysis of the crown component worsened, however the mucosal sub-analysis improved. There were no significant changes in bone levels, but the plaque index, bleeding on probing and probing depths worsened in both groups.

Conclusion: At 5 years, standard zirconia abutments achieved better aesthetic outcomes, although with similar clinical behaviour.

Introduction

Single tooth implant-supported restorations in the anterior maxilla is a very well established treatment for tooth loss, having demonstrated a high survival rate (Hjalmarsson et al., 2016), although presenting a high degree of aesthetic risk. These implant-supported restorations need to provide stability in both the hard and soft peri-implant tissues (Schropp & Isidor, 2015), as well as a harmonic integration with the neighbouring dentition (Jung et al., 2007). The use of standard metal abutments and porcelain fused-to-metal crowns have demonstrated outstanding long-term functional and mechanical properties (Lekholm et al., 2006; Mangano et al., 2015), although may result in aesthetic complications , mainly at sites with peri-implant soft tissue dehiscences/deficiencies, which usually develop long time after the placement of the restoration, especially if the implant is too buccally placed (Sailer et al., 2009, Zucchelli et al., 2019, Sanz-Martín et al., 2020, Romandini et al., 2021).

To avoid these aesthetic complications, zirconia abutments were introduced as an alternative to titanium abutments, combining appropriate mechanical properties, together with a non-metallic colour that would prevent the dull greyish discoloration of the peri-implant mucosa in case of mucosal recession (Cai et al., 2018). Several systematic reviews have reported high survival rates in single tooth implant restorations with both metal and ceramic abutments, also resulting in a predictable clinical behaviour with minimal technical or aesthetic complications (Cai et al., 2018, Cao et al., 2019, Dini et al., 2021, Jung et al., 2018, Linkevicius & Vaitelis, 2015, Naveau et al., 2019, Pitta et al., 2020, Sanz-Martín et al., 2018, Sanz-Sánchez et al., 2018, Zarauz

et al., 2021). However, there is still controversy on the influence of the abutment material (metal vs. ceramic) on the long-term aesthetic result and the stability of the peri-implant tissues, since there is a lack of appropriately designed clinical trials to evaluate this important clinical question (Zarauz et al., 2021). In a previously published one year randomised clinical trial (RCT), the use of zirconia abutments showed a tendency towards better aesthetic outcomes, although the differences were not statistically significant (Carrillo de Albornoz et al. 2014). Furthermore, zirconia abutments demonstrated stable soft and hard tissues but with more technical complications (Carrillo de Albornoz et al. 2014).

It was, therefore, the aim of this 5 five-years follow-up RCT to evaluate the aesthetic outcomes and stability of peri-implant tissues in single tooth implant restorations using different prefabricated abutment materials (zirconia versus titanium).

Material and Methods

Study Design

This clinical investigation was designed as a prospective, randomized, controlled clinical trial with a parallel design of 5-year duration comparing single tooth implant-supported restorations with either zirconia or titanium abutment. The allocation ratio was 1:1. Reporting of this trial was done in accordance with CONSORT guidelines (Moher et al., 2010).

The study protocol was approved by the Research and Ethics Committees of San Carlos University Hospital (Madrid, Spain)(code P-07/221) and its execution was

conducted in accordance with the principles of good clinical practice (ICH/ISO 14155) and the Helsinki Declaration (2008). This study was retroactively registered in ClinicalTrials.gov (NCT02315794).

Study Population

The inclusion criteria as well as the treatment procedures were included in the previous publication reporting the 1 year follow-up results (Carrillo de Albornoz et al., 2014). Briefly, the patient population was selected from those attending the Postgraduate Periodontal Clinic of the Faculty of Odontology at the University Complutense of Madrid. Eligible patients aged ≥ 18 years, had one tooth scheduled for implant placement in the anterior maxilla (incisors, canines, and bicuspids) with natural adjacent teeth, had adequate bone quality and quantity for implant installation without the need of bone augmentation and presence of ≥2 mm of keratinized tissue. Patients were excluded if: (a) had systemic or local disease that would interfere with dental implant therapy, (b) were heavy smokers (> 10 cigarettes/day), (c) had untreated periodontitis or generalized gingivitis and (d) had severe bruxism or clenching habits. During surgical phase, the selected subjects were excluded if: implants were not positioned according to the prosthetic requirements, there was need for hard or soft tissue augmentation or there was inadequate primary implant stability.

