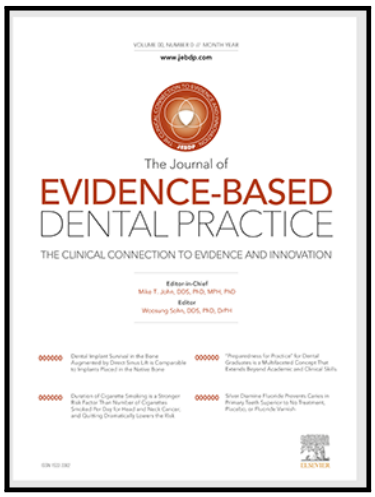
Journal Pre-proof



Survival rate of implant-supported, single-tooth restorations based on zirconia or metal abutment in patients with tooth agenesis: A 5-years prospective clinical study.

Mandana Hosseini , Nils Worsaae , Klaus Gotfredsen

PII: S1532-3382(24)00002-2
DOI: https://doi.org/10.1016/j.jebdp.2024.101970
Reference: YMED 101970

To appear in: *The Journal of Evidence-Based Dental Practice*

Received date: 13 October 2023
Revised date: 22 December 2023
Accepted date: 13 January 2024

Please cite this article as: Mandana Hosseini , Nils Worsaae , Klaus Gotfredsen , Survival rate of implant-supported, single-tooth restorations based on zirconia or metal abutment in patients with tooth agenesis: A 5-years prospective clinical study., *The Journal of Evidence-Based Dental Practice* (2024), doi: https://doi.org/10.1016/j.jebdp.2024.101970

Survival rate of implant-supported, single-tooth restorations based on zirconia or metal abutment in patients with tooth agenesis: A 5-years prospective clinical study.

Mandana Hosseini (Corresponding author)

Section of Oral Rehabilitation, Department of Odontology, Faculty of Health Science, University of Copenhagen, Denmark, Postal address: Nørre Allé 20, Copenhagen N-2200, e-mail: manho@sund.ku.dk

Nils Worsaae[1]

Department of Oral and Maxillofacial Surgery, University Hospital, Rigshospitalet, Copenhagen, Denmark, Postal address: Blegdamsvej 9, 2100 CPH, Denmark, e-mail: nils@worsaae.com

Klaus Gotfredsen

Section of Oral Rehabilitation, Department of Odontology, Faculty of Health Science, University of Copenhagen, Denmark, Postal address: Nørre Allé 20, Copenhagen N-2200, e-mail: klg@sund.ku.dk

Author contributions: Conceptualization: Klaus Gotfredsen; methodology: All authors; investigation: Mandana Hosseini, Klaus Gotfredsen; data organization: Mandana Hosseini; writing of the draft: Mandana Hosseini; review of the draft: All authors read and approved the final manuscript.

Running title: implant-supported crowns, 5-year study

Conflict of interest: The author of this article has no conflict of interest. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

1. Working status now: retired

Abstract

Purpose: The primary aim was to investigate survival rate of zirconia versus metal abutments, and the secondary aim was clinical outcomes of all-ceramic versus metal-ceramic crowns on single-tooth implants.

Material and Methods: Patients with tooth-agenesis participated to previously published prospective clinical study with three-year follow-up were recalled after five years. Biological variables included survival and success rate of implants, marginal bone level, modified Plaque and Sulcus Bleeding Index and biological complications. Technical variables included restoration survival rate, marginal adaptation and technical complications. The aesthetic outcome of crowns and peri-implant mucosa in addition to patient-reported outcome were recorded. Descriptive analysis, linear mixed model for quantitative data, or generalized linear mixed model for ordinal categorical data were applied; significance was set to 0.05.

Results: Fifty-three patients (mean age: 32.4 years), with 89 implants participated to the 5-years examination. The implants supported 50 zirconia abutments with 50 all-ceramic (AC) crown and 39 metal abutments with 29 metal-ceramic (MC) and 10 AC crowns.

The Implant and restoration survival rate was 100% and 96%, respectively. No clinically relevant biological difference between implants supporting metal or zirconia abutments was registered. The technical complications were veneering fracture of AC-crowns (n=3), crown loosening of MC-crowns (n=4) and one abutment screw loosening (MC-crown on metal abutment). MC-crowns had significantly better marginal adaptation than AC-crowns (p=0.01). AC-crowns had significantly better color and morphology than MC-crowns (p=0.01).

Conclusions: Zirconia-based single-tooth restorations are reliable alternative materials to metal-based restorations with favorable biological and aesthetic outcome, and few technical complications.

Keywords: survival rate, dental implant, Single-Tooth, dental abutments, dental crowns, zirconium dioxide

Introduction

Using dental implants as a replacement of missing teeth in partially dentate arches is an established treatment option with a high long-term survival rate.[1,2] In addition, rehabilitation with implants compared to tooth-supported fixed prosthesis is a tooth conserving procedure. The prosthetic options are implant-supported single crowns or implant-supported fixed dental

