Fracture Strength of Conometric Joint Implants Versus Internal Hexagon Abutment Joint Design: An In Vitro Study

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The dental implant is an effective long-term procedure for oral edentulism due to its efficacy to support functional masticatory loading forces. The implant prosthetic joint is considered a key factor for interface stability due to its biological and biomechanical implications. The present investigation aimed to evaluate the fracture strength of 2 different implant prosthetic joints. This investigation tested 10 implants for each group: a conometric implant joint (group I) and internal hexagon implant (group II). The implant abutment joint was coupled using a calibrated torquemeter. The samples were assessed using a loading fracture test and radiographically evaluated to observe the interface changes and deformations. The means and standard deviations of the group I and group II maximum force (N) were 553 ± 51 N and 432 ± 43 N. The Young elastic modulus of group I and group II implants were 183.97 ± 11.71 GPa and 143.72 ± 15.93 GPa. The conometric joint was reported to have a higher strength than the regular internal hexagon implant connection. The study findings could have clinical implications for implant durability and peri-implant tissue stability in favor of the conical joint design.

Key Words: implant–abutment joint, endosseous dental implant, fatigue loading

INTRODUCTION

The missing or decayed teeth replaced by a dental implant device are considered helpful for partial or complete edentulism rehabilitations.[1] The long-term predictability of implant-supported rehabilitation needs optimal osseointegration and effective maintenance of healthy peri-implant tissues.[2,3]

The dental implant procedure is certainly considered highly predictable reporting a success rate of more than 90% due to novel advances in implant microdesign and macrodesign, optimized surgical protocols, and surface interventions.[4]

The role played by the implant prosthetic connection is considered in the literature an essential factor for marginal hard and soft tissue long-term stability and biomechanics.[5,6] Several aspects have been correlated with peri-implant marginal bone resorption, including the implant–abutment interface design, the contact angle and length, the prosthetic index design, and the tolerances of the components, including the coupling screw profiles. The macro and implant geometry report constant improvements considering the mechanical and chemical properties able to increase the component's stability, the wearing resistance, and the material's longevity.[7,8] Various platform designs, including internal and external implant prosthetic joints and cone-morse (CM) connections,[9–11] are available. Historically, the external hexagon connection represents a standard design with a higher tendency to produce component instability and micromovements under functional horizontal load.[10,12,13]

Internal hexagons are joint designs characterized by different subvariants that gain an advantage due to higher lateral load stability and strength, implant fixture stress, and decreased micromovements.[11]

The cone morse (CM) prosthetic joint is a special internal connection characterized by increased implant stability, implant chamber wall sealing contact between the implant–abutment interfaces, and a decreased tendency to produce micromovements under lateral forces.[14,15]

CM implants generally have an implant–abutment contact angle inferior than 8°, but the interface contact length differed between the implant systems and joint design.[16]

Some CM profiles are characterized by a prosthetic internal index, which gives an antirotational geometry in the apical component of the abutment.[16]

According to the recent literature,[17] CM joints have been purposed by the International Team for Implantology study group[18] reporting a decrease of marginal bone loss compared with internal hexagon designs. Today, many manufacturers consider different CM designs with different cone angles, whereas no

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https://doi.org/10.1563/aaid-joi-D-25-00001

Figure 1. Group I: internal conometric joint implant (Close BL, ISOMED Albignasego PD Italy).

differences in marginal bone loss have been detected comparing different angle cutoff (less than 8° versus more than 8° angles).[17]

This behavior could be explained as the result of an increased coupling stability of the conical connection, avoiding the transversal forces and the lateral solicitations on the bone–implant interface.[9,19,20] In addition, the CM joint is characterized by the frictional interaction between the abutment and the dental implant's internal chamber, significantly reducing the interface microgaps and the bacterial colonization of this area.[21]

The in-bench dynamic loading tests have been purposed in the literature to verify within a standardized environment a simulation of a long-term effects and wearing of functional loading on implant devices.[22,23]

The present investigation aimed to evaluate the fracture strength and rigidity of 2 implant prosthetic joint designs through a mechanical simulation.

