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RESEARCH ARTICLE

# *In vivo* Evaluation of Zirconia Abutments in Implant supported Restorations in Partially Edentulous Patients

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## ABSTRACT

Dental implants have been a universally accepted option for prosthetic rehabilitation of partially edentulous patients. Titanium implants abutments exhibit a dull grayish hue and give an unnatural appearance. Abutments based on zirconia are one of the alternatives to titanium abutments. To date, few comparative studies have reported on esthetic and biological outcomes of implant-supported restorations with zirconia abutments.

**Purpose:** To clinically evaluate the esthetic performance of zirconia abutments in implant-supported restorations.

**Materials and methods:** A total of 24 anterior implant sites were chosen for the placement of implants. A delayed loading protocol was followed; 12 zirconia abutments were placed along with 12 titanium abutments in the contralateral sites. Biological and esthetic variables were recorded by a periodontist and prosthodontist. The patients were followed 2 weeks, 1, 3, and 6 months postinsertion.

**Results:** All the data for Copenhagen index score and visual analog scale scores were evaluated by the prosthodontist at follow-up appointments; the means were tabulated. The data were statistically analyzed using Statistical Package for the Social Sciences software utilizing paired t-test; p value was found to be significant for all parameters except distal papilla and symmetry, which showed p = 0.257 and p = 0.110 respectively.

**Conclusion:** According to the results of this study, esthetic performances of zirconia abutment in implant-supported restorations were determined to be higher than those values associated with titanium abutments.


**Keywords:** Esthetic abutments, Implant esthetics, Titanium abutment, Zirconia.

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## INTRODUCTION

Abutments and dental implants were usually fabricated out of commercially pure titanium.[1] Titanium has demonstrated good biocompatibility and mechanical properties.[2] However, from an esthetic point of view, titanium abutments sometimes result in an abnormal bluish hue to the soft tissue.[3] Hence, for achieving optimal mucogingival esthetics, there was a need for tooth colored abutments.[4] With increased demand for esthetic restorations, tooth colored abutment materials have gained popularity.[5-7] Among the various tooth colored materials used for abutments are alumina, combination of zirconia and titanium, or purely zirconia ceramics.[8] Alumina showed promise but had a drawback of fracturing near the neck of the abutment due to its poor flexural strength.[9] Abutments and crowns fabricated from zirconia are one of the most recent alternatives to metal abutments.[10] Until now, there have not been many *in vivo* studies or randomized control trials that have assessed the biologic and esthetic variables related to zirconia-based implant-supported restorations. Hence, this study was designed to evaluate the esthetic and biological aspects of zirconia abutments *in vivo*.

The aim of this study was to evaluate the clinical performance of zirconia abutment-based implant-supported restorations in partially edentulous patients. The objectives were to evaluate the clinical results of zirconia *vs* titanium abutments in implant-supported restorations in terms of esthetic and biologic outcomes. The primary research question was whether zirconia abutments resulted in better esthetic and biologic outcomes in implant-supported restorations in clinical situations. The study was carried out for 4 years. The recent scientific literature showed very few comparative studies have been reported on esthetic and biological outcomes of implant-supported restorations using zirconia abutments. Zirconia abutments, if successful, could be used as a viable treatment option to rehabilitate those who are afflicted with partial edentulism, especially in esthetic zone.

In 1993, a novel ceramic abutment (CerAdapt, Nobel Biocare), which was made of densely sintered alumina, was introduced for Brånemark system implants (Nobel Biocare).[5-7] It was indicated for single crowns and fixed partial dentures (FPDs) in anterior teeth including

premolar regions with documented evidence of encouraging results with prospective clinical studies.[11,12]

Furthermore, abutments made of densely sintered yttrium-stabilized zirconia were introduced for use as support for implant-supported single-tooth crowns.[13,14] Alumina as well as zirconia was characterized by tissue compatibility,[15] low corrosion potential, low thermal conductivity, and superior mechanical properties compared with conventional ceramics.[16-19] Moreover, zirconia has a flexural strength and fracture toughness almost twice as high as alumina.[20] Zirconia has been considered to be a promising ceramic abutment as it has high flexural strength (1,400 MPa) and desirable optical properties. Through its common use in orthopedics (e.g., hip joint replacements) for many years, the biocompatibility of zirconia has been extensively documented.[21,22] Zirconia abutments are either prefabricated or custom made.[23]