prosthesis. The promising outcomes of implant-supported single crowns have resulted in more frequent use of this treatment modality compared to the other implant-supported treatment options.[3] Prognosis of implant treatment may be influenced using different crown materials. Metal-ceramic crowns on metal abutments have been widely used in the past and is one of the most well-documented type of restorations.[4] Thus, these materials are still the "golden standard" in regions with a high risk of fractures. Due to development of other prosthetic materials with better optical properties than metal-supported restorations, a large number of ceramic restoration materials have been introduced with zirconium dioxide (zirconia) as the most promising ceramic material due to a high flexural strength and fracture toughness.[5] In addition to the good mechanical properties, the favorable optical properties of zirconia may extend the indications in fixed prosthodontics to implant-supported abutments and crowns.[6-8] The choice of material for implant-supported restorations may not only influence the treatment prognosis from a technical and an aesthetic point of view, but also the biological outcome.[9] Plaque accumulation at abutment and crown material combined with different mucosal adhesion to abutment and crown materials may lead to local inflammation.[10-16] The effect of different implant-supported restoration materials on plaque accumulation and mucositis needs, however, to be further investigated *in vivo*. In addition to clinical and radiological investigations, assessment of a potential impact of treatment on the individual patient's well-being is important.[17] The recommended method to measure patient-reported outcome is to use a validated questionnaire for oral health related quality of life.[17] An urgent need of clinical studies within implant dentistry including both clinical and patient-reported outcomes have been underlined by a recent review study.[18]

The aim of the present prospective clinical study was to analyze the survival rate and the biological, technical, aesthetic and patient-reported outcomes of implant-supported, single-tooth restorations based on metal or ceramic crowns and abutments in patients with tooth agenesis.

Materials and methods:

Study design

This manuscript presents the results of a five-year prospective study. The study protocol was accepted by the Danish Regional Committee on Biomedical Research Ethics (F-23016016) and the STROBE guidelines and Declaration of Helsinki were followed. The 3-years results of this study are published.[19]

Participants

The included patients had tooth agenesis and were referred to the School of Dentistry in Copenhagen for prosthetic rehabilitation on single-tooth implants. Patients were consecutively recruited and received information and agreed to participate in this clinical study. The participants were healthy patients requiring replacements with single-tooth restorations without any contraindications for dental implant treatment. Fifty-nine patients (35 women and

24 men, mean age: 27.9 years, SD: 9.3, range: 18–50 years) treated with 98 implants (Astra Tech Implant System®, Dentsply Sirona, Mölndal, Sweden) fulfilled the inclusion criteria. The implants were inserted by three oral surgeons at The Department of Oral and Maxillofacial Surgery, Glostrup University Hospital, Copenhagen, Denmark, according to the standard surgical guidelines from the manufacturer. Four to six months after implant insertion, the patients were referred for prosthetic treatments to the School of Dentistry in Copenhagen. Impressions were taken at fixture level and the treating prosthodontists selected the abutment and crown materials based on the principle of the best treatment for the individual patient. The single-tooth restorations composed of all-ceramic crowns on zirconia abutments (AC-C), metal-ceramic crowns on metal abutments (MC-M) or all-ceramic crowns on metal abutments (AC-M). The abutments were zirconia (Zir, ZirDesign™, Astra Tech Implant System®), titanium (Ti, TiDesign™. Astra Tech Implant System®) or cast-to gold alloy (GA, CastDesign,Astra Tech Implant System®) abutments. All restorations were fabricated at the same dental laboratory. The AC crowns composed of zirconia copings (Procera Zirconia, Nobel BiocareTM, Gothenburg, Sweden n=61) or pressable lithium disilicate glass-ceramic (IPS Empress, Ivoclar Vivadent®, Schaan, Liechtenstein, n=3) veneered with nano-fluorapatite glass-ceramic (IPS Empress 2, Ivoclar Vivadent®, n=64). The MC crowns were composed of gold alloy copings (ORION WX, Elephant Dental BV, Hoorn, Netherlands, n=34) with fluorapatite leucite-reinforced glass-ceramic (IPD d.SIGN, Ivoclar Vivadent®, n=34). The abutments were screw-retained using a screw torque of 25 Ncm in accordance with the manufacturer's recommendation, and all crowns were cement-retained. The treatments were completed with careful instruction of all patients in oral hygiene at the time of crown cementation. All patients were guaranteed for a period of five years for care coverage of inserted implants and restorations as they were treated in regional dental service regulated by the health legislation in Denmark.

Variables

After prosthetic treatment, all patients were recalled to baseline (after 8 weeks), 3- and 5-year examinations. Clinical photographs of the restorations including neighboring teeth and marginal peri-implant mucosa were obtained. The intraoral radiographs were recorded by using long cone paralleling-technique with Eggen's film holders. The assessments and analysis of data were performed by a researcher, who was not involved in the treatments.

The clinical examinations included registration of implant survival, mobility, biological complications as well as modified Plaque Index (mPlI) and modified Sulcus Bleeding Index (mBI) at four aspects of each implant-supported crown. The median values of four mPlI and mBI scores were used for each implant-supported crown.[20] A implant was deemed successful if the marginal bone loss (MBL) was less than 2.3 mm between the baseline and 5-year examination, based on a marginal bone loss less than 1.5 mm during the first year and less than 0.2 mm annually.[21]

Diagnosis of peri-implantitis was based on a combination of bleeding and/or suppuration by gentle probing, probing pocket depth (PPD) more than 5 mm, and a marginal bone level located

at least 3 mm apical to the most coronal intra-osseous part of the implant after the first year of the loading.[22] Additionally, diagnosis of peri-implant mucositis was based on the presence of suppuration/bleeding by gentle probing and/or registration of fistula in the absence of bone loss after initial bone remodeling [22].

The radiologic assessments included mesial and distal marginal bone level, evaluation of the marginal fit of the crowns using a modified marginal adaptation score ranging from 1 to 4 and presence/absence of cement excess.[23] The peri-implant marginal bone loss was measured as the change in mesial and distal marginal bone level from baseline to the 5-year examination. According to the study protocol, any changes in marginal bone level indicating "bone gain" were set to 0 mm.