Intervention

Each patient received a dental implant (ELEMENT RC; Thommen Medical AG, Grenchen, Switzerland), in a single tooth gap healed site (minimum 4 months after extraction). Implants were positioned, following manufacturer's recommendations, leaving the 1

mm polished collar supra-crestally, and a healing abutment were positioned for non-submerged healing. After 3 months of healing, each implant was allocated to receive a zirconia abutment (SPI® ART; Thommen Medical AG, Grenchen, Switzerland) or a titanium abutment (CPTi Gr 4; SPI® EASY; Thommen Medical AG, Grenchen, Switzerland). Full ceramic CAD/CAM cemented crowns (3M ESPE's Lava™; Saint Paul, Minnesota, USA) were delivered to all patients following identical clinical and laboratory process. A single experienced restorative dentist using one dental laboratory carried out all the prosthetic procedures. Restorations were cemented with hybrid glass-ionomer permanent cement (3M ESPE RelyX™ Luting Cement; Saint Paul, Minnesota, USA). After oral hygiene instructions, all subjects were enrolled in a supportive periodontal program and committed to return after 1 month and then once a year for 5 years. More details of intervention, randomization, treatment allocation and blinding have been described in the previous publication (Carrillo de Albornoz et al., 2014).

Outcomes

Outcomes were assessed at 1 month, 1 year and 5 years after the delivery of the final restoration.

The aesthetic outcomes were the primary outcome of this RCT. These outcomes were assessed using the Implant Crown Aesthetic Index (ICAI) (Meijer et al., 2005). The ICAI is an index evaluating nine different dimensions, five variables evaluate the implant-supported restoration, and four variables rate the peri-implant mucosa. As previously described in the 1-year publication, the parameters related only to the soft tissue (ICAI

mucosa), and the parameters related to the crown (ICAI crown) were also presented independently from the overall ICAI score (ICAI Total). ICAI was recorded by one previously calibrated examiner (A.C.). The calibration consisted of evaluating standardized clinical photographs of 20 patients. The achieved level of agreement according was 0.77 Kappa score, which is considered high (0.61–0.80) (Landis & Koch 1977). Standardized photographs were used to assess the ICAI. Standardized intra-oral radiographs were taken using a long-cone paralleling technique and an individualized tooth positioner made of auto-polymerizing silicon key (Dentsply Rinn; Elgin, United States).

As previously described in detail (Carrillo de Albornoz et al., 2014), secondary outcomes included: (1) clinical parameters of peri-implant health (probing depth (PD), recession (REC) and bleeding on probing (BOP)), (2) evaluation of radiographic crestal bone level changes (mesial and distal marginal bone loss (MBL), defined as the distance measured between the implant shoulder (considering 1 mm collar of polished surface placed supra-crestally) and the first clearly visible bone-implant contact (BIC)), and (3) patient-related outcomes (using a six-grade scale (Vermylen et al., 2003) ranging from "extremely negative" (score 1) to "extremely positive" (score 6) and a 10 cm visual analogue scale (VAS) was also used to rate the patient's aesthetics satisfaction (Meijndert et al., 2007)). PD and REC were measured to the nearest 1 mm using a CPC-15 manual periodontal probe (Hu-Friedy, Leinmen, Germany) at six sites per implant.

Furthermore, the following clinical parameters were also recorded at each follow-up visit:

- Thickness of the mucosa – measured by placing a calibrated endodontic file 2 mm apical to the peri-implant mucosal margin.
- Width of the keratinized mucosa – vertical measurement with a periodontal probe between the mucosal margin at its zenith and the mucogingival line.
- Presence of the papilla mesial and distal to the implant site – measured by means of the Papilla Index (Jemt, 1997).
- Full Mouth Plaque Score (FMPS) and Full Mouth Bleeding Score (FMBS).
- Presence of biological complications such as mucositis or peri-implantitis, following the new classification of peri-implant conditions (Berglundh *et al.*, 2018).
- Presence of technical complications, classified in major (e.g. implant fracture), medium (e.g. abutment fracture) or minor (e.g. abutment screw loosening) according to Lang et al., (2012).

All clinical outcome variables were assessed by one calibrated examinator (L.F.).

Data analysis

All data were entered in an Excel sheet and checked for entry errors. A subject level analysis was performed for each parameter. Proportions were used to describe qualitative data whereas mean, standard deviation (SD) and/or Confidence Interval (CI) were used to describe quantitative variables. Kolmogorov–Smirnov tests were applied for each quantitative variable to assess the "goodness of fit" to normal distribution and normality was achieved for all the variables. McNemar test and chi-square and Fisher

tests were applied to evaluate intra- and inter- group differences in qualitative data. Intra- and inter-group differences to evaluate longitudinal variations over time for quantitative data were determined by repeated measures ANOVA using Greenhouse–Geisser corrections for intra-group factors and the interaction effects. Where interaction effects were significant, additional Student t-tests were applied. The statistician doing the data analysis was blind to treatment allocation. This statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS, version 25.0 for Windows; SPSS Inc., Chicago, IL, USA) selecting a significant level of p = 0.05.