Materials and Methods

Dental implants tested

The test considered 2 different implant–joint geometries for the present investigation. Group I considered an internal conometric connection with an inclination of 2.5° per side (Close BL, ISOMED, Albignasego PD, Italy) (Figure 1). The implant body was characterized by a tapered geometry. The neck presented an inverted taper without thread, which can preserve the cortical bone and form a single body with prosthetic reconstruction. The group II implant considered an internal hexagonal prosthetic joint and tapered body geometry (TI c-BL, ISOMED) (Figure 2). The samples were embedded in a resin block, and a loading angle of 30° ± 2° was applied to conduct the fracture test. A radiograph was taken before and after the test to observe the effects of the loading on the implant–abutment joint coupling. The loading model, the loading angle, and the testing assessments were performed considering the study design described by UNI: ISO14801 (Figure 3).[24]

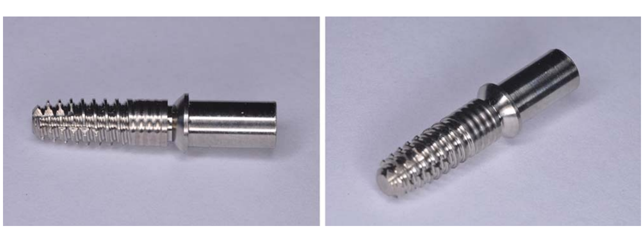

Figure 2. Group II: internal hexagonal joint implant (TI c-BL, ISOMED Albignasego PD Italy).

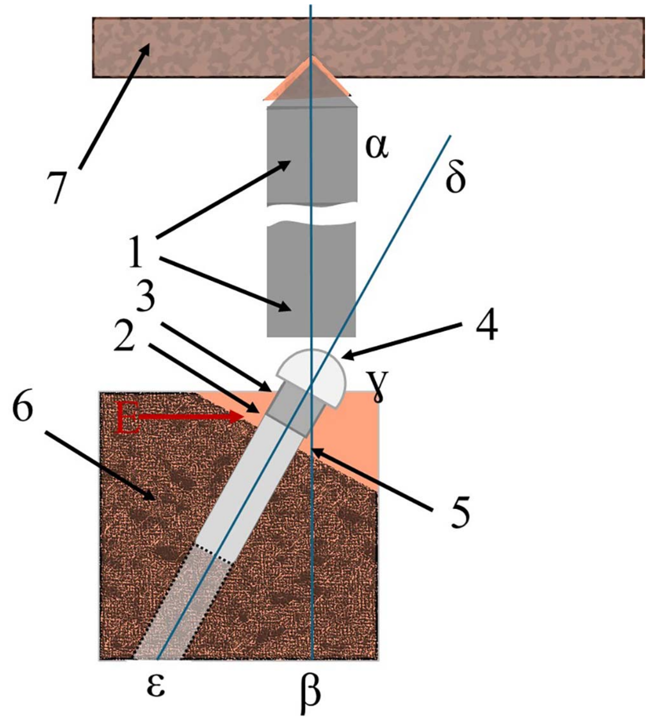

Figure 3. Dental implant configuration in testing block. (1,7: loading components, 2,3,5: abutment components, 2: bone level, 3: abutment supporting parts, 4: cylinder, 6: dental implant in resin cylinder. Line A-B: loading force cycles axis, line α-ε: inclination of dental implant with 30° ± 2° axis).

Testing conditions

The fracture test was conducted in a controlled environment under constant temperature and humidity (temperature: 22°C ± 3°C; relative humidity: 65% ± 4%). The loading test was performed using a single-axis ZT-HIGH (IMADA, Rome, Italy) for mechanical tests with a load cell. The test is passed in the case of nonevident structural defects and permanent deformations on the surface of the hemispherical cap (Figure 4). The present investigation considered the maximum peak, the initial distortion peak, and the Young elastic modulus as study variables. At the end of the experiments, a radiograph was taken to observe the effect of the loading on the implant prosthetic interface.