Technical outcome variables included clinical registration of the crown and abutment survival, complications such as loosening or fracture of the abutment screws, loss of retention and crown fractures including chipping of the veneering ceramics as well as radiologically evaluated marginal adaptation scores.

The aesthetic outcome was evaluated by using the Copenhagen Index Score based on photographs from each follow-up.[23,24] The aesthetic parameters of crown morphology score, crown color match score corresponded to the Color and Tooth Form of the White Esthetic Scores (WES), and the scores of mucosal discoloration score, and papilla index score, mesially and distally corresponded to the Soft Tissue Color, Mesial Papilla and Distal Papilla Scores of the Pink Esthetic Scores (PES).[25] Each score ranged from 1 for the best to 4 for the poorest aesthetic outcome.

The patient-reported outcome was evaluated using a Danish version of the Oral Health Impact Profile questionnaire (OHIP-49) before the prosthetic treatment and at the baseline, 3- and 5-year observation. Each answer was scored with a Likert response scale from 0 (never experienced problem) to 4 (problem experienced very often). The summary of questions 3, 4, 20, 22, 31 and 38 was used to describe the patient-reported aesthetic outcome,[23] and the masticatory function was expressed by the summary scores of questions 1, 28, 29 and 32.[26] The overall oral health impact on quality of life was described by a summary of the scores from all 49 OHIP questions.

Statistical methods

Statistical analyses of outcome variables were performed with the IBM® SPSS® Statistics (Armonk, NY, USA, version 28.0.0.0). Descriptive analyses of data were performed. To account for individual differences in response to the different types of restorations, models had to incorporate patients as a random subject. For the quantitative data (differences in bone level and bone loss), analyses were performed using a linear mixed model. For ordinal categorical data at implant level (differences in mPII, mBI, marginal adaptation score, and professional-reported aesthetic scores in the test and control groups), generalized linear mixed model analyses were applied. For description of the patient-reported outcomes, the patients were the statistical unit; thus, the Mann–Whitney U test for difference in the total scores between

groups of patients and the Wilcoxon signed-rank test for difference in the total scores between examinations were used. The statistical significance level was set at $p < .05$.

Results

Fifty-three patients (33 women, 20 men; mean age: 32.4 years), with 89 implants participated in the 5-year examination (mean observation time: 62.5, SD: 6.8 months). Thus, the number of drops outs was 6 patients with 9 implants.

The implant-supported restorations were composed of 29 metal-ceramic crowns cemented on metal abutments, and 60 all-ceramic crowns (copings: zirconia, n= 58; glass-ceramic, n=2) on 50 zirconia and 10 metal abutments. The number and characteristic of patients and their implant-supported restorations are listed in Table 1 and 2.

Biological outcomes

Table 3 demonstrates a summary of the biological outcomes at the 5-year examination. The survival of the implants was 100 % and no mobility of implants was registered.

The median values for plaque (mPII) and bleeding index (mBI) scores were 1 (range 0—3) for all abutments. Analyses of the implant success was based on previously described biological criteria, i.e. MBL less than 2.3 mm from baseline to the 5-years examination; thus, four implants in four patients did not meet this biological success criterion (GA abutments: n=3, Zir abutment: n=1). Consequently, the success rate of implants included in the 5-years examination with Ti, Zir and GA abutments was 100%, 98% and 86.4 %, respectively. One of these implants with GA abutment also fulfilled criteria for peri-implantitis and was subsequently referred for treatment (Figure 1).

The mean marginal bone loss (MBL) was less than 0.7 mm for all abutment materials (Zir: MBL=0.13, SD=0.61, n= 50; Ti: MBL=0.20, SD=0.50, n=17; GA: MBL=0.63, SD=1.06, n=21).

Technical outcomes

The survival rate of restorations was 96% as three AC-C and one MC-M restorations were remade during the 5 years of follow-ups.

At the 5-year examination, three new technical complications were registered. One minor ceramic chip-off fracture (AC-C restoration with zirconia-based crown, region 23), which was polished; one loosed crown (MC-M restoration with Ti abutment, region 35), which was re-cemented; and one abutment screw loosening (AC-C restoration, region 25), which was remounted. The radiological examinations demonstrated cement excess at one implant with AC-C restoration without marginal bone loss (Figure 2).

Figure 3 demonstrated significantly better marginal adaptation of restorations with MC compared to AC crowns (p=0.007, missing: AC: n=1, MC: n=1). There was no significant correlation between the MBL and marginal adaptations ($MBL_{\text{score 1}} = 0.16 \pm 0.70$; $MBL_{\text{scores 2 or 3}} = 0.49, \pm 0.82$; p=0.060).

Aesthetic outcome

The analysis of aesthetic scores were based on restoration materials (crown morphology and color scores based on crown material and mucosal discoloration and papilla scores based on abutment materials, Table 4). There was significantly better crown morphology (p=0.012) and crown color match (p=0.009) for AC compared to the MC-crowns.

The scores of the mucosal discoloration and the papilla index were not significantly different between different abutments. Figure 4 illustrates the changes of peri-implant mucosa color and papilla length between baseline and the 5-year examinations. The mucosal discoloration scores increased (deterioration) and papilla index scores decreased (improvement) statistically significant ($p<0.001$).

The mucosal discoloration increased up to three scores at 36% of the implants. Although, the mucosal discoloration increased more frequently at Ti abutments than at other abutment materials (Zir=32%, Ti=53%, GA=32%), the statistical difference between abutment materials was no significant.