Results

Study population

Thirty-eight patients were screened as potential candidate for the study, 30 were successfully enrolled and 25 patients completed the 5-year follow-up visit (Figure 1). Recruiting period started in September 2010 and ended in December 2011. Among the 38-screened subjects, seven were excluded as they did not satisfy all the inclusion/exclusion criteria, and one patient refused to sign the informed consent. Thus, 30 patients were randomized after being enrolled, but 5 patients dropped-out from the study for the following reasons: economic problems (3), need for orthodontic therapy (1), and moved to another city (1). At 1 year of follow-up, 25 patients completed the study. From 1 to 5 years, patients were seen annually for data measurements and for individualized supportive therapy. No dropouts were registered at the 5 years follow-

up visit. At baseline, the test and the control group didn't show any statistically relevant difference, as described in the previous publication (Carrillo de Albornoz *et al.*, 2014).

Primary outcome: aesthetic evaluation

The mean ICAI values for both test and control groups are summarized in table 1. The overall score at 1 month, 1 year and 5 years after final restoration delivery was 7.82 (SD 3.25), 7.64 (SD 3.59) and 7.82 (SD 3.52) for the zirconia abutment group and 10.64 (SD 4.41), 11.29 (SD 5.43) and 11.57 (SD 5.68) for the titanium abutment group respectively. Differences were statistically significant in the overall inter-group comparison (p=0.037), meaning a different trend of the ICAI values over time comparing the test and control group. This is the consequence of the clear tendency to present significant differences between groups at 1 month (p=0.089), 12 months (p=0.065) and 60 months (p=0.068). Regarding ICAI-crown analysis, a significant worsening of the score was found in both titanium and zirconia abutment groups from 1 to 5 years. The 1 month, 1 year and 5 years ICAI-crown scored 2.09 (SD 2.02), 2.27 (SD 1.90) and 4.18 (SD 3.43) for the zirconia abutment group and 3.43 (SD 3.46), 4.43 (SD 4.77) and 5.64 (SD 4.33) for the titanium abutment group respectively. Conversely, ICAI-mucosa significantly improved from 1 to 5 years also in both groups (intra-group comparisons). The ICAI-mucosa at 1 month, 1 year and 5 years was 5.73 (SD 3.04), 5.36 (SD 3.01) and 3.64 (SD 1.36) for the zirconia abutment group and 7.21 (SD 2.72), 6.86 (SD 3.16) and 5.93 (SD 2.27) for the titanium abutment group respectively. A tendency in inter-group differences in ICAI-mucosa scoring was also observed, favouring zirconia abutments (p=0.053) (figure 2).

The detailed analysis of the nine components of the ICAI index demonstrated statistically significant differences in the following items (Figure 3): (1) colour and translucency of the crown significantly worsened in the titanium abutment group from 12 to 60 months (p=0.004) and (2) colour and translucency of the mucosa significantly worsened in the zirconia abutment group from 12 to 60 months (p=0.011).

In both groups there was an improvement in the Papilla Index (Jemt, 1997) over time. Mesial papilla significantly improved from 1 month to 12 months, and from 12 to 60 months in test and control groups (intra-group comparison). In the distal aspect, the papilla scoring was significantly better in zirconia abutment group compared to titanium abutment group at both the 1- and 5-years evaluation (Table 2, Figure 4).

Survival rate, biological and technical complications

A cumulative survival rate of 100% was observed in both groups, as all the implants completed the follow-up period. Peri-implantitis was observed in 1 (9,1%) and 3 patients (21.4%) the in the zirconia and titanium groups respectively, considering a threshold of progressive bone loss > 1.5 mm of bone loss between 1 and 5 years. Mucositis was present in 100% of the patients at 5 years, as all the abutments presented at least one site with bleeding on probing at 5 years (table 4). No mechanical complications were observed in any of the groups in the follow-up period from 12-60 months.

Clinical and radiographic outcomes

The results from all the clinical variables are reported in table 2. Full mouth plaque scores significantly increased at 60 months in both groups (intra-group comparison),

these differences not being statistically significant between groups. Similarly, full mouth bleeding score significantly worsened over time, being statistically significant at the 1- and 5-years in the intra-group comparisons. Probing depths and percentages of bleeding on probing significantly increased in both groups from 1 to 5 years. In the inter-group comparison, a tendency towards shallower probing depths was observed in the implants restored with zirconia abutments (p=0.059). Detailed information of the absolute and relative distribution of the implants bleeding on probing is found in table 4 (supplementary files).

Keratinized mucosa thickness increased over time, being significant in the change from 1 month to 1 year (0.45 mm and 0.54 mm in zirconia and titanium abutment groups respectively). Conversely, keratinized mucosa height decreased over time, with a significant reduction from 12 to 60 months (-1.6 mm test and -1.29 for the control group).

