Comparative In Vitro Study of Implant-Supported Restorations: Implant-Abutment Complex With and Without Prosthetic Finishing Line

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Purpose: The aim of this study was to evaluate the mechanical behavior of implant-supported cemented restorations placed on two types of abutment design, with and without a prosthetic finish line, evaluating fracture resistance and the type of fracture produced in the abutment-crown complex. Materials and Methods: Eighty zirconia restorations supported by tapered implants were divided into two groups: group I, with 40 zirconia crowns cemented onto individualized zirconia abutments with a chamfered finish line (1 mm deep); and group II, with 40 zirconia crowns cemented onto individualized zirconia abutments without a finish line. All specimens underwent thermocycling and dynamic loading before static load testing to evaluate their fracture resistance. Results: Fracture resistance values (N) and the type of fracture were analyzed. The mean fracture resistance was 462.1 ± 66.3 N in group I and 343 ± 40 N in group II. In group I, fractures were produced in the prosthetic fixation screw; in group II, all mechanical failures were produced in the transepithelial abutment’s cervical area. Conclusion: Group I specimens showed greater fracture resistance than group II. The fracture type in group I occurred in the prosthetic screw. Group II fractures occurred in the zirconium oxide abutment. Int J Oral Maxillofac IMplants 2018;33:747–753. doi: 10.11607/jomi.6214

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Dental treatments pursue several goals: to provide the patient with adequate function, esthetics, and oral health.1–6 Various alternatives are available for replacing a single lost anterior tooth (fixed partial denture, removable partial denture, resin-bonded fixed partial denture, or implant-supported restoration). The classic treatment is a fixed partial denture abutted to the pair of teeth adjacent to the edentulous span; this type of prosthetic restoration is predictable in the short term and satisfies the criteria of outline, comfort, function, speech, and oral health.7 However, a three-piece fixed partial denture suffers limitations in terms of the restoration itself, and more importantly, the abutment teeth on either side. Creugers et al, in a review of 42 articles published over a 28-year period, calculated a survival rate of 74% for these fixed partial dentures after a 15-year follow-up.8 Caries (11%) and endodontic treatment of the abutment teeth (15%) were the main causes of prosthetic failure. The abutment teeth were more susceptible to caries when oral hygiene and prosthetic fit were inadequate, with a rate of loss of up to 30% after 14 years, due to endodontic treatment failure,9–11 dental fracture,12 advancing periodontal disease, or loss of retention.13,14

Since the mid-1980s, dental implants have been used for treating this type of case. Increasing numbers of dentists consider treatment by means of implants to be the most conservative treatment type, as it does not involve the teeth adjacent to the edentulous span, which remain intact.15 In 2005, Misch et al published a case series of 276 maxillary single implants used to restore teeth missing as a result of agenesis. The implants were placed in 255 patients with follow-ups ranging from 2 to 16 years, presenting an overall survival rate for both implants and crowns of 98.6%.16 A
A literature review conducted by Goodacre et al found that studies of single implants showed higher survival rates than any other prosthetic type, with a mean survival of 97%.

Implant-supported restorations can be classified as screwed or cemented. Due to the anatomy of the alveolar ridge in the maxillary anterior region, it is often necessary to angle the implant toward vestibular, which will require a cemented prosthetic restoration. Cemented prostheses are characterized by having an abutment joining the implant and the restoration; this is necessary to retain the prosthetic crown, which is cemented onto the abutment.

Cemented restorations can be classified according to two types of prosthetic finish line positioned on the abutment: (1) horizontal preparation with a finish line (curved chamfer, flat chamfer, straight shoulder, beveled shoulder) designed to support the edge of the cemented restoration; and (2) vertical preparation without a defined finish line or knife-edge finish line, also known as the biologically oriented preparation technique (BOPT). The latter type—preparation without a finish line, vertical preparation—consists of eliminating any horizontal component from the implant-supported abutment, making it completely conical so that when the prosthetic crown is cemented in place, the complex imitates a natural tooth's anatomical crown; this will create a new prosthetic emergence (anatomical crown) at the cementoenamel junction (CEJ) similar to a natural tooth.

The aim of this study was to evaluate the mechanical behavior of implant-supported restorations cemented onto two types of abutment design, with and without a prosthetic finish line, evaluating fracture resistance and the type of fracture produced in the abutment-crown complex.

On this basis, the present work proposes the following hypotheses:

1. Crowns cemented onto abutments without a prosthetic finishing line obtain lower fracture resistance than crowns cemented onto abutments with a chamfered finishing line.
2. The type of fracture produced in the abutment-crown complex is the same in both designs.

**MATERIALS AND METHODS**

Eighty samples were divided into two study groups: group I, with 40 zirconia crowns cemented onto individualized zirconia abutments with a chamfered finish line (1 mm deep); and group II, with 40 zirconia crowns cemented onto individualized zirconia abutments without a finish line.

The study used 80 tapered implants (Kohno, Sweden & Martina) 11.5 mm in length and 4.25 mm in diameter, with 2-mm-depth internal hex connections. The zirconia abutments were designed using Echo2 computer-aided design/computer-assisted manufacture (CAD/CAM) software (Sweden & Martina) and presented standardized parameters: 10-mm height (measured from the implant's prosthetic platform to its most incisal point) and an axial convergence of 6 degrees. Group I abutments had a clinical height of 8 mm (from the finish line to its most incisal point) and a diameter of 5 mm, with a 1-mm-deep chamfer finish line (Fig 1). Group II abutments had a height of 10 mm from the implant platform to their most incisal point and a diameter of 4.25 mm; in this group, in the cervical area, all crowns were situated 2 mm from the abutment's prosthetic platform, to simulate the start of the convex emergence of the anatomical crown of a natural tooth (Fig 2). All the abutments had titanium prosthetic platforms (T-Connect, Sweden & Martina), which act as a base support, avoiding contact between the body of the zirconia abutment and the implant platform.
Crowns were designed and fabricated using CAD/CAM technology with a zirconia core covered with a veneer of injected ceramic (IPS e.max ZirPress, Ivoclar Vivadent).

To evaluate the specimens’ in vitro fracture resistance, the procedure followed International Standardization Organization ISO 14801 specifications: (1) implants were set in epoxy resin (Exakto-Form, Breident), which has an elasticity module of 3 GPa or higher; (2) specimens were prepared to simulate peri-implant bone loss leaving 3 mm of implant exposed, measured from the implant collar in the coronal-apical direction; and (3) specimens were placed at an angle of 30 degrees to the direction of loading.

When the implants had been fixed in measuring cylinders, the abutments were screwed to the implants applying a torque of 30 Nw/cm with an ISD900 prosthetic screwdriver (NSK, Nakanishi). Access chimneys to the abutment screws were sealed with polytetrafluoroethylene (PTFE). The restorations were cemented to the corresponding abutments using dual-curing resin cement (RelyX Unicem 2, 3M ESPE).

All specimens were subjected to a process of dynamic loading and thermocycling. This artificial aging consisted of 240,000 mastication cycles (Chewing Simulator CS-4.2 economy line; SD Mechatronik) applying a vertical load of 8 kg with a 2.5-mm vertical movement and a speed of 60 mm/s. The load was applied 2 mm below the crowns’ incisal edge with a steel ball of 2-mm diameter (Fig 3). Thermocycling with distilled water was applied simultaneously to dynamic loading (Thermocycling TC-3; SD Mechatronik) with temperature changes of 5°C to 55°C every 30 seconds (Fig 4). After dynamic loading and thermocycling, specimens were static load tested to evaluate their (crown-abutment) mechanical fracture resistance. The assay was performed with a Shimadzu AG-X plus universal test machine (Shimadzu) with a 5,000-N load cell. The crosshead speed was 0.5 mm/min, and the load was applied until fracture occurred with a horizontal load applicator, which made contact with the crowns’ incisal edge (Fig 5).

All the data obtained were processed using TRAPEZIUM-X software (single serial 942356CA, Shimadzu), and statistical analysis was performed with the SPSS 14.0 for Windows statistical software package (SPSS). Parametric statistical analysis (Shapiro-Wilk test; $P > .05$) was performed applying Welch correction; the statistical significance level was 5% ($\alpha = .05$) with a power of 0.69.

RESULTS

Static load testing obtained mean fracture resistance values of 462.1 ± 66.3 N for group I (abutments with a chamfered finish line) and 345.6 ± 38.8 N for group II (restorations without a finish line). The $t$ test data showed that fracture resistance in group I was significantly higher than group II ($t = 6.78; P < .001$, $t$ test with Welch correction) (Table 1) (Fig 6).

In analysis of the type of fracture produced by static load testing, it was found that group I samples fractured at the level of the prosthesis fixation screw (100% of specimens) without affecting the cemented restoration (Fig 7). For group II restorations, all mechanical failures were produced in the cervical area of the transepithelial abutment (100% of specimens) without affecting the prosthesis fixation screw (Fig 8). Thus, mechanical behavior was seen to be quite different between the groups depending on the morphology of the abutment beneath the cemented restoration (with or without a finish line).

DISCUSSION

Implant dentistry is one of the areas of contemporary dentistry that has undergone the most technical advance and growth. Implant placement has become one of the treatments of choice when it comes to replacing missing teeth, especially single teeth, due to the excellent clinical outcomes observed in the long term.20 The first-ever research on the use of implants...
for single restorations in the anterior region was published by Jemt in 1986, who described a restoration comprising a titanium abutment screwed to the implant and a ceramic-metal crown cemented onto the abutment.21 Other clinical studies have shown excellent results for crowns supported by titanium abutments.22 However, in spite of the good results offered by titanium abutments, one of its disadvantages is its dark gray color. Various studies have observed that titanium abutments provoke gray discoloration in peri-implant soft tissues that compromises the esthetic outcome.23,24 In 1993, Prestipino and Ingber described the use of aluminum abutments in the anterior region that aimed to eliminate the grayish “halo” produced by other metals.25,26 These abutments could be individualized in terms of color and size, and presented good biocompatibility, low corrosion, and low thermal conductivity. However, clinical studies have shown that peri-implant tissue stability lasted for 3 or 4 years, and furthermore, some abutments were seen to fracture.27,28 They were not strong enough to resist the occlusal forces exercised in the anterior region, and for this reason, the use of zirconium oxide was proposed for fabricating abutments due to this material’s greater fracture resistance. Zirconium oxide, also known as zirconia, came into use for fabricating abutments in 1997.29 In 2004, Glauser et al described yttrium-stabilized sintered zirconia as the material of choice for producing implant-supported abutments.30 According to a 2003 in vitro study by Yildirim et al, zirconia abutments offer greater fracture resistance than aluminum oxide abutments.31 Although the introduction of zirconia has improved the behavior of ceramics for implant dentistry, their main problem continues to be their mechanical response to traction forces. Nevertheless, clinical studies have shown the success of zirconia abutments over periods of 1 year,32 3 years,33,34 4 years,35 5 years,36–38 7 years, and 12 years.39

The present study design and specimens followed norms specified by the International Standardization Organization in UNE-EN ISO 14801:2007 for dynamic fatigue testing of endosseous dental implants, a protocol used in many other published studies.40,41 Many such trials have included artificial aging procedures.
(dynamic loading and thermocycling) that aim to reproduce the conditions that dental restorations are subjected to in the oral medium (mechanical stress and temperature changes).40 Most authors affirm that in vitro trials of the fracture resistance of new ceramic materials must include fatiguing, as prostodontic restorations are bound to undergo some reduction in strength derived from the conditions of their functional life in the mouth.42–44 Iijima et al and Kohorst et al found that zirconia prostodontic frameworks suffered 54% to 64% reductions in fracture resistance as a result of fatiguing.35–47

Most studies have compared different finish lines, such as horizontal beveled or flat shoulders, or have compared titanium with zirconia abutments, but very few have compared zirconia abutments with and without a finish line.38–40 Adatia et al (2009) obtained a mean fracture resistance of zirconia abutments without a finish line of 429 N, a significantly lower value than abutments with a 0.5-mm chamfer and 1-mm-deep chamfer (576 N and 547 N, respectively). Like most of the published research, this study only dealt with the strength of the transepithelial abutment but did not consider the mechanical behavior of the whole abutment-crown complex as in the present work.51 In the present study, group I samples—abutments with a finish line and zirconia crown—obtained similar fracture resistance (462.1 ± 66.3 N) to those published by Att et al (475 ± 252 N).52 Gehrke (291.4 ± 27.8 N)41 and Joo et al (292.74 ± 37.15 N)53 obtained lower fracture resistance values for implant-supported restorations, while Kim et al obtained higher values (729.2 ± 35.9 N).54 The present results for zirconia crowns on abutments without a finish line (group II) cannot be compared with any other, as no other study has analyzed the mechanical behavior of crowns cemented to abutments without a finish line, since all previous studies have only considered the abutment alone. In the present study, the fracture resistance in group I was significantly higher than group II, and thus, the first study hypothesis was accepted.

In analysis of the types of fracture observed in the present study, 100% of abutments with a prosthetic finish line (group I) presented screw fractures, while for abutments without a finish line (group II), fracture occurred in the abutment itself at its interface with the crown, rejecting the study’s second hypothesis. The fracture type and reduction in fracture resistance obtained in group II could be explained by an increase in the lever arm caused by 2-mm cervical exposure of the abutment without crown coverage. In group I, fractures were produced in the screw, which is the weakest area of the implant-abutment-crown complex. The results for samples with a finish line differ from those obtained by Yildirim et al, Adatia et al, and Mitsias et al in that the most frequently observed fracture type was in the cervical area of the transepithelial abutment. This difference is probably due to the fact that these authors analyzed abutments fabricated entirely from zirconia without a titanium interface on the abutments’ prosthetic platform.31,51,55

According to Agustín-Panadero and Solá-Ruiz,5 the clinical use of abutments without a prosthetic finish line on the teeth presents a series of biologic advantages in terms of the gingiva. Regarding implant-supported restorations, Canullo et al recently published an 18-month prospective clinical study that demonstrated the advantages of this technique for adjacent soft, hard, and peri-implant tissues.56 According to Loi and Di Felice,1 the advantages of the technique are:

• the possibility of creating a prosthetic finish line at different levels within the sulcus, at a depth of less than 1.5 mm respecting biologic space
• the option of leveling gingival emergence profiles
• optimal marginal fit between the restoration and abutment2
• increased prosthetic retention due to the telescopic prosthetic design
• allows gingival thickening and adaptation to the new shape, leading to greater gingival stability in the long term.1,2

Other authors5 argue that there are disadvantages to be considered, such as the following:

• It is a more complex technique.
• It can be difficult to place the prosthetic margin correctly, as the position is not determined by a finish line. When the dentist and/or laboratory technician lack experience with the technique, there is a danger of uncontrolled invasion of the peri-implant groove.
• It may be difficult to remove excess cement.
• The technique is not backed by scientific evidence, and there are few prospective clinical trials confirming the technique’s efficacy.6

All these issues concerning preparation without a finish line, as outlined in the literature,1,2,29 are biologic ones, mainly related to gingival tissues adjacent to teeth and implants. For this reason, the present in vitro investigation of the technique’s mechanical outcomes provides important new information for assessing its possible clinical use for zirconia restoration placement. The present study suffered the limitations of all in vitro studies in that they generate information that cannot always be extrapolated to in vivo practice. The study was innovative, as it proposes a new abutment design for implant-supported prosthetic restorations.
However, in light of the recent findings, it would appear unadvisable to adopt the use of zirconia crowns on zirconia abutments prepared without a finish line due to the higher risk of fracture.

CONCLUSIONS

Abutments supporting zirconium oxide restorations with a chamfer finishing line show higher fracture resistance than restorations without a prosthetic finishing line. The type of fracture in restorations without a finishing line occurs in the abutment at their union with the crown’s cervical area. The type of fracture in restorations with a chamfer finishing line was produced in the screw, leaving the abutment-crown complex intact. When placing zirconia crowns on zirconia abutments, it is advisable to use an abutment design with a prosthetic finish line, as it presents a lower risk of fracture.

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REFERENCES