Scarano et al[24] reported that the degree of coverage by bacteria was 12% for zirconia and 19% for titanium surfaces *in vivo*. They demonstrated that zirconium oxide is a suitable material for implant abutments with a low colonization potential. Manicone et al[25] presented a systematic overview on zirconia ceramics and indicated a high success rate for zirconia FPDs and zirconia implant abutments. Rimondini et al[26] suggested *in vitro* yttria-tetragonal zirconia polycrystal accumulated fewer bacteria than Ti in terms of total number of bacteria and presence of potential putative pathogens, such as rods. Nascimento et al[27] found significant difference in total cell count of *Candida* species between commercially pure titanium and machined pure titanium. An *in vivo* animal study analyzed soft tissue responses to implant abutments made of titanium, $ZrO_2$, Ti, and Au-Pt alloy and established no difference in the soft tissue dimensions between Ti and $ZrO_2$ abutments at 2 and 5 months of healing, but a significant difference was found between the two materials and Au-Pt alloy.[28] Similarly, Kohal et al[4] found no difference in soft tissue integration around rough titanium and zirconia implants in a monkey model. Lima et al[29] and Al-Ahmad et al[30] found that Ti and $ZrO_2$ surfaces displayed similar biological properties in terms of biofilm composition and bacterial adherence. The attachment, growth pattern, and the hereditic effect of human gingival fibroblasts cultivated on titanium and different zirconia surfaces (smooth and rough) were also investigated. Human gingival fibroblast showed equivalent biological responses to both grooved zirconia ceramic and pure titanium surfaces.[31] van Brakel et al[32] compared the health of the soft tissues toward zirconia and titanium abutments in man, as observed using histological data. No differences in soft tissue health were seen in peri-implant soft tissue adjacent to zirconia and titanium abutment surfaces. Zirconia abutments also showed a high level of precision fit.[33] With standard internal diameter trichannel connection implants, the maximum load capacity of zirconia abutment was significantly higher than that of the other commercial alumina-based abutments.[34]

In a systematic review of *in vivo* studies of implant-supported restorations by Sailer et al,[35] the rate of marginal bone level exceeding 2 mm was higher for implants supporting metal than for those supporting ceramic abutments. In that systematic review, metal abutments referred to both gold alloy and titanium abutments, and ceramic abutments referred to oxide ceramics, i.e., alumina and zirconia abutments. Rimondini et al[26] reported lower accumulation and colonization of bacterial plaque on zirconia than on titanium surfaces while comparing plaque accumulation on abutments. Few patients and clinicians have different views regarding esthetics of a restoration.[36] Distal papilla measurements were less reliable than mesial, which may be due to practical limitations to reproduce the distal papilla by photographs.[37] Gingiva biotype and cervical dimension of abutment would also influence papilla dimension.[38,39]

## MATERIALS AND METHODS

The study was carried out on consenting patients aged 18 years or more who had at least two teeth missing in the anterior esthetic zone and desired implant-supported restorations. The inclusion criteria were patients who required tooth replacements with implant-supported restorations, had no contraindications for oral implant treatment, e.g., uncontrolled diabetes, metabolic bone disorders, past radiotherapy in head and neck, current chemotherapy, or other diseases with an influence on bone healing, and who would participate in follow-up examinations. The study sample was to include 24 implant sites. These sites need to be fully healed (teeth extracted/lost > 4 months before implant placement), have adequate bone quality and quantity, have adequate gingival biotype of 1.5 to 2 mm thickness, and opposed by natural teeth or a fixed prosthesis.

The exclusion criteria included conditions requiring chronic antibiotics or steroids, renal failure, severe or uncontrolled metabolic disorder, alcoholism or drug abuse, human immunodeficiency virus infection or smoking >10 cigarettes per day or chewing tobacco, and severe bruxism/clenching or persistent intraoral infection.