The radiographic analysis of the marginal bone loss did not show significant changes over time (table 2). Marginal bone loss frequency distribution is showed in table 3.

Patient-related Outcome variables

An overall high patient acceptance of the treatment was evidenced by the high scores from both the six-grade scale written questionnaire and the visual analogue scale (VAS). There were no significant differences between groups. The VAS scores were 8.5 (SD 1.7), 9.0 (SD 1.7) and 8.8 (SD 1.1) for the zirconia abutment group and 8.5 (SD 1.6), 9.0 (SD 1.4) and 9.0 (SD 1.8) for the titanium abutment group at 1 month, 1 year and 5 years of follow-up respectively.

Discussion

The present RCT evaluated the long-term efficacy (5 years) of using two different abutment materials (zirconia vs. titanium) in single implant supported restorations. The results showed that the overall ICAI score throughout time was significantly better when using zirconia abutments, but this improvement was mainly due to the mucosal component, since the crown component worsened in both groups. This mucosal component resulted in improvements of the interdental papilla, mainly the distal papilla demonstrated better results when a zirconia abutment was used. This improvement in the aesthetic outcome was achieved despite higher plaque index scores, deeper probing depths and higher percentages of bleeding on probing. However, marginal bone levels remained stable during the 5 years follow up. There were no significant differences between groups for the clinical and radiological outcome measurements. Patient reported outcomes revealed a high degree of patient satisfaction with the treatment received, without significant differences between treatment groups

The significantly higher aesthetic outcome when using zirconia abutments has also been reported in other clinical studies, what supports the concept that was used. These findings agree with multiple studies that conclude that ceramic abutments in comparison to metallic abutments provide a better matching with peri-implant and natural tooth soft tissues in aesthetically relevant sites, thus providing a more "nature-like" outlook to the restored area (Cai et al., 2018, Linkevicius & Vaitelis, 2015, Naveau et al., 2019). However, other clinical studies have reported that the abutment material has no impact on the soft tissue aesthetic outcomes (Sanz-Sánchez et al., 2018). A recent

systematic review using the Pink Esthetic Score (PES), PES/White Esthetic Score (WES, i.e. mod/PES) reported that the abutment material or the abutment configuration did not influence the peri-implant soft tissue aesthetic parameters when considering medium to long term observation (Zarauz et al., 2021).

For evaluating the aesthetic outcomes as primary outcome in this clinical trial we used of a composite index (ICAI) with the advantage of assessing different parameters in addition to colour. The sub-analysis of the ICAI-crown showed a significant worsening in both groups of the crown component from 12-60 months, being rated as moderate aesthetics in the zirconia abutment group and poor aesthetics in the titanium abutment group. The main factor in this result was the colour and translucency of the crown, which significantly worsened in the titanium group. These differences may be due to the aging of metal abutments in contact with highly translucent all-ceramic fixed partial dentures (Martinez-Rus et al., 2017). Aging of zirconia has been mainly associated with changes in the microstructure (transformation from tetragonal to monoclinic structure). In vitro studies have shown that hydrothermal aging reduced the translucency and therefore the aesthetic outlook (Walczak et al., 2019). Furthermore, the crown post treatment, such as the make-up (staining, grazing) and the glazing may improve the aesthetic outcome for the zirconia, but it is also subject to degradation and ageing (Manziuc et al., 2021). A recent systematic review evaluated the impact of low temperature degradation on different types of zirconia and concluded that the optical properties were compromised with increased time (Hajhamid et al., 2022, Alfrisany et al., 2022).

Contrarily, the ICAI-mucosa component experienced a significant improvement in both groups from 12-60 months, with a clear tendency for better aesthetic outcomes in zirconia abutment group (p =0.053). The main responsible factor for this improvement were the papillae height, followed by the position and contours of the labial peri-implant mucosal margin. Implant papillae height increased in most patients (84%), which may be due to the reduced but healthy periodontium of these patients, being mainly recruited from a supportive periodontal programme. However, better outcomes were obtained in the zirconia abutment group, being significant for the distal papilla comparison. This tendency towards increasing papilla height with time has been previously reported in other clinical studies (Priest, 2003).

The position of the mucosal margin remained stable over time in both groups, what is in agreement with the results from a recent systematic review evaluating the influence of abutment material on the stability of peri-implant soft tissue levels (Sanz-Sánchez et al., 2018).