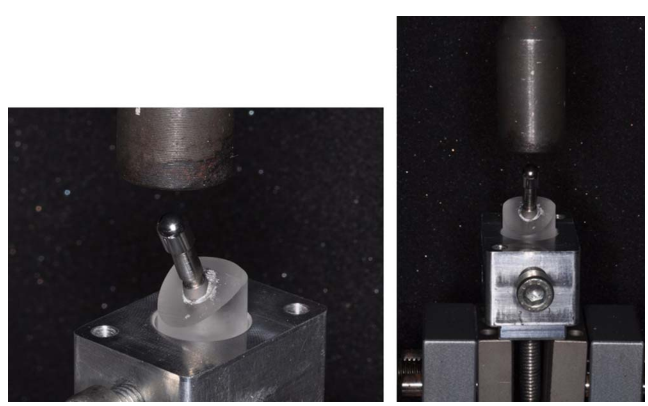

Figure 4. Detail of the loading cell prepared for the mechanical test.

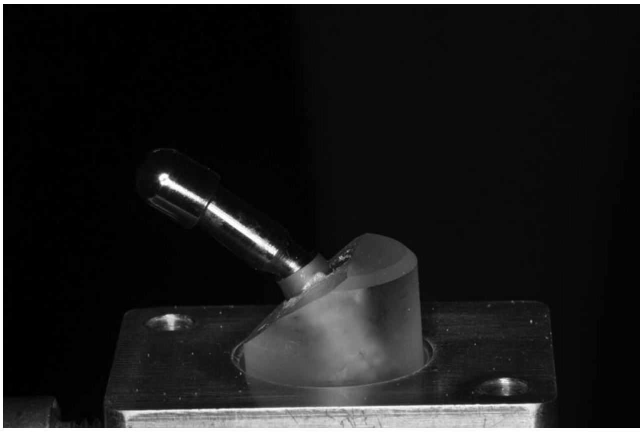

Figure 5. Group I: detail of the sample after the fracture test.

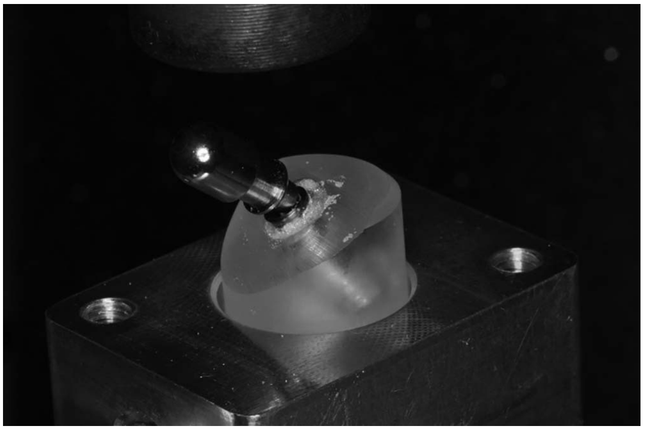

Figure 7. Group II: detail of the sample after the fracture test.

Statistical analysis

The dedicated software package GraphPad 8 (Prism, San Diego, CA) conducted and independently reviewed the statistical analysis. Descriptive statistics consider the means and standard deviations of the variables. The Mann-Whitney nonparametric test was conducted to evaluate the parameters. The level of significance was considered for a *p*-value $< .05$. The sample size has been calculated through G*Power software (version 3.1.9.6, Franz Faul, University of Stuttgart) considering the following parameters: effect size: 1.2; alfa error: 0.05 power 80%, and a group allocation ratio 1/1. The computational model reported a minimum sample size of 20 implants.

Results

Loading test

The initial distortion for group I and group II implants was, respectively, 467 $\pm$ 41 N and 412 $\pm$ 28 N (Figures 5 through 9). The maximum force peaks of group I and group II implants were, respectively, 553 $\pm$ 51 N and 432 $\pm$ 43 N. A significant difference in initial distortion and maximum force peaks was observed comparing group I and group II implants ($p < .05$). The Young elastic modulus of conometric implants (group I) was 183.97 $\pm$ 11.71 GPa, whereas the internal hexagon joint (group II) was 143.72 $\pm$ 15.93 GPa. A significantly higher Young elastic modulus of the group I implant was observed comparing the internal hexagon implants (HIs) (group II) ($p < .05$) (Figures 4 through 8 and the Table).