The height of the papilla increased mesially at 40% and distally at 52% of the implants. The changes of the papilla height were not significantly different between different abutment materials.

Patient-reported outcome

The mean summary of all OHIP scores as well as the OHIP-scores for OHIP-questions related to the aesthetic and the masticatory function were significantly different ($p<0.001$) before the prosthetic treatment compared to the baseline examinations performed after the prosthetic treatment, but the mean values did not differ significantly between baseline and the 3-year examinations or between the 3-year and the 5-year examinations (Figure 5).

Among all OHIP questions, scores of the question about food impaction (OHIP-7) and the question related to sensitive teeth (OHIP-13) had the highest mean values at the baseline, and the 3- and 5-years examinations. The mean values of scores of these questions did not differ significantly between the examinations.

At the 5-years examination, the mean values of OHIP-7 and OHIP-13 were not significantly different between patients with oligodontia (n=10) and hypodontia (n=43), nor between patients treated with at least two implants (n=17) and patients treated with only one implant (n=36), or between patients with implants placed only in the premolar regions (n=12) compared to patients with implants only in the anterior region (n=37).

Discussion

In the present study, the five-year survival rates of implants supporting metal-ceramic and all-ceramic restorations were not different since. Similar survival rates were reported by a recent published RCT of all-ceramic and metal-ceramic restorations on single-tooth implants and by a consensus report based on prospective and retrospective clinical trials of metal-ceramic and

zirconia-ceramic implant-supported single crowns.[1,27] The success rates of the zirconia and titanium abutments in our study were comparable, which is supported by a review study of clinical outcomes of these two types of abutments.[28] Only one implant met all criteria for diagnosis of peri-implantitis. Based on criteria for diagnosis of peri-implantitis, a one-year examination after implant loading is necessary,[22] and the lack of this examination can be argued as a drawback of our study design.

Biological outcomes such as plaque accumulation, peri-implant mucositis and marginal bone loss were in general not different for implants with metal or zirconia abutments due to optimal oral hygiene in the majority of the patients, and the statistical difference in the mean PPD was not clinically relevant supported by five-year results of other studies of implants with metal- or zirconia-based crowns.[1,29]

In agreement with our study, a crown survival rate of 96% was reported by a five-year cohort study including a larger number of metal-ceramic and all-ceramic implant-supported crowns.[30] However, the complication rate was higher in that study compared to our study, which could be explained by inclusion of lithium disilicate crowns as the main crown material in that study with higher risk of ceramic fracture compared to zirconia crowns.

In our study, chippings or even more severe fractures of veneering were only registered for all-ceramic restorations, while crown loosening was only observed for metal-ceramic restorations. Veneering fractures have been reported as the most frequent complication, and framework materials seem to influence veneering fractures, particularly that a higher risk may be associated with zirconia compared to metal cores.[30,31] Using monolithic instead of bi-layered all-ceramic implant-supported crowns has been recommended to reduce this complication.[3]

In the literature, the number of studies comparing metal and zirconia abutments is relatively low.[32] According to *in vitro* studies, zirconia abutments have lower fracture resistance and higher fracture incidence than titanium abutments,[33,34] but both materials meet the clinical requirement for occlusal forces. In our study, the lower survival rate of zirconia compared to titanium abutments was related to technical complications at the crown level such as veneering fracture or unacceptable marginal adaptation.[19] A few other clinical studies of metal and zirconia abutments with five years follow-up similarly reported no technical complications on zirconia and titanium abutments.[27,35,36]

The marginal adaptation at the interface between crowns and abutments showed more optimal results for the metal-ceramic compared to the all-ceramic crowns. Optimal marginal adaptation resulted in less marginal bone loss but with no statistically significant difference compared to the marginal bone loss for implants with an apparent radiological marginal gap. An *in vitro* study has reported on less marginal discrepancy of monolithic zirconia crowns compared with metal-ceramic crowns,[37] and other investigations have demonstrated different effects of veneering on marginal gap of zirconia copings.[38-40] To reduce the risk of marginal discrepancy together with the risk of cement excess at the peri-implant tissue, prosthetic designs such as a screw-retained or a hybrid design have been suggested.[41-43]

A higher risk of aesthetic failure for metal-ceramic than zirconia-based implant-supported single crowns has been also reported by other study.[1] The color of the peri-implant mucosa in our study was more favorable for implants supporting zirconia compared to metal abutments; however, no statistical difference was found. Using objective measurement methods such as spectrophotometers, has also demonstrated less peri-implant mucosal discoloration at zirconia compared to metal abutments.[44-46] The mucosal discoloration at implant sites supporting zirconia abutments might be due to a thinner peri-implant tissue allowing the implant color to shine through the buccal mucosa.[47] During our study, the discoloration of mucosa increased significantly regardless of the choice of abutment material, which may be associated with a reduction of the buccal peri-implant tissue thickness.[48,49]

The length of the interdental papilla is supposed to have a positive effect on the perception of aesthetics [50]. In our study, the length of the mesial and distal papilla was not related to the abutment material. The length of the papilla increased significantly indicating spontaneous regeneration of papillae over time.[51]

As some of the patients in our study received different restoration materials, the patient-reported outcomes were analyzed based on other factors. Our results indicated a significant positive effect of prosthetic treatment on the quality of life which remained stable during the follow-up time in our study. The most substantial problem was food impaction and sensitive teeth throughout the study period, which could be associated with the risk of gingival retraction around adjacent teeth due to surgical periosteal releasing incisions.[27,52] Still, more clinical studies on adverse effects of implant treatment on the adjacent teeth/tissues and on patient satisfaction are needed. Other limitations of this study were limited number of participants and the variations in the treatment region and materials. Randomized or prospective studies with larger number of participants are preferred for future studies.