Eligible patients would be assessed by clinical examination, medical and dental history, and radiographs (Fig. 1). The clinical and radiological registrations (both panoramic and intraoral periapical radiographs) were performed intra- and postoperatively (Fig. 2). Surgery was performed with local anesthesia under aseptic conditions in an outpatient environment, following the standard flap or flapless technique and abiding by the manufacturer's

**Fig. 1:** Preoperative evaluation

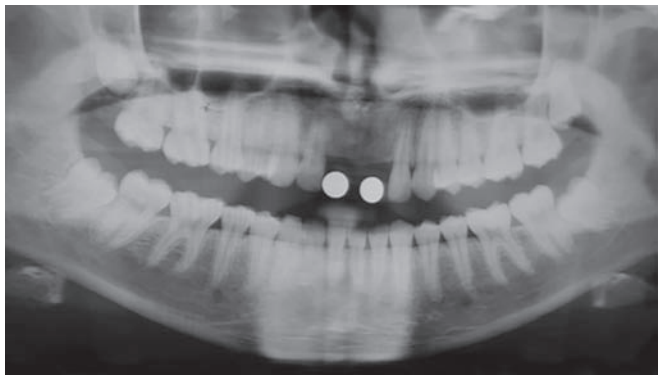


**Fig. 2:** Preoperative orthopantomogram

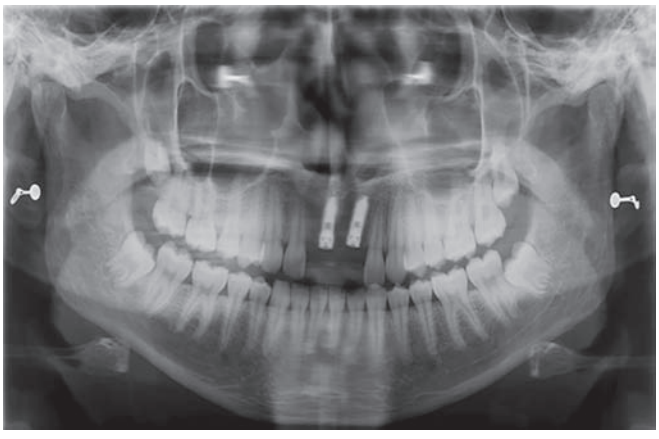


**Fig. 3:** Implant placement orthopantomogram

**Fig. 4:** Tooth 11 with titanium abutment and tooth 21 with zirconia abutment

recommendation on sequential steps in implant placement. Implants were from AB Dental Company, Israel, ranging from 3.3 to 3.5 mm in diameter and 10 to 11.5 mm in length. Any implant lacking primary stability when tested intraoperatively by clinically checking for mobility with the help of blunt-ended instruments was excluded from further study participation. Patients with inadequate bone during surgery were excluded.

The delayed loading protocol was followed for the purpose of the study. Implant site allocation for control or experimental group was done randomly. Healing abutments were placed after 3 months of implant placement. Impressions were made with elastomeric impression materials using impression copings. Twelve anterior implant sites were selected for zirconia abutments and 12 anterior implant sites for titanium abutments, which were used as controls (Fig. 3). The abutments were manufactured by ALB Surgicals (West Patel Nagar, New Delhi, India) with AB implants, Israel. The abutments were placed 2 weeks after healing abutment placement (Fig. 4). The restorations were fabricated thereafter with all ceramic crowns (Fig. 5). All anterior implant sites with zirconia abutments received all ceramic crowns. Biological variables in terms of modified plaque index and esthetic variables (in terms of five criteria of Copenhagen index)

**Fig. 5:** Postoperative intraoral

were recorded by a periodontist and prosthodontist. Variables for Copenhagen index score (CIS) were crown morphology, crown color match, symmetry, mucosal discoloration, and mesial and distal papilla. The examiners were calibrated using dental examination calibration procedure manual (Columbus State Community College) with weighted kappa 0.64 to 1.00.[40] The patients were followed up after 2 weeks, 1, 3, and 6 months.

The implants placed were evaluated clinically and radiologically. Criteria for the evaluation were as follows:

**Table 1:** Modified plaque index[23]

| |
|---|
| 0: No detection of plaque |
| 1: Plaque only recognized by running a probe across the smooth marginal surface of implant |
| 2: Plaque can be seen by naked eye |
| 3: Abundance of soft matter |