Interestingly, the colour of the labial mucosa deteriorated with time, being significantly worse in the group of zirconia abutments. These results are in contrast with studies that have objectively evaluated colour differences between titanium and zirconia abutments using calibrated devices such as spectrophotometers or colorimeters. However, in this clinical trial the soft tissue thickness was > 2 mm in both groups, which is the accepted threshold for masking the possible effect of the abutment material (Sala et al., 2017, Jung et al., 2007, Ferrari et al., 2017). Pitta et al. (2020), in a systematic review, supported the choice for all ceramic or "white" abutments in aesthetically demanding cases after evaluating the colour of 266 abutments. The results showed significantly lower ΔE

values for ceramic abutments when compared to the overall metal abutments, although differences were not significant when titanium (ΔE 10.4) and zirconia (ΔE 8.5) were compared. Although, different authors recommend the use of white zirconia for a better soft tissue matching (Zarauz et al., 2020), this may not be an ideal abutment material in terms of soft tissue colour outcomes. Other options, including color-modified zirconia or modified titanium abutments, have been proposed, which need to be further explored in well-designed clinical trials (Benic et al., 2016).

Presence of gingiva is conditioned by the existence of teeth with a functional periodontal ligament (Karring et al., 1971). As teeth are lost, gingiva disappears and the remaining keratinized mucosa does not have the regenerative capability of the periodontal ligament and hence, will diminish with time, irrespective from the placement of dental implants, which of course, lack this tissue. It is, therefore, plausible that ensuing shrinkage of the keratinized mucosa will occur and in cases of minimal amounts or lack of keratinized tissue a soft tissue augmentation procedure may be considered.

Although the use of zirconia abutments may be limited due to their reduced mechanical properties, there were no technical complications reported during the 5-year follow-up in the present study. The reliability of ceramic abutments has been confirmed in clinical studies demonstrating high survival rates (100%) of implant-supported all-ceramic restorations after a mean follow-up time of 7.2 years (Fenner et al., 2016). Moreover, in a recent systematic literature review and meta-analysis on different abutment materials (Sanz-Sánchez et al., 2018), the reported incidence of technical complications was low, being slightly greater but non-significant in the ceramic when compared to titanium (8.7% and 5.9% respectively).

The results from the clinical parameters demonstrated that plaque accumulation, peri-implant mucosal inflammation and probing depth increased with time in both groups, although a tendency towards deeper PD was reported in the titanium abutment group. The plaque index at the end of the 5 years follow up was above 40% in most of the patients enrolled in this study, despite being enrolled in a supportive periodontal program with regular visits at least once a year. This highlights the need for even shorter recall appointments to prevent the long term occurrence of peri-implant diseases (Monje et al., 2016).

In recent systematic reviews comparing probing depths of implant restoration with different abutment material, no significant differences were reported, although a lower bleeding on probing percentages were reported on zirconia when compared to titanium abutments (Sanz-Martín et al., 2018, Sanz-Sánchez 2018). The present study found no statistically significant difference in the bleeding on probing between groups. As mentioned in detail in the previous publication about the limitations of this RCT (Carrillo de Albornoz 2014), in this study no sample size was calculated before the study started, what limits the power of the statistical inference.

Regarding marginal bone level changes over time, there was a general bone stability observed in both groups, with minimal changes from 12-60 months (0.23 ± 0.65 and 0.38 ± 0.71 in zirconia and titanium abutment groups respectively). These long term results and the lack of differences depending on the abutment material has also been reported in systematic reviews (Sanz-Sánchez et al., 2018, Linkevicius & Vaitelis, 2015, Sanz et al. 2018)

In conclusion, and considering the limitations of the study, the results from this RCT have shown that:

- The use of zirconia abutments during a 5-year follow-up provided better aesthetic results when compared to titanium abutments.
- More technical complications were noted with the use of zirconia abutments during the first year, but from 1-5 years, no additional mechanical complications were observed in any of the studied abutments.
- Changes in marginal bone levels did not show significant changes over time.

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Figure Legend

Figure 1 - Five years follow-up study diagram flow.

Figure 2 - Graphic representation of the mean value and 95% CI of the ICAI Total *(left)*, ICAI Crown *(center)* and ICAI Mucosa *(right)* scores 1 month after the placement of the definitive crown, at 1 year and at 5 years.

Figure 3 - Frequency of distribution of the implant crown aesthetic index (ICAI) parameters and the overall score 1 month after the placement of the definitive crown, at 1 year and at 5 years. # intra-group statistically significant difference ($p<0.05$).

Figure 4 - Clinical photos of two patients belonging to the test (*upper raw*) and the control (*lower raw*) group. The green line shows the distal papilla level, the violet line shows the mesial papilla level.