Conclusion

This prospective clinical study indicated that zirconia abutments and all-ceramic crowns are reliable alternative prosthetic materials to metal abutment and metal-ceramic crowns on single-tooth implants with favorable biological and aesthetic outcome, and few technical complications. However, abutment materials had no effect on the aesthetic outcome of the peri-implant mucosa. More clinical studies with long follow-ups are needed.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Morton D, Gallucci G, Lin WS, et al. Group 2 ITI Consensus Report: Prosthodontics and implant dentistry. *Clinical oral implants research*. Oct 2018;29 Suppl 16:215-223. doi:10.1111/clr.13298

2. Howe MS, Keys W, Richards D. Long-term (10-year) dental implant survival: A systematic review and sensitivity meta-analysis. *Journal of dentistry*. May 2019;84:9-21. doi:10.1016/j.jdent.2019.03.008

3. Pjetursson BE, Sailer I, Latyshev A, Rabel K, Kohal RJ, Karasan D. A systematic review and meta-analysis evaluating the survival, the failure, and the complication rates of veneered and monolithic all-ceramic implant-supported single crowns. *Clinical oral implants research*. Oct 2021;32 Suppl 21(Suppl 21):254-288. doi:10.1111/clr.13863

4. Jung RE, Zembic A, Pjetursson BE, Zwahlen M, Thoma DS. 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. *Clinical oral implants research*. Oct 2012;23 Suppl 6:2-21. doi:10.1111/j.1600-0501.2012.02547.x

5. Tinschert J, Zwez D, Marx R, Anusavice KJ. Structural reliability of alumina-, feldspar-, leucite-, mica- and zirconia-based ceramics. *Journal of dentistry*. Sep 2000;28(7):529-35. doi:10.1016/s0300-5712(00)00030-0

6. Edelhoff D, Brix O. All-ceramic restorations in different indications: a case series. *Journal of the American Dental Association (1939)*. Apr 2011;142 Suppl 2:14s-9s. doi:10.14219/jada.archive.2011.0338

7.Hanawa T. Zirconia versus titanium in dentistry: A review. *Dental materials journal*. Jan 31 2020;39(1):24-36. doi:10.4012/dmj.2019-172

8. van Brakel R, Meijer GJ, Verhoeven JW, Jansen J, de Putter C, Cune MS. Soft tissue response to zirconia and titanium implant abutments: an in vivo within-subject comparison. *J Clin Periodontol*. Oct 2012;39(10):995-1001. doi:10.1111/j.1600-051X.2012.01931.x

9. de Oliveira Silva TS, de Freitas AR, de Albuquerque RF, Pedrazzi V, Ribeiro RF, do Nascimento C. A 3-year longitudinal prospective study assessing microbial profile and clinical outcomes of single-unit cement-retained implant restorations: Zirconia versus titanium abutments. *Clin Implant Dent Relat Res*. Jun 2020;22(3):301-310. doi:10.1111/cid.12888

10. Ismail F EM, Grade S, Stiesch M In Situ Biofilm Formation on Titanium, Gold Alloy and Zirconia Abutment Materials. *Dentistry*. 2016;6(11):400. doi:10.4172/2161-1122.1000400

11. Yamane K, Ayukawa Y, Takeshita T, Furuhashi A, Yamashita Y, Koyano K. Bacterial adhesion affinities of various implant abutment materials. *Clinical oral implants research*. Dec 2013;24(12):1310-5. doi:10.1111/j.1600-0501.2012.02574.x

12. de Avila ED, Avila-Campos MJ, Vergani CE, Spolidório DM, Mollo Fde A, Jr. Structural and quantitative analysis of a mature anaerobic biofilm on different implant abutment surfaces. *J Prosthet Dent*. Apr 2016;115(4):428-36. doi:10.1016/j.prosdent.2015.09.016

13. de Freitas AR, Silva TSO, Ribeiro RF, de Albuquerque Junior RF, Pedrazzi V, do Nascimento C. Oral bacterial colonization on dental implants restored with titanium or zirconia abutments: 6-month follow-up. *Clin Oral Investig*. Jul 2018;22(6):2335-2343. doi:10.1007/s00784-018-2334-0

14. Esfahanizadeh N, Mirmalek SP, Bahador A, Daneshparvar H, Akhoundi N, Pourhajibagher M. Formation of biofilm on various implant abutment materials. *General dentistry*. Sep-Oct 2018;66(5):39-44.