**Table 2:** Copenhagen index score[24]

| *Copenhagen Index Score* | |
|---|---|
| Harmony and symmetry | According to facial midline, the tooth axis, and the smile line |
| | Score 1: Optimal symmetry, Score 2: Almost symmetry, Score 3: Asymmetric, Score 4: Very asymmetric |
| Crown morphology | Based on "Ideal Shape" with regards to prominences, surface contours and dimensions of the crown compared with contralateral natural tooth |
| | Score 1: Optimal, Score 2: Almost optimal, Score 3: Suboptimal, Score 4: Unacceptable |
| Color match of the crown | Comparison of the hue, value, chroma and transluency to natural dentition |
| | Score 1: Optimal, Score: 2: Almost optimal, Score 3: Suboptimal, Score 4: Unacceptable |
| Discoloration of buccal mucosa | The degree of grayish discoloration of marginal mucosa |
| | Score 1: No discoloration, Score 2: Light grayish, Score 3: Distinct greyish, Score 4: Visible metal |
| Papilla level | The papilla height mesially and distally |
| | Score 1: Papilla filled the entire proximal space, Score 2: At least ½ the height of papilla was present, Score 3: Less than ½ the height of papilla but there was a convex curvature of papilla present, Score 4: No papilla. |

Biological variables were recorded in terms of modified plaque index (Table 1)[41] and esthetic variables were recorded in terms of CIS (Table 2)[42] and visual analog scale (VAS) (Table 3).[43]

## RESULTS

All patients selected returned for recalls. All the data for modified plaque index were recorded with the help of periodontal probe and a disclosing solution at the follow-up visits after 3 weeks, 1, 3, and 6 months, and their mean was tabulated by the periodontist (Table 4). All the data for CIS and VAS scores were evaluated by the prosthodontist and the periodontist at follow-up appointments and their mean tabulated as shown in

**Table 3:** Overall CIS and VAS score[25]

| *Sl. no.* | *Overall CIS* | *Visual analog score* |
|---|---|---|
| 1 | Excellent | Very bad esthetics |
| 2 | Very good | Bad esthetics |
| 3 | Good | Average esthetics |
| 4 | Poor | Good esthetics |
| 5 | Very poor | Very good esthetics |

**Table 4:** Modified plaque index scores

| *No. of cases* | *Patient's name* | *Teeth no.* | *ZR-based restoration* | *Ti-based restoration* |
|---|---|---|---|---|
| 1 | Zuala | 11,21 | 0 | 0 |
| 2 | Nehal | 11,21 | 0 | 1 |
| 3 | Do Virender | 21,22 | 0 | 1 |
| 4 | Vinod | 11,21 | 1 | 1 |
| 5 | Renu Singhal | 11,21,22,23 | 1 | 1 |
| 6 | Madhu Gupta | 11,21,22 | 1 | 1 |
| 7 | Arvind | 11,21 | 1 | 1 |
| 8 | V K Syal | 11,21 | 2 | 2 |
| 9 | R P Singh | 11,21 | 1 | 1 |
| 10 | Wo Rathore | 11,21 | 0 | 0 |
| 11 | Sgt Vinay | 11,21 | 0 | 0 |
| 12 | Sep Narayan | 11,21 | 0 | 1 |

Tables 5 and 6. The data were then statistically analyzed using Statistical Package for the Social Sciences software utilizing paired t-test (Tables 7 and 8); p value was found to be significant for all parameters except distal papilla and symmetry. Graphical representation of modified plaque index and VAS is shown in Graphs 1 and 2. Graph 3 shows the graphical representation of all the six parameters of CIS.

## DISCUSSION

The study results showed modified plaque indices and VAS scores with highly significant results (p = 0.000). Among the CIS criteria, all the criteria showed significant results, with mucosal discolorations and crown color match showing highly significant p-value = 0.000 except distal papilla measurements that showed p = 0.257 and symmetry showing p = 0.110, which were not significant. These results showed that only distal papilla and symmetry measurements had no effect on titanium or zirconia abutments. Distal papilla measurements were less reliable than mesial, which may be due to practical limitations to reproduce the distal papilla by photographs.[37] Gingiva biotype and cervical dimension of abutment would also influence papilla dimension.[38,39]

The study results showed zirconia abutments retained less plaque than titanium abutments as zirconia abutments may represent a material surface less attractive or smoother for plaque retention compared with titanium. According to Andersson and Odén[16] zirconia generates more stable peri-implant soft tissue and hence, less plaque retention. The material properties, surface roughness, and glass content also allowed less plaque retention than titanium. This result is in accordance with that of Meier et al.[17] The study results also showed better esthetics in zirconia abutments than titanium surfaces. This can also be accepted in terms of better soft tissue emergence profile and better maintenance of interdental

