

Fracture Strength of Standard and Small Diameter Prosthetic Abutments for Full-Arch Implant-Supported Restorations

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This study tested the fracture strength of prosthetic abutments with different sizes and combinations to support a 5-implant milled framework with distal extension. Prosthetic abutments with different dimensions (4.8-mm diameter mini conical abutment and 3.5-mm diameter microconical abutment) were screwed to 5 threaded implants. The following groups were divided ($n = 3$): G1 with 5 miniconical abutments (standard size), G2 with 5 microconical abutments (small sized), G3 with a combination of 3 small sized abutments and 2 standard sized abutments, and G4 with a combination of 2 small sized abutments and 3 standard sized abutments. Standardized titanium frameworks for full-arch fixed dental prosthesis were milled with equidistant holes for each of the 5 implants and abutments. A loading point was selected at 18 mm away from both distal implants. A universal testing system was used for the fracture strength tests and load was applied at a crosshead speed of 0.5 mm/min on the previously described loading points until component fracture. Mean fracture strength for each group was statistically compared ($\alpha = 0.05$). Prosthetic screws were the only fractured components for all tested groups. Mean fracture strength was: G1, 1130.22 N; G2, 1031.36 N; G3, 757.9 N; and G4 792.03 N ($P < .05$). All prosthetic abutments and combinations that were tested provide adequate fracture strength for clinical use. However, the combination of standard and small diameter abutments leads to lower fracture strength compared with when only standard sized prosthetic abutments were used, irrespective of the abutment diameter (4.8- or 3.5-mm).

Key Words: dental implants, prosthetic abutment, implant-supported, fracture strength

INTRODUCTION

The correct selection of the prosthetic abutments influences the long-term success of implant-support restorations. Optimized load sharing between implants and low microgap between abutments and prosthesis are critical for maintenance of osseointegration.¹⁻⁵ Prosthetic screw loosening remains a problem of single-tooth implant restorations.⁶ Screw preload should resist masticatory loads without loosening—the manufacturer recommended torque level is therefore essential for prosthesis stability.⁷ Diamond-like carbon (DLC) coated screws further improve preload maintenance.^{8,9}

Screw loosening and screw fracture remain common complications in implant-supported restorations.¹⁰ Occurrence of screw loosening events is affected by excessively long cantilevers, increased prosthetic abutment height, and framework alloy.¹⁰⁻¹² Other contributing factors for screw complications

include inadequate screw preload, screw overtightening, and occlusal overload from parafunction or occlusal interferences.¹⁰

Internal tapered implants allow interimplant distances as low as 2 mm with minimum bone remodeling.¹³⁻¹⁵ Placement of contiguous wider prosthetic abutments is problematic when a small interimplant distance is present and small diameter abutments were therefore developed. However, the size reduction of prosthetic abutments could compromise their mechanical behavior and fracture strength. Smaller abutments could also lead to increased screw complications.

There is little information available on the mechanical behavior of reduced size abutments. This study will compare the fracture strength of prosthetic abutments with different sizes and combinations to support a 5-implant milled framework with distal extension. The tested null hypothesis was that no significant differences would be found between the different abutment sizes and combinations that were tested.

MATERIALS AND METHODS

Five threaded implants (Titamax CM Cortical, 3.75 by 13 mm, Neodent, Curitiba, Brazil) were placed in a polymethyl methacrylate (PMMA) model to simulate mandibular rehabili-

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FIGURE 1. Prosthetic abutments tested in the study (left, standard diameter; and right, small diameter).

tation with a full-arch fixed dental prosthesis (FAFDP). Prosthetic abutments with different dimensions (4.8-mm diameter miniconical abutment and 3.5-mm diameter microconical abutment, Neodent) (Figure 1) were screwed to the implants using a 32 Ncm torque. Both prosthetic abutments had 4.5 mm in height. The following groups were divided ($n = 3$): G1 with 5 miniconical abutments (standard sized abutment),

G2 with 5 microconical abutments (small-sized abutment), G3 with a combination of 3 small-sized abutments and 2 standard-sized abutments (mixed abutments), and G4 with a combination of 2 small-sized abutments and 3 standard-sized abutments (mixed abutments) (Figure 2a through d).

Standardized titanium frameworks for FAFDPs were milled (Neodent Digital, Neodent) with equidistant holes for each of the 5 implants and abutments (Figure 3). The frameworks had a 20-mm distal extension from the most distal implants on both sides. A loading point was selected at 18 mm away from both distal implants. The frameworks were specifically designed for each group and prosthetic abutment combination. Frameworks were screwed to the abutments with a 10 Ncm torque load with the aid of a ratchet wrench and according to instructions from the manufacturer (Neodent). Screws with same size and design were used for all groups in the study.