	Zirconia abutment			Titanium abutment		
	Mean	SD	95% CI	Mean	SD	95% CI
ICAI-Total*						
1 month	7.82	3.25	5.63 - 10.00	10.64	4.41	8.09 -13.19
12 months	7.64	3.59	5.23- 10.05	11.29	5.43	8.15 - 14.42
60 months	7.82	3.52	5.46 - 10.18	11.57	5.68	8.29 - 14.85
Change 1-12 m	-0.18	1.66	-3.23 - 2.86	0.64	2.37	-3.21 - 4.49
Change 12-60 m	0.18	4.85	-2.98 - 3.34	0.29	5.31	-4.03 - 4.60
ICAI-Crown						
1 month	2.09	2.02	0.73 -3.45	3.43	3.46	1.43 - 5.43
12 months	2.27 #	1.90	0.99 - 3.55	4.43 #	4.77	1.68- 7.18
60 months	4.18 #	3.43	1.88 - 6.49	5.64 #	4.33	3.15 - 8.14
Change 1-12 m	0.18	0.60	-1.56 - 1.93	1.00	2.29	-2.25 - 4.25
Change 12-60 m	1.91#	3.33	-0.60 - 4.42	1.21#	3.98	-2.32 - 4.75
ICAI-Mucosa						
1 month	5.73	3.04	3.69 - 7.77	7.21	2.72	5.64 - 8.79
12 months	5.36 #	3.01	3.34 - 7.39	6.86 #	3.16	5.03 - 8.68
60 months	3.64 #	1.36	2.72 - 4.55	5.93 #	2.27	4.62 - 7.24
Change 1-12 m	-0.36	1.36	-3.05 - 2.32	-0.36	2.24	-2.65 – 1.94
Change 12-60 m	-1.73#	3.13	-3.86 - 0.41	-0.93#	3.22	-3.08 - 1.22

Table 1 - Mean values and mean changes with standard deviation and 95% confidence intervals (CI) of the Implant Crown Aesthetic Index (ICAI) in patients treated with zirconia and titanium abutments 1 month, 1 year and 5 years after the definitive crown placement. * inter-group statistically significant difference ($p<0.05$). # intra-group statistically significant difference ($p<0.05$).

	Zirconia abutment			Titanium abutment		
	Mean	SD	95% CI	Mean	SD	95% CI
FMPS (%)						
1 month	30.36%	20.97%	16.28% - 44.45%	36.36%	17.40%	26.31% - 46.40%
12 months	30.00% #	10.26%	23.11% - 36.89%	36.69% #	22.40%	23.15% - 50.23%
60 months	40.00% #	26.18%	22.41% - 57.59%	50.14% #	25.92%	35.18% - 65.11%
Change 1-12 m	-0.36%	18.46%	-12.76% - 12.04%	-1.54%	19.39%	-13.26% - 10.18%
Change 12-60 m	10.00%#	23.91%	-6.06% - 26.06%	16.92%#	26.86%	0.69% - 33.15%
FMBS (%)						
1 month	6.36% #	5.41%	2.73% - 10.00%	8.07% #	8.77%	3.01% - 13.13%
12 months	12.27% #	5.04%	8.89% - 15.66%	15.29% #	9.12%	10.02% - 20.55%
60 months	27.73% #	16.81%	16.43% - 39.02%	27.21% #	15.15%	18.47% - 35.96%
Change 1-12 m	5.91%#	5.97%	1.90% - 9.92%	7.21%#	8.96%	2.04% - 12.39%
Change 12-60 m	15.45%#	16.74%	4.21% - 26.70%	11.93%#	15.48%	2.99% - 20.87%
BOP implant						
1 month	0.33	0.33	0.11 - 0.56	0.25	0.27	0.10 - 0.40
12 months	0.36 #	0.28	0.18 - 0.55	0.42 #	0.27	0.26 - 0.57
60 months	0.62 #	0.30	0.42 - 0.82	0.64 #	0.22	0.51 - 0.77
Change 1-12 m	0.03	0.44	-0.27 - 0.33	0.17	0.38	-0.05 - 0.39
Change 12-60 m	0.26#	0.51	-0.09 - 0.60	0.23#	0.25	0.08 - 0.37
BOP adjacent teeth						
1 month	0.16	0.20	0.02 - 0.29	0.17	0.22	0.05 - 0.30
12 months	0.20	0.14	0.11 - 0.30	0.24	0.16	0.15 - 0.34
60 months	0.24	0.16	0.13 - 0.34	0.23	0.18	0.12 - 0.33
Change 1-12 m	0.05	0.17	-0.07 - 0.16	0.07	0.21	-0.05 - 0.19
Change 12-60 m	0.03	0.23	-0.13 - 0.19	-0.02	0.29	-0.19 - 0.15
PD implant						
1 month	2.62	0.72	2.14 - 3.10	3.38	1.02	2.79 - 3.97
12 months	2.94 #	0.50	2.60 - 3.28	3.36 #	0.83	2.88 - 3.84
60 months	3.79 #	0.54	3.43 - 4.15	4.13 #	0.71	3.72 - 4.54
Change 1-12 m	0.32	0.63	-0.11 - 0.74	-0.02	0.78	-0.48 - 0.43
Change 12-60 m	0.85#	0.58	0.46 - 1.24	0.77#	0.97	0.21 - 1.33
PD adjacent teeth						
1 month	2.27 #	0.28	2.08 - 2.46	2.35 #	0.53	2.04 - 2.65
12 months	2.55 #	0.44	2.26 - 2.85	2.85 #	0.50	2.56 - 3.13
60 months	2.64	0.34	2.42 - 2.87	2.75	0.67	2.36 - 3.14
Change 1-12 m	0.28#	0.36	0.04 - 0.52	0.50#	0.58	0.16 - 0.84
Change 12-60 m	0.09	0.30	-0.11 - 0.30	-0.10	0.79	-0.55 - 0.36
REC implant						
1 month	0.00	0.00	0.00 - 0.00	0.01	0.05	-0.02 - 0.04
12 months	0.00	0.00	0.00 - 0.00	0.05	0.10	-0.01 - 0.11
60 months	0.03	0.07	-0.02 - 0.08	0.35	1.06	-0.27 - 0.96
Change 1-12 m	0.00	0.00	0.00 - 0.00	0.04	0.10	-0.02 - 0.10