**Table 5:** Copenhagen index score

| No. of cases | Crown morphology | | Crown color match | | Mucosal discoloration | | Mesial papilla | | Distal papilla | | Symmetry | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | With Zr | With Ti | With Zr | With Ti | With Zr | With Ti | With Zr | With Ti | With Zr | With Ti | With Zr | With Ti |
| 1 | 1 | 1 | 1 | 2 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 2 | 1 | 1 | 1 | 2 | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 2 |
| 3 | 1 | 1 | 1 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 2 |
| 4 | 1 | 1 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 5 | 2 | 2 | 1 | 3 | 3 | 4 | 2 | 2 | 1 | 2 | 1 | 1 |
| 6 | 2 | 2 | 1 | 3 | 3 | 4 | 2 | 1 | 1 | 1 | 2 | 1 |
| 7 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 1 | 1 | 1 | 2 | 2 |
| 8 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 1 | 1 | 1 | 1 | 2 |
| 9 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 2 |
| 10 | 1 | 1 | 1 | 2 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 1 |
| 11 | 1 | 2 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 12 | 1 | 2 | 1 | 3 | 2 | 3 | 2 | 1 | 1 | 1 | 1 | 1 |

**Table 6:** Visual analog scale scores

| No. of cases | Patient's name | Teeth no. | Implant restoration over zirconia abutment | Implant restoration over titanium abutment |
|---|---|---|---|---|
| 1 | Zuala | 11,21 | 5 | 4 |
| 2 | Nehal | 11,21 | 5 | 4 |
| 3 | Do Virender | 21,22 | 5 | 4 |
| 4 | Vinod | 11,21 | 5 | 3 |
| 5 | Renu Singhal | 11,21,22,23 | 3 | 3 |
| 6 | Madhu Gupta | 11,21,22 | 3 | 3 |
| 7 | Arvind | 11,21 | 4 | 3 |
| 8 | V K Syal | 11,21 | 3 | 3 |
| 9 | R P Singh | 11,21 | 5 | 3 |
| 10 | Wo Rathore | 11,21 | 5 | 4 |
| 11 | Sgt Vinay | 11,21 | 5 | 4 |
| 12 | Sep Narayan | 11,21 | 5 | 4 |

**Table 7:** Paired sample statistics

| Parameter | Abutment | Mean | Std. deviation | Std. error mean |
|---|---|---|---|---|
| Symmetry | With Zr | 1.3333 | 0.48154 | 0.09829 |
| | With Ti | 1.5833 | 0.50361 | 0.10280 |
| Mucosal discoloration | With Zr | 1.8333 | 0.70196 | 0.14329 |
| | With Ti | 3.0833 | 0.50361 | 0.10280 |
| Crown morphology | With Zr | 1.3333 | 0.48154 | 0.09829 |
| | With Ti | 1.5033 | 0.65386 | 0.13347 |
| Mesial papilla | With Zr | 1.7500 | 0.44233 | 0.09029 |
| | With Ti | 1.4167 | 0.50361 | 0.10280 |
| Distal papilla | With Zr | 1.3333 | 0.48154 | 0.09829 |
| | With Ti | 1.1667 | 0.38069 | 0.07771 |
| Crown color match | With Zr | 1.1667 | 0.38069 | 0.07771 |
| | With Ti | 2.4167 | 0.50361 | 0.10280 |
| Visual analog scale scores | With Zr | 4.4167 | 0.88055 | 0.17974 |
| | With Ti | 3.5000 | 0.51075 | 0.10426 |
| Modified plaque index | With Zr | 0.5833 | 0.65386 | 0.13347 |
| | With Ti | 0.8333 | 0.56466 | 0.11526 |
| Overall CIS | With Zr | 8.5833 | 1.74248 | 0.35568 |
| | With Ti | 11.250 | 1.25974 | 0.25714 |

