COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF PRE-FABRICATED DENTAL IMPLANT- ABUTMENT CONNECTIONS

- AN *IN VITRO* STUDY

Dissertation Submitted to

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MASTER OF DENTAL SURGERY

BRANCH I
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DEPARTMENT OF PROSTHODONTICS & CROWN & BRIDGE

CERTIFICATE

This is to certify that this dissertation entitled **“COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF PRE FABRICATED DENTAL IMPLANT ABUTMENT CONNECTIONS - AN *IN VITRO* STUDY”** is a genuine work done by **Dr. K.VIJAY** under my guidance during his post graduate study period between 2013-2016.

This Dissertation is submitted to THE TAMILNADU Dr. M.G.R MEDICAL UNIVERSTY, in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY IN PROSTHODONTICS & CROWN & BRIDGE - BRANCH I.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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This is to certify that this dissertation entitled "**COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF PRE FABRICATED DENTAL IMPLANT ABUTMENT CONNECTIONS- AN *IN VITRO* STUDY"** is a bonafide research work done by Dr.Vijay.K under the guidance of , ***Dr. T.J. Suneetha,*** Department of Prosthodontics and Crown and Bridges, Rajas Dental College and Hospital,Kavalkinaru, Tirunelveli-627105.

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TITLE: COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF PRE FABRICATED DENTAL IMPLANT ABUTMENT CONNECTIONS - AN *IN VITRO* STUDY.

Background: Dental Implants are widely used for treating single, partial or total edentulism with high success rate and predictability. There are several designs in the implant abutment connection which aim at better fit to improve mechanical stability and avoid screw loosening or fracture. Internal hex connections were designed to increase the implant abutment contact surface area inorder to improve abutment stability. It has been shown that internal hex implants provide better force distribution when compared with external hex implants. However there is no frictional locking between the mating parts of the abutment and the implants and most of these force are resisted by the screw. So, morse taper connections whose implant and abutment mating parts (conical and angulated) are overlapped, represents an alternative to internal or external hexagon connection designs. Another design is triconal connection with mechanical fit which helps in mechanical locking .Hence this in-vitro study was designed to comparatively evaluate the of fracture resistance of different dental implants abutment connections.

Materials and Methods: In the present study, three implant systems were used namely: Adin Implant System with internal hex (IH), Adin Implant System with morse taper connection (MT) and Equinox Implant System with triconal connection(TC). Six Implant –abutment assemblies were used for each system. Installation torques of 35 Ncm for each