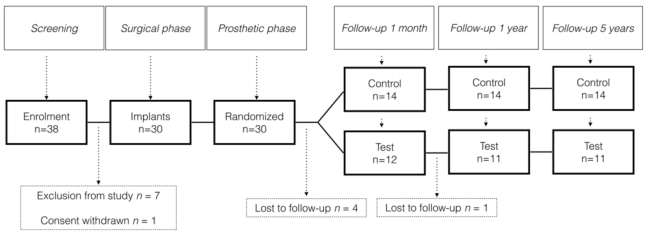
Change 12-60 m	0.03	0.07	-0.02 - 0.09	0.30	1.04	-0.30 - 0.89
REC adjacent teeth						
1 month	0.78	1.08	0.05 - 1.51	1.19	1.18	0.47 - 1.90
12 months	0.81	0.97	0.12 - 1.50	1.51	1.14	0.85 - 2.17
60 months	0.76	0.95	0.12 - 1.40	1.40	1.15	0.74 - 2.06
Change 1-12 m	0.09	0.62	-0.35 - 0.53	0.40	0.65	0.00 - 0.79
Change 12-60 m	-0.03	0.49	-0.39 - 0.32	-0.11	0.64	-0.48 - 0.26
Crown Length						
1 month	7.20	1.50	6.19 - 8.21	7.65	1.31	6.90 - 8.41
12 months	7.15	1.35	6.24 - 8.06	7.46	1.32	6.70 - 8.22
60 months	7.26	1.48	6.26 - 8.25	7.59	1.30	6.84 - 8.34
Change 1-12 m	-0.05	0.37	-0.30 - 0.20	-0.19	0.45	-0.45 - 0.07
Change 12-60 m	0.11	0.50	-0.23 - 0.44	0.12	0.94	-0.42 - 0.67
Mesial Papilla Index						
1 month	1.45 } #	0.69	0.99 - 1.92	1.00 } #	0.68	0.61 - 1.39
12 months	1.91 = #	0.70	1.44 - 2.38	1.50 = #	1.02	0.91 - 2.09
60 months	2.55 } #	0.52	2.19 - 2.90	2.00 } #	0.71	1.57 - 2.43
Change 1-12 m	0.46#	0.69	-0.01 - 0.92	0.50#	0.65	0.12 - 0.88
Change 12-60 m	0.64#	0.67	0.18 - 1.09	0.39#	0.77	-0.08 - 0.85
Distal Papilla Index*						
1 month	1.55	0.69	1.08 - 2.01	0.93	0.73	0.51 - 1.35
12 months	1.64*	0.81	1.09 - 2.18	1.29*	0.99	0.71 - 1.86
60 months	1.73*	0.65	1.29 - 2.16	1.15*	0.55	0.82 - 1.49
Change 1-12 m	0.09	0.30	-0.11 - 0.29	0.36	0.75	-0.07 - 0.79
Change 12-60 m	0.09	0.54	-0.27 - 0.45	-0.08	1.04	-0.70 - 0.55
Keratinized mucosa thickness						
1 month	1.91 } #	0.70	1.44 - 2.38	2.18 } #	0.70	1.78 - 2.58
12 months	2.36 } #	0.50	2.02 - 2.70	2.71 } #	1.05	2.11 - 3.32
60 months	2.70	0.89	2.06 - 3.34	2.82	0.70	2.42 - 3.22
Change 1-12 m	0.45#	0.82	-0.10 - 1.01	0.54#	1.28	-0.20 - 1.27
Change 12-60 m	0.30	0.95	-0.38 - 0.98	0.11	0.88	-0.40 - 0.62
Keratinized mucosa height						
1 month	5.55	1.29	4.68 - 6.41	4.50	1.47	3.61 - 5.39
12 months	5.41 } #	1.71	4.26 - 6.56	5.11 } #	1.51	4.24 - 5.98
60 months	4.15 } #	0.91	3.50 - 4.80	3.82 } #	1.64	2.88 - 4.77
Change 1-12 m	-0.14	1.23	-0.96 - 0.69	0.38	0.92	-0.17 - 0.94
Change 12-60 m	-1.60#	1.08	-2.37 - -0.83	-1.29#	1.48	-2.14 - -0.43
Implant shoulder (1 mm supracrestally) - bone contact						
1 month (all)	1.62	0.18	1.49 - 1.75	1.76	0.36	1.54 - 1.98
12 months (all)	1.56	0.27	1.38 - 1.74	1.88	0.37	1.64 - 2.11
60 months (all)	1.77	0.63	1.31 - 2.22	2.20	0.83	1.65 - 2.76
Change 1-12 m (all)	-0.02	0.18	-0.15 - 0.11	0.16	0.18	0.04 - 0.27
Change 12-60 m	0.23	0.65	-0.24 - 0.69	0.38	0.71	-0.17 - 0.92