15. Furuhashi A, Ayukawa Y, Atsuta I, Rakhmatia YD, Koyano K. Soft Tissue Interface with Various Kinds of Implant Abutment Materials. *J Clin Med*. May 28 2021;10(11)doi:10.3390/jcm10112386

16. Wen C, Muhetaer HJ, Gao Z, Wu J. Dual response of fibroblasts viability and Porphyromonas gingivalis adhesion on nanostructured zirconia abutment surfaces. *Journal of biomedical materials research Part A*. Oct 2022;110(10):1645-1654. doi:10.1002/jbm.a.37414

17. Tonetti MS, Jepsen S. Clinical efficacy of periodontal plastic surgery procedures: consensus report of Group 2 of the 10th European Workshop on Periodontology. *J Clin Periodontol*. Apr 2014;41 Suppl 15:S36-43. doi:10.1111/jcpe.12219

18. Sailer I, Barbato L, Mojon P, et al. Single and partial tooth replacement with fixed dental prostheses supported by dental implants: A systematic review of outcomes and outcome measures used in clinical trials in the last 10 years. *Clinical oral implants research*. Mar 25 2022;doi:10.1111/clr.13926

19. Hosseini M, Worsaae N, Schiodt M, Gotfredsen K. A 3-year prospective study of implant-supported, single-tooth restorations of all-ceramic and metal-ceramic materials in patients with tooth agenesis. *Clinical oral implants research*. Oct 2013;24(10):1078-87. doi:10.1111/j.1600-0501.2012.02514.x

20. Mombelli A, van Oosten MA, Schurch E, Jr., Land NP. The microbiota associated with successful or failing osseointegrated titanium implants. *Oral microbiology and immunology*. Dec 1987;2(4):145-51. doi:10.1111/j.1399-302x.1987.tb00298.x

21. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *Int J Oral Maxillofac Implants*. 1986 1986;1(1):11-25. Not in File.

22. Berglundh T, Armitage G, Araujo MG, et al. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *J Periodontol*. Jun 2018;89 Suppl 1:S313-s318. doi:10.1002/jper.17-0739

23. Dueled E, Gotfredsen K, Trab Damsgaard M, Hede B. Professional and patient-based evaluation of oral rehabilitation in patients with tooth agenesis. *Clinical oral implants research*. Jul 2009;20(7):729-36. doi:10.1111/j.1600-0501.2008.01698.x

24. Hosseini M, Gotfredsen K. A feasible, aesthetic quality evaluation of implant-supported single crowns: an analysis of validity and reliability. *Clinical oral implants research*. Apr 2012;23(4):453-8. doi:10.1111/j.1600-0501.2011.02162.x

25. Belser UC, Grütter 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*. Jan 2009;80(1):140-51. doi:10.1902/jop.2009.080435

26. Goshima K, Lexner MO, Thomsen CE, Miura H, Gotfredsen K, Bakke M. Functional aspects of treatment with implant-supported single crowns: a quality control study in subjects with tooth agenesis. *Clinical oral implants research*. Jan 2010;21(1):108-14. doi:10.1111/j.1600-0501.2009.01809.x

27. Hosseini M, Worsaae N, Gotfredsen K. A 5-year randomized controlled trial comparing zirconia-based versus metal-based implant-supported single-tooth restorations in the premolar region. *Clinical oral implants research*. Aug 2022;33(8):792-803. doi:10.1111/clr.13960

28. Halim FC, Pesce P, De Angelis N, Benedicenti S, Menini M. Comparison of the Clinical Outcomes of Titanium and Zirconia Implant Abutments: A Systematic Review of Systematic Reviews. *J Clin Med*. Aug 28 2022;11(17)doi:10.3390/jcm11175052

29. Shen XT, Li JY, Luo X, Feng Y, Gai LT, He FM. Peri-implant marginal bone changes with implant-supported metal-ceramic or monolithic zirconia single crowns: A retrospective clinical study of 1 to 5 years. *J Prosthet Dent*. Sep 2022;128(3):368-374. doi:10.1016/j.prosdent.2020.12.010

30. Rammelsberg P, Lorenzo Bermejo J, Kappel S, Meyer A, Zenthöfer A. Long-term performance of implant-supported metal-ceramic and all-ceramic single crowns. *J Prosthodont Res*. Jul 2020;64(3):332-339. doi:10.1016/j.jpor.2019.09.006

31. Schwarz S, Schröder C, Hassel A, Bömicke W, Rammelsberg P. Survival and chipping of zirconia-based and metal-ceramic implant-supported single crowns. *Clin Implant Dent Relat Res*. May 2012;14 Suppl 1:e119-25. doi:10.1111/j.1708-8208.2011.00388.x

32. Hu J, Atsuta I, Ayukawa Y, Zhou T, Narimatsu I, Koyano K. Effect of titanium or zirconia implant abutments on epithelial attachments after ultrasonic cleaning. *Journal of oral science*. 2020;62(3):331-334. doi:10.2334/josnusd.19-0332

33. Att W, Kurun S, Gerds T, Strub JR. Fracture resistance of single-tooth implant-supported all-ceramic restorations: an in vitro study. *J Prosthet Dent*. Feb 2006;95(2):111-6. doi:10.1016/j.prosdent.2005.12.003

34. Hosseini M, Kleven E, Gotfredsen K. Fracture mode during cyclic loading of implant-supported single-tooth restorations. *J Prosthet Dent*. 8/2012 2012;108(2):74-83. Not in File. doi:S0022-3913(12)60110-3 [pii];10.1016/S0022-3913(12)60110-3 [doi]

35. 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*. Jan-Feb 2013;28(1):281-7. doi:10.11607/jomi.2668

36. Zembic A, Bösch A, Jung RE, Hämmerle 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. *Clinical oral implants research*. Apr 2013;24(4):384-90. doi:10.1111/clr.12044

37. Paul N, Raghavendra Swamy KN, Dhakshaini MR, Sowmya S, Ravi MB. Marginal and internal fit evaluation of conventional metal-ceramic versus zirconia CAD/CAM crowns. *Journal of clinical and experimental dentistry*. Jan 2020;12(1):e31-e37. doi:10.4317/medoral.55946