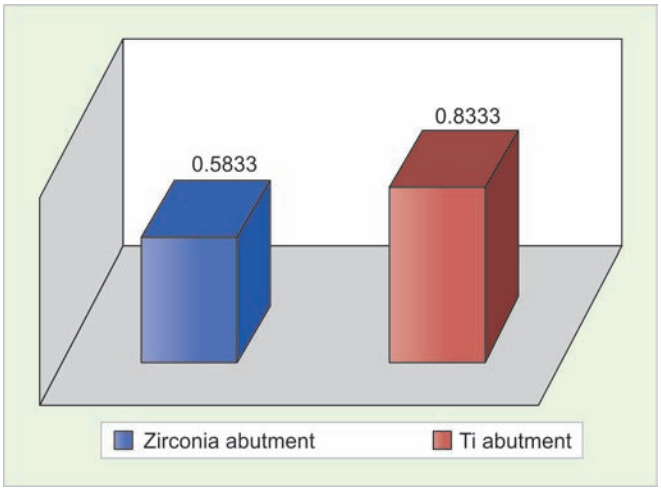
**Table 8:** Paired sample t-test

| Parameter | Mean | Std deviation | Std error mean | 95% CI of the difference | | t-value | df | Sig (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | | |
| Modified plaque index | −2.5000 | 0.44233 | 0.09029 | −0.43678 | −0.06322 | −2.769 | 23 | 0.011 |
| CIS overall | −2.66667 | 1.12932 | 0.23052 | −3.14354 | −2.18980 | −11.568 | 23 | 0.000 |
| Visual analog scale scores | 0.91667 | 0.65386 | 0.13347 | 0.64056 | 1.19277 | 6.868 | 23 | 0.000 |
| Crown morphology | −0.25000 | 0.44233 | 0.09029 | −0.43678 | −0.06322 | −2.769 | 23 | 0.011 |
| Crown color match | −1.25000 | 0.44233 | 0.09029 | −1.43678 | −1.06322 | −13.844 | 23 | 0.000 |
| Mucosal discoloration | −1.25000 | 0.44233 | 0.09029 | −1.43678 | −1.06322 | −13.844 | 23 | 0.000 |
| Mesial papilla | 0.33333 | 0.48154 | 0.09829 | 0.13000 | 0.53667 | 3.391 | 23 | 0.003 |
| Distal papilla | 0.16667 | 0.70196 | 0.14329 | −0.12975 | 0.46308 | 1.163 | 23 | 0.257 |
| Symmetry | −0.25000 | 0.73721 | 0.15048 | −0.56130 | 0.06130 | −1.661 | 23 | 0.110 |

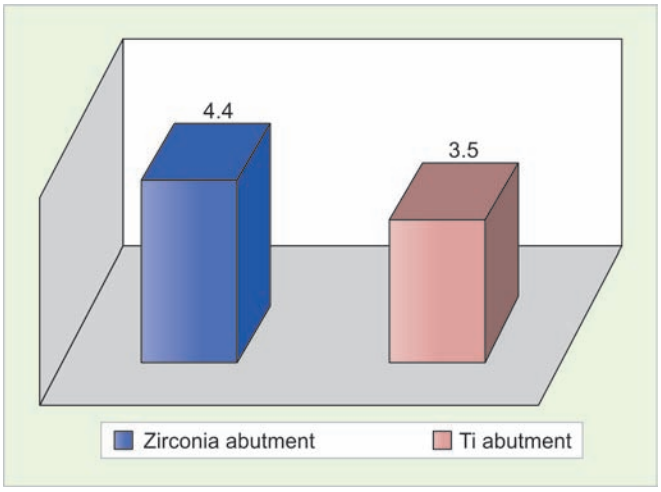
papilla with zirconia abutments, thereby resulting in better esthetics.

One of the limitations of this study is that it was not a long-term study; the study period was only 4 years. Long-term study would be required to validate the results. Also, further only one prosthodontist and periodontist evaluated the outcomes, and patient-reported outcomes were not taken into consideration.

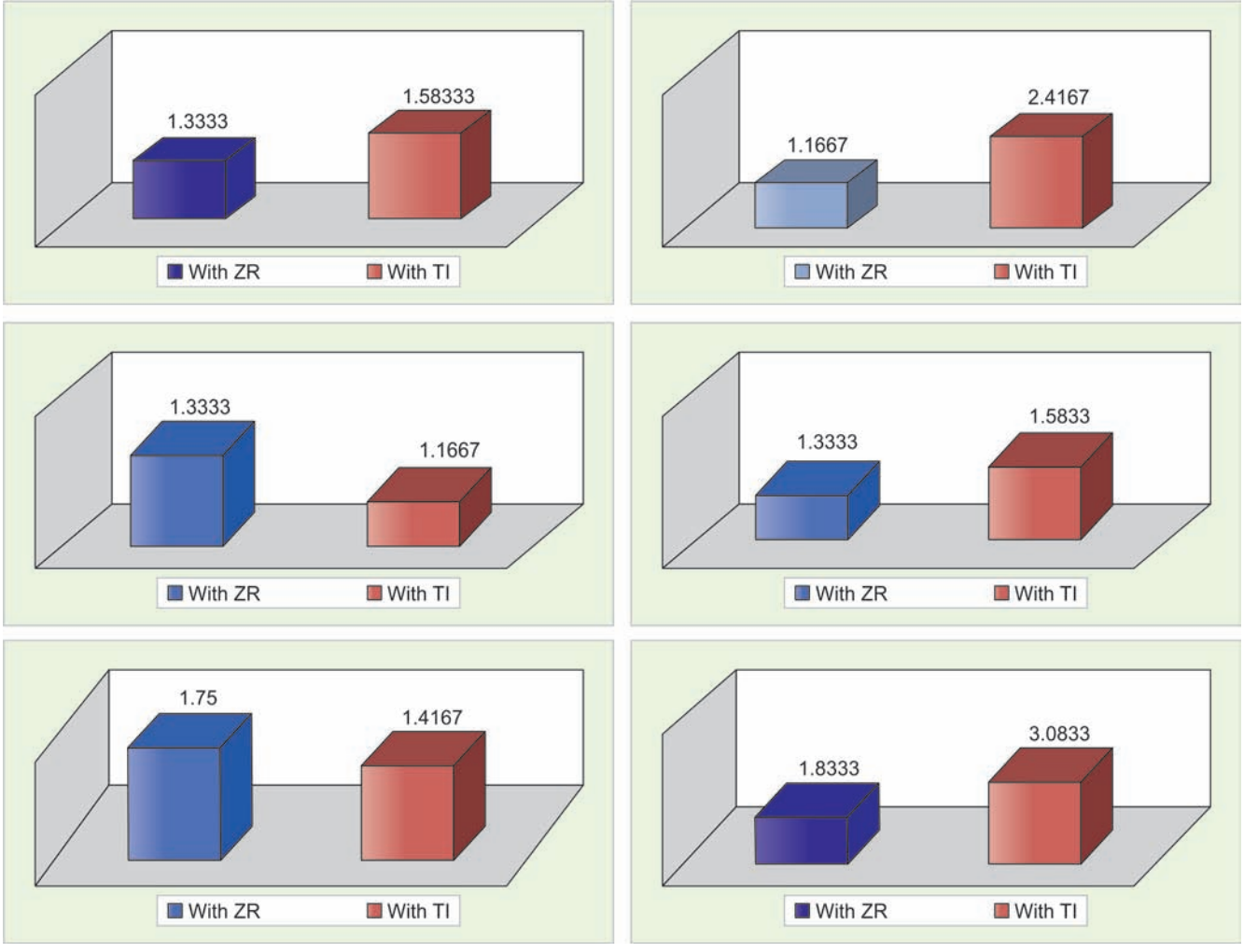
The cumulative incidence of biological complications after 5 years was estimated at 5.2% (95% confidence




**Graph 1:** Modified plaque index




**Graph 2:** Visual analog scale




**Graph 3:** Copenhagen index score

interval [CI]: 0.4–52%) for zirconia and 7.7% (95% CI: 4.7–12.5%) for titanium abutments. Esthetic complications tended to be more frequent with metal abutments.[25] Zirconia opacity has been useful in adverse clinical situations, e.g., for masking of dyschromic abutment teeth. Zirconia implant abutments can also be used to improve the esthetic outcome of implant-supported rehabilitations.[35] The study done by Sailer et al[44] had shown results not in accordance to results of this study. They showed that both crowns on zirconia and titanium abutments induced a similar amount of discoloration of the soft tissue compared with the gingiva of natural teeth.

## CONCLUSION

The study results suggested that zirconia abutments showed significant difference in terms of biological and esthetic outcomes when compared with titanium abutments. Zirconia abutments may be used as a viable alternative to currently available titanium abutments in implant-supported restorations, especially in the esthetic zone. There is a need for more long-term clinical studies so that zirconia abutments can be used as a viable alternative to titanium abutments.

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