Discussion

Dental implant longevity and durability are considered critical points in clinical practice. It is a result of the advances in geometry design, biomaterial chemistry, surface properties, and protocol optimization.[25] The most common factors in dental implant failure concern poor oral hygiene, bone quality, systemic and local medical status commissions, and biomechanical factors.[26,27] Implant joint mechanical failure represents one of the most common complications in the clinical practice that is involved in numerous sequelae in terms of biological and prosthetic consequences. The complication severity could include the coupling screw and abutment unscrewing/fracture.[28] The implant joint mechanical complications could be heterogeneous with a clinical incidence of approximately 9%, including major and minor events.[29] The fracture of the implant body is rare and clinically could be determined by inadequate implant diameter/length, masticatory and prosthetic overloading, impairments of the coupling components, parafunction, and bruxism.[28] The decrease in resistance properties could be theoretically influenced by fatigue wearing and corrosion in the oral cavity environment. In addition, the fixture body design seems to contribute to the implant abutment strength and the durability of the interface.[30] Another hypothesis could include the titanium surface treatment as a variable that could influence the long-term mechanical

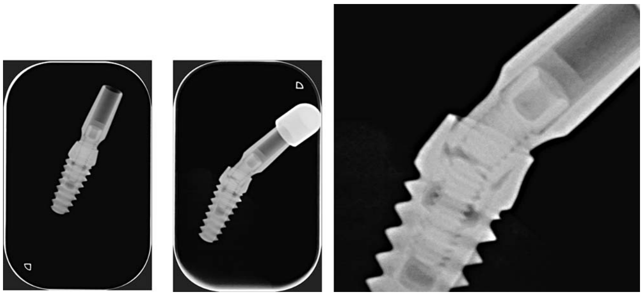

Figure 6. Group I: radiograph evaluation of the conometric joint implant tested. Left: Prior fracture strength test. Middle: after the loading. Right: detail of the implant–joint connection after the test.

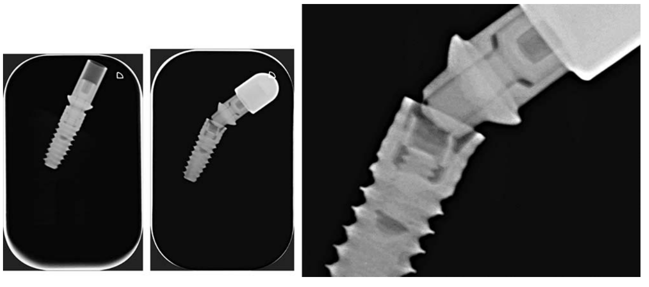

Figure 8. Group II: radiograph evaluation of the internal hexagon joint implant tested. Left: Prior fracture strength test. Middle: after the loading. Right: detail of the implant–joint connection after the test.

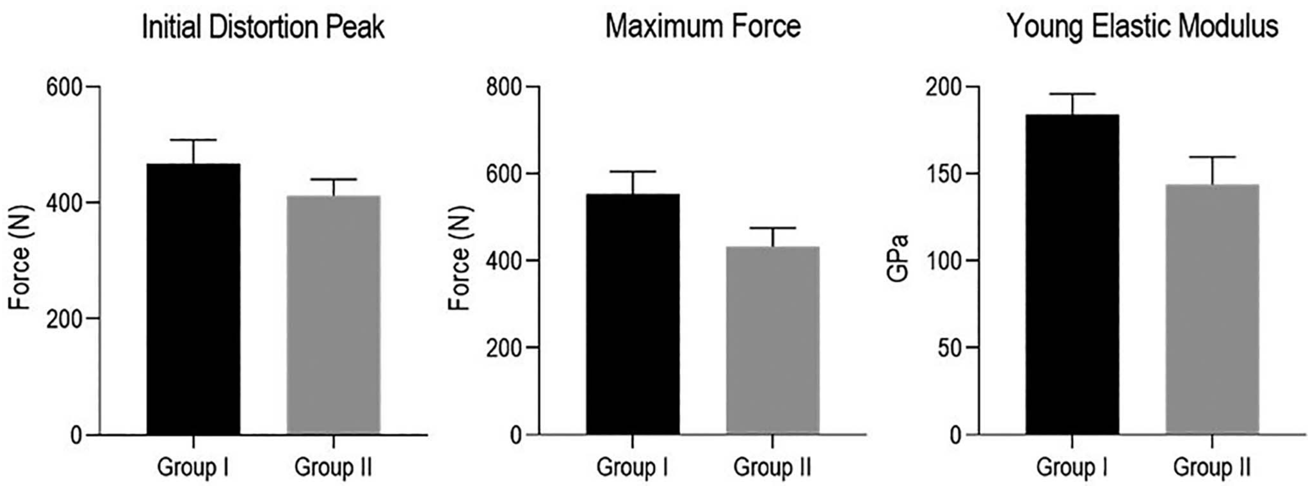

Figure 9. Summary charts describing the initial distortion peak, maximum force to the fracture, and the elastic modulus of group I and group II implants ($p < .05$).