38. Mohaghegh M, Firouzmandi M, Ansarifard E, Ramazani L. Marginal Fit of Full Contour Monolithic Zirconia in Different Thicknesses and Layered Zirconia Crowns. *Journal of International Society of Preventive & Community Dentistry*. Sep-Oct 2020;10(5):652-658. doi:10.4103/jispcd.JISPCD_25_20

39. Rayyan MR. Marginal Adaptation of Monolithic High-Translucency Versus Porcelain-Veneered Zirconia Crowns. *Int J Prosthodont*. Jul/Aug 2019;32(4):364-366. doi:10.11607/ijp.5985

40. Del Piñal M, Lopez-Suarez C, Bartolome JF, Volpato CA, Suarez MJ. Effect of cementation and aging on the marginal fit of veneered and monolithic zirconia and metal-ceramic CAD-CAM crowns. *J Prosthet Dent*. Feb 2021;125(2):323.e1-323.e7. doi:10.1016/j.prosdent.2020.06.036

41. Tinedo-López PL, Malpartida-Carrillo V, Ortiz-Culca F, Guerrero ME, Amaya-Pajares SP, Özcan M. Vertical Marginal Discrepancy of Retrievable Cement/Screw-retained Design and Cement-retained Implant-supported Single Metal Copings. *The journal of contemporary dental practice*. Aug 1 2020;21(8):829-834.

42. Weber HP, Kim DM, Ng MW, Hwang JW, Fiorellini JP. Peri-implant soft-tissue health surrounding cement- and screw-retained implant restorations: a multi-center, 3-year prospective study. *Clinical oral implants research*. Aug 2006;17(4):375-9. doi:10.1111/j.1600-0501.2005.01232.x

43. Tosches NA, Brägger U, Lang NP. Marginal fit of cemented and screw-retained crowns incorporated on the Straumann (ITI) Dental Implant System: an in vitro study. *Clinical oral implants research*. Jan 2009;20(1):79-86. doi:10.1111/j.1600-0501.2008.01591.x

44. Pitta J, Zarauz C, Pjetursson B, Sailer I, Liu X, Pradies G. A Systematic Review and Meta-Analysis of the Influence of Abutment Material on Peri-implant Soft Tissue Color Measured Using Spectrophotometry. *Int J Prosthodont*. Jan/Feb 2020;33(1):39-47. doi:10.11607/ijp.6393

45. Vazouras K, Gholami H, Margvelashvili-Malament M, Kim YJ, Finkelman M, Weber HP. An Esthetic Evaluation of Different Abutment Materials in the Anterior Maxilla: A Randomized Controlled Clinical Trial Using a Crossover Design. *Journal of prosthodontics : official journal of the American College of Prosthodontists*. Oct 2022;31(8):673-680. doi:10.1111/jopr.13520

46. Peng M, Fei W, Mandana H, Klaus G. [Influence of all-ceramic and porcelain-fused-to-metal restorations on peri-implant gingival discoloration:a spectrophotometric comparison]. *Shanghai Kou Qiang Yi Xue*. 4/2013 2013;22(2):219-223. Not in File.

47. Totou D, Naka O, Mehta SB, Banerji S. Esthetic, mechanical, and biological outcomes of various implant abutments for single-tooth replacement in the anterior region: a systematic review of the literature. *International journal of implant dentistry*. Sep 8 2021;7(1):85. doi:10.1186/s40729-021-00370-7

48. Bienz SP, Pirc M, Papageorgiou SN, Jung RE, Thoma DS. The influence of thin as compared to thick peri-implant soft tissues on aesthetic outcomes: A systematic review and meta-analysis. *Clinical oral implants research*. Jun 2022;33 Suppl 23(Suppl 23):56-71. doi:10.1111/clr.13789

49. Hosseini M, Worsaae N, Gotfredsen K. Tissue changes at implant sites in the anterior maxilla with and without connective tissue grafting: A five-year prospective study. *Clinical oral implants research*. Jan 2020;31(1):18-28. doi:10.1111/clr.13540

50. Yu YC, Alamri A, Francisco H, Cho SC, Hirsch S. Interdental Papilla Length and the Perception of Aesthetics in Asymmetric Situations. *International journal of dentistry*. 2015;2015:125146. doi:10.1155/2015/125146

51. Jemt T. Regeneration of gingival papillae after single-implant treatment. *Int J Periodontics Restorative Dent*. Aug 1997;17(4):326-33.

52. Gholami GA, Hariri S, Amid R, et al. Average and Maximum Papilla Heights around Dental Implants in the Anterior Maxillary Region: A Retrospective Clinical Study. *International journal of dentistry*. 2022;2022:4235946. doi:10.1155/2022/4235946

Table. 1. Characteristic of patients and number of implants per patient participated to the 5-year examination.

Included patients (n)	53
Drop-out (n)	6
Gender	
Male (n)	20
Female (n)	33
Age; years (mean, range)	32,4 (23-54)
Number of tooth agenesis/patient	
Hypodontia (1-5 teeth missing)	43
Oligodontia (> 5 teeth missing)	10
Included implants (n)	89
Number of implants per patient	
	34 patients with 1 implant
	14 patients with 2 implants
	1 patient with 3 implants
	1 patient with 4 implants
	1 patient with 6 implants
	2 patients with 7 implants

Table. 2. Frequencies of implant-supported restorations with different materials at toothless regions at 5-year examination.