Table 2 - Mean values and mean changes with standard deviation and 95% confidence intervals(CI) of clinical and radiographic outcomes. Full Mouth Plaque Score (FMPS), Full Mouth Bleeding Score (FMBS), Bleeding on probing (BoP), Pocket Depth (PD), recession (REC), Crown Length, Papilla Index (Jemt, 1997), keratinized mucosa thickness, keratinized mucosa height and radiographic marginal bone loss (1 mm collar

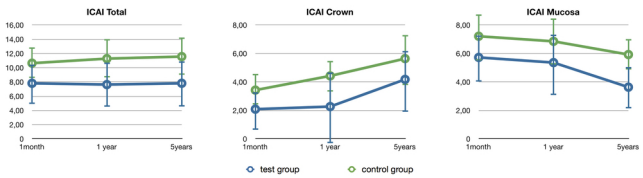
placed supracrestally) in patients treated with zirconia and titanium abutments 1 month, 1 year and 5 years after the definitive crown placement. * inter-group statistically significant difference ($p<0.05$). # intra-group statistically significant difference ($p<0.05$).

	Zirconia abutment						Titanium abutment					
	1 month*		12 months		60 months		1 month*		12 months		60 months	
	n	%	n	%	n	%	n	%	n	%	n	%
Bone loss < 0.5 mm	2	20,00%	4	36,36%	3	30,00%	5	38,46%	2	16,67%	1	9,09%
Bone loss 0.5 - 1.0 mm	8	80,00%	7	63,64%	5	50,00%	3	23,08%	5	41,67%	5	45,45%
Bone loss 1.0 - 1.5 mm	0	0,00%	0	0,00%	1	10,00%	5	38,46%	4	33,33%	1	9,09%
Bone loss 1.5 - 2 mm	0	0,00%	0	0,00%	0	0,00%	0	0,00%	1	8,33%	3	27,27%
Bone loss > 2mm	0	0,00%	0	0,00%	1	10,00%	0	0,00%	0	0,00%	1	9,09%

Table 3 – Absolute and relative frequency distribution of the radiographic Marginal Bone Loss in patients treated with zirconia and titanium abutments 1 month, 1 year and 5 years after the definitive crown placement. * inter-group statistically significant difference ($p<0.05$).



JCPE_13787_Figure 1.jpg



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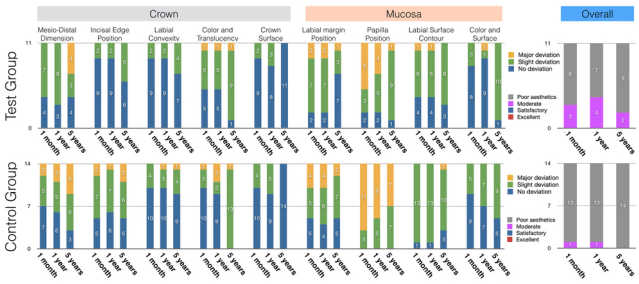

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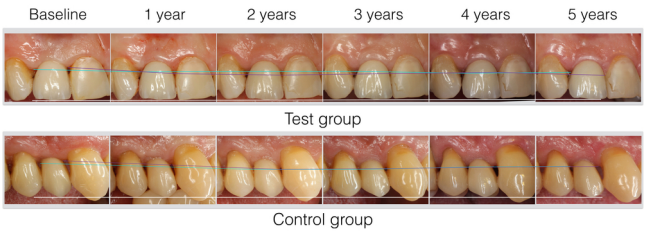

JCPE_13787_Figure 4.jpg