A universal testing system was used for the fracture strength tests (3382 Floor Model Universal Testing System, Instron, Norwood, Mass). Load was applied at crosshead speed of 0.5 mm/min on the previously described loading points until component fracture (Figure 4). Mean fracture strength for each group was statistically compared using specialized software (JMP 8.0, SAS Institute, Cary, NC). One-way analysis of variance and Tukey–Kramer multiple comparisons test were used for statistical comparison between groups ($\alpha = 0.05$).

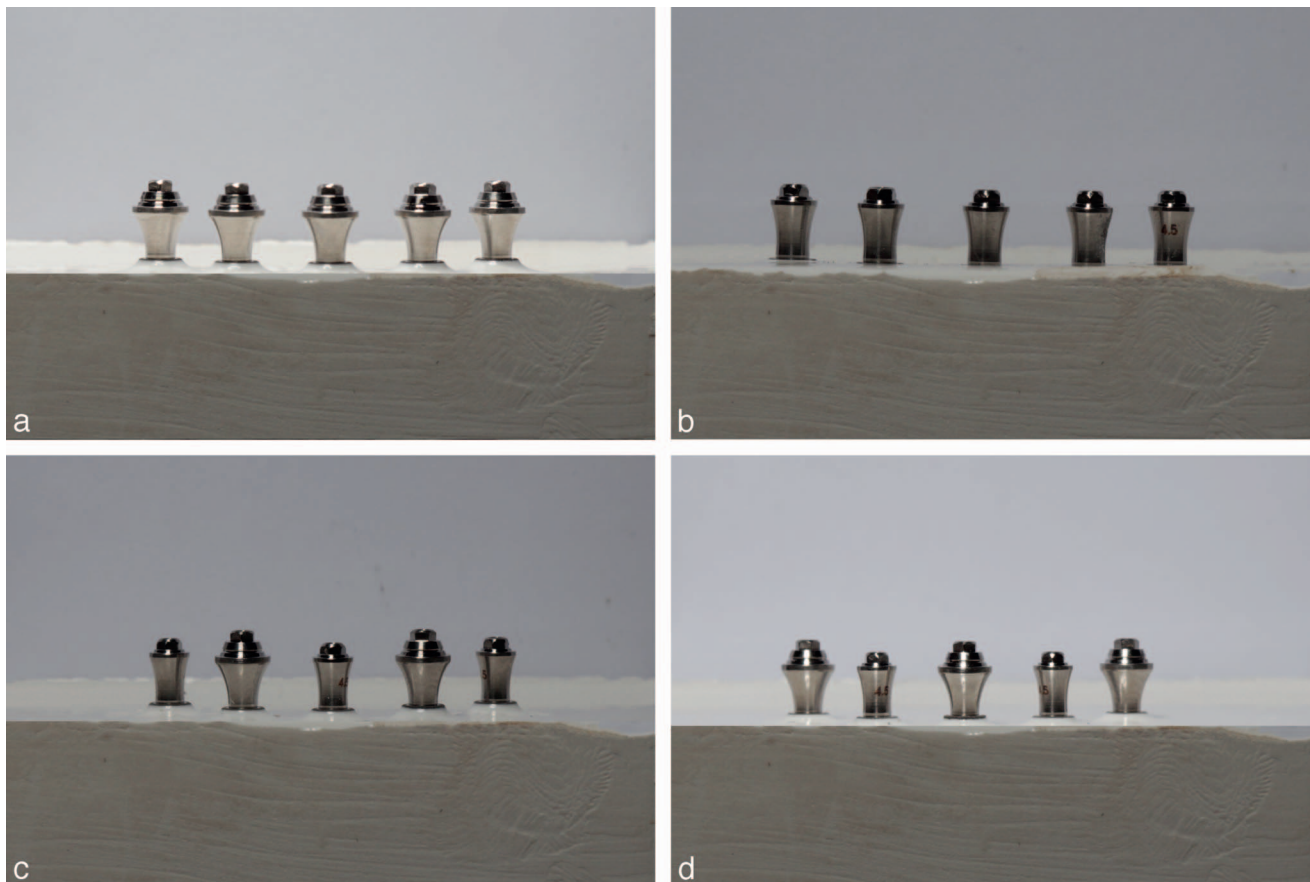


FIGURE 2. Prosthetic abutment combinations that were tested (a–d: G1–G4, respectively).



FIGURE 3–5. **FIGURE 3.** Milled framework used for fracture strength testing. **FIGURE 4.** Fracture strength testing. **FIGURE 5.** Fractured prosthetic screws after fracture strength testing showing intact screws number 1 and 5.

RESULTS

Prosthetic screws were the only fractured components for all tested groups. The screws located on implants number 2, 3, and 4 were fractured whereas the screws located on implants 1 and 5 remained intact for all groups (Figure 5). Fracture location was at the first thread inside the abutment for all groups and screws. Table 1 shows the fracture strength results found for each group in the study. Group G1 presented the highest fracture strength results ($P < .05$). A 30% decrease on fracture strength was found for groups G3 and G4. A post hoc power analysis computed the achieved power for fracture strength between groups. Fracture strength was tested on 3 specimens per group. Achieved power was above 99% for the tested

specimens, mean, and standard deviation found for each group ($\alpha = 0.05$; effect size $f = 5.243992$).