Restoration		Region††	
Type of restorations†	Number (n)	Anterior (n)	Posterior (n)
AC-C	50 (abutments: Zir, n=50)	39	11
MC-M	29 (abutments: Ti, n=14; GA: n=15)	12	17
AC-M	10 (abutments: Ti, n=3; GA: n=7)	9	1
Total	**89**	**60**	**29**

† AC: all-ceramic crowns, MC: Metal-ceramic crowns, C: ceramic abutment of zirconia (Zir), M: metal abutment of Gold alloy (GA) or titanium (Ti).

†† Anterior: incisors or canines; Posterior: premolars or molars

Table 3. Biological outcome at implants with three different abutment materials five years after loading

Biological variables	Type of abutments		
	Zirconia (Zir-design)	Titanium (Ti-design)	Gold alloy (Cast-to)
Implant survival (%)	100 %	100 %	100 %
Implant mobility (%)	0%	0 %	0 %
Modified Plaque Index			
Score 0	33 %	41 %	24 %
Score 1	35 %	24 %	57 %
Score 2	22 %	29 %	19 %
Score 3	10 %	6 %	0 %
Modified Sulcus Bleeding Index			
Score 0	39 %	41 %	19 %
Score 1	33 %	18 %	48 %
Score 2	16 %	41 %	19 %
Score 3	12 %	0 %	14 %
Probing Pocket Depth (mean)			
Buccal	2.11 mm	2.23 mm	2.86 mm
Mesially	2.00 mm	1.46 mm	2.57 mm
Lingually	2.42 mm	2.23 mm	3.00 mm
Distally	2.14 mm	2.31 mm	2.57 mm

Total mean	**2.17 mm** (+/-0.75)	**2.06 mm** (+/-0.66)	**2.75 mm** (+/-1.44)*
Marginal Bone Level			
<2 mm	88 % (n=44)	94 % (n=16)	77 % (n=17)
2-2.9 mm	8 % (n=4)	6 % (n=1)	18 % (n=4)
≥3 mm†	4 % (n=2)	0 % (n=0)	5 % (n=1)
Total	**100% (n=50)**	**100% (n=17)**	**100% (n=22)**
Biological success rate based on marginal Bone loss (MBL) between baseline and 5-years examination			
<2.3 mm	98 % (n=49)	100 % (n=17)	86 % (n=19)
≥2.3 mm‡	2 % (n=1)	0 % (n=0)	14 % (n=3)
Total	**100% (n=50)**	**100% (n=17)**	**100% (n=22)**

* Statistically significant difference compared to Ti (p= 0.021) and Zir (p= 0.011) abutments, although no clinical relevant difference

†peri-implantitis, mesially and/or distally

‡ Implants without biological success: the sum of 1.5 mm and 0.8 mm (0.2 mm annually after first year)

Table 4. Frequency of the aesthetic scores based on crown or abutment materials.

Aesthetic variables for different restoration materials		Score 1 (%)	Score 2 (%)	Score 3 (%)	Score 4 (%)
Crown morphology*	AC	56	41	3	0
	MC	28	69	3	0
Crown colour match*	AC	58	41	2	0
	MC	31	62	7	0
Mucosal discoloration	Zir	62	18	12	8
	Ti	29	47	24	0
	GA	45	45	5	5
Papilla, mesially	Zir	43	51	4	2
	Ti	41	59	0	0
	GA	45	55	0	0
Papilla, distally	Zir	46	46	6	2
	Ti	65	12	23	0
	GA	64	32	4	0

AC: all-ceramic crown; MC: metal-ceramic crowns; Zir: zirconia abutment; Ti: Titanium abutment; GA: Gold alloy abutment

* AC versus MC *crowns:* significant difference

Figure legends

Figure 1. Peri-implantitis at implant in regio 13 supporting metal abutment and metal-ceramic crown.

Figure 2. Radiological registration of cement excess at 5-year examination.

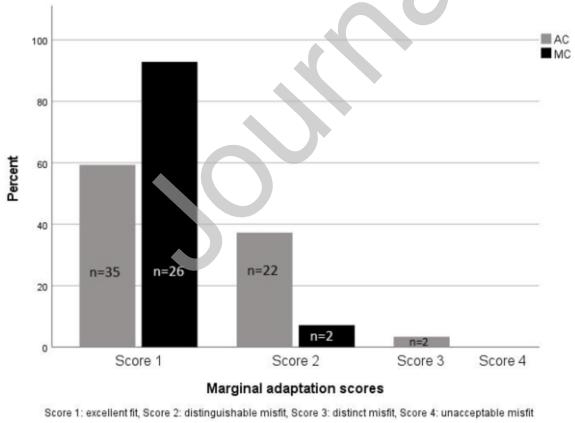


Figure 3. Bar chart of marginal adaptation scores (crowns: all-ceramic/AC, one missing; metal-ceramic/MC, one missing).

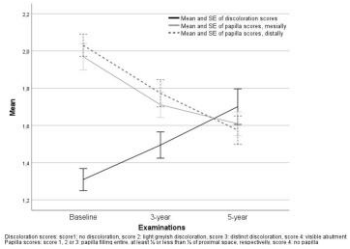


Figure 4. Line chart demonstrating changes of papilla and discoloration scores (mean, error bars (+/- 1 SE)).

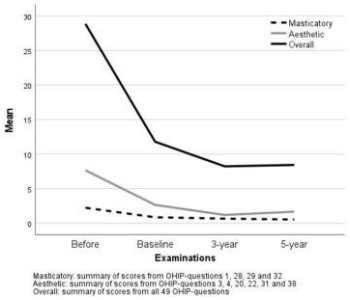


Figure 5. Line chart demonstrating the mean values of OHIP-49 scores before and after prosthetic treatment.