response and the incidence of body fractures. The role of surface treatments is to modify implant body texture improving osseointegration, mechanical strength and wearing resistance. Recently, Tardelli et al considered the effect of surface treatments on zirconia body implants.[31] The authors reported decreased zirconia implant fracture resistance with dry treatment, including polishing, annealing, vapor deposition coating, laser treatment, and sandblasting/hydrofluoric acid etching.[31] This association is poorly investigated on titanium implant, and more studies are necessary to comply with the requirements of Associação Brasileira de Normas Técnicas, American Society for Testing and Materials, and International Organization for Standardization standards.

The limits of the present investigation certainly concern the application of a single loading vector, which was considered to avoid multiple torsional forces typical of a physiological masticatory loading condition. In vivo, the long-term exposure of the dental implant body in the oral cavity could change the behavior under the dynamic effect of the oral environment, including the mouth humidity, temperature, pH, bacterial factor, and masticatory loading. These aspects could significantly affect the measurable impact of the interface wearing and the structural resistance of the implant prosthetic coupling. In addition, the implant fracture could be induced by physiological loading in the presence of marginal bone; prosthetic impairments, including nonpassive infrastructure adaptation; or titanium alloy defects.[31] In other terms, the proposed study model can reduce the confounding variables connected with the inhomogeneity of the loading conditions and vectors of the oral cavity. Also, microstructural defects in the titanium alloy could significantly initiate the loading strength and fracture incidence. The present investigation compared 2 different implant–joint designs characterized by similar macrogeometry. The conical implant group was characterized by an internal coupling angle of 2° and an inverted tapered crestal module design. The primary evidence confirmed by the study findings seems to report an increased Young modulus of the conical implant system of approximately 21.87%, an increase of the initial distortion point of approximately 11.78% and a maximum force peak of approximately 21.88% compared with the internal hexagon joint implant. The implant system rigidity could be correlated to the mechanical friction determined by the conical tapered prosthetic joint that plays a remarkable role in the connection interface, reducing the interface microgaps and micromovements under the function. In this way, the differences in internal chamber volume between the 2 coupling designs could produce 2 different responses considering HI and CM implants. The higher rigidity and compression strength of CM implants that emerged from the test could produce a positive effect with biological and biomechanical implications in the clinical practice. The crestal module fracture is a clinical complication with severe consequences, concluding with the failure of the implant interface. Moreover, the solid interface generated by the CM coupling seems to produce a reduction in terms of microgaps, unscrewing, fracture, and uncoupling tendencies.[9] The microgaps also affect the peri-implant tissue balance, and bacteria microleakage.[32] In the literature, a higher risk of microleakage is correlated with internal prosthetic joints compared with CM implants.[33] This evidence confirms that the conical joint implants can provide an efficient interface seal that a recent meta-analysis associates with a lower risk of peri-implant complications and marginal bone loss.[34]

Table

Summary of the descriptive statistics of the study parameters

	Group I	Group II
Initial distortion (N)	467 ± 41 N	412 ± 28 N
Maximum force (N)	553 ± 51 N	432 ± 43 N
Implant diameter	4 mm	4 mm
Implant length	10 mm	10 mm
Young elastic modulus (E)	183.97 ± 11.71 GPa	143.72 ± 15.93 GPa

Conclusions

Within the limits of the present investigation, the conical implant prosthetic joint showed higher fracture resistance and rigidity compared with the internal hexagon connection. The abutment–joint stability could improve dental implant durability under oral masticatory function.

Note

This research received no external funding. All experimental data to support the findings of this study are available. Contact the corresponding author upon request. The authors have annotated the entire data-building process and empirical techniques presented in the paper. The authors declare no conflict of interest.

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