DISCUSSION

Fracture strength of prosthetic abutments with different sizes and combinations supporting a 5-implant milled framework with distal extension was tested. Prosthetic abutments with 4.8-mm and 3.5-mm diameter were used alone or combined with each other to support a 5-element cantilever bar for implant-supported fixed prosthesis. The results support rejection of the tested null hypothesis since significant differences were found between the different abutment sizes and combinations that were tested. The highest screw fracture strength was found when

Group 1	Group 2	Group 3	Group 4
Mean \pm SD	Mean \pm SD	Mean \pm SD	Mean \pm SD
Tukey test	Tukey test	Tukey test	Tukey test
1130.22 \pm 22.48	1031.36 \pm 18.11	757.9 \pm 9.84	792.03 \pm 42.03
A	B	C	C

*Different letters indicate statistical significance between comparisons ($P < .05$). $F = 146.96$; $q = 4.529$.

only standard sized abutments were used. It can be speculated that the wider abutments optimized the stress transfer to the prosthetic screws compared to small sized abutments or to mixed-size abutments. However, a finite element analysis is recommended in a future study to further understand this issue.

A bilateral loading point located distal to implants number 1 and 5 was used for the fracture strength testing. The framework distal extension was used to simulate a critical occlusal load condition and to further challenge the biomechanical behavior of the restoration components. It is thus expected that the implants closer to the loading point would receive the highest loads.¹⁷ It can also be expected that fractures would occur near the beginning of the cantilever arms.^{10,18} However, no screws or components fractured on the distal implants in this study. Fractured prosthetic screws were present on implants 2, 3, and 4. The use of an anterior load (ie, near implant number 3) would mainly stress the loaded implant, with possibly little load transfer to the nearest implants. However, further studies are needed to understand such biomechanical behavior. Component deformation is also affected by prosthetic abutment height and framework alloy.¹¹ This study used the same abutment height and framework alloy for all groups to avoid bias.

Fracture of the prosthetic screw is preferable in an implant-supported restoration, due to an easier retrieval compared with a fractured prosthetic abutment screw. There are 2 main regions of load concentration on the screws that could ultimately lead to fracture: The first region is between the screw head and screw stem; the second region is located at the first screw thread.¹² This is in agreement with the results found in this study—screw fracture for all groups was located at the first screw thread.

The prosthetic screws should resist physiological masticatory loads. Maximum occlusal loads recorded on literature report and average of 723 N on the second molar region.¹⁹ Men were found to present a maximum bite force of 847 N whereas women presented a 597 N bite force.²⁰ All groups tested in this study showed higher values of fracture strength compared with the average bite force near the second molar region and should therefore resist clinical use. All prosthetic abutments and implants resisted the fracture strength tests. Fracture of the prosthetic screws further suggests that such screws are the weakest link in implant-supported restoration—screw torque loss or screw fracture are expected when occlusal overload is present, thus protecting the remaining implant-restoration components. All screws had the same size and configuration for all groups in the study. All frameworks were screwed to the abutments by using DLC coated screws to improve preload maintenance.^{8,9} An earlier study¹⁶ found no differences in reliability when comparing DLC coated vs noncoated abutments and or screws used to support single crowns. However, the authors found an increased Weibull modulus (low variability of the results) with DLC coating.¹⁶

Some limitations of in vitro studies are expected and caution is advised when transferring the results to the oral environment. A PMMA model was used to simulate the mandible. Conversely to bone structures, PMMA is an isotropic material thus providing limited replication of D2/D3 bone properties commonly found in the mandible. Furthermore, the

different shape and resorption patterns present in the mandible were not simulated in the PMMA model. This could have significantly influenced the flexural properties of the prosthetic components and the results that were found. Further fatigue tests are suggested to evaluate whether small diameter abutments can resist cyclic masticatory loading present in the oral environment. A finite-element analysis could aid in determining the stress distribution along the entire prosthetic structure, including the abutments, and simplify the simulation of different load locations along the framework.

CONCLUSION

The results suggest that all prosthetic abutments and combinations that were tested provide adequate fracture strength for clinical use. However, the combination of standard and small diameter abutments leads to fractured prosthetic screws with lower fracture strength compared with when only standard sized prosthetic abutments were used, irrespective of the abutment diameter (4.8- or 3.5-mm).

ABBREVIATIONS

DLC: diamond-like carbon
FAFDP: full-arch fixed dental prosthesis
PMMA: polymethylmethacrylate

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NOTE

The authors declare no conflicts of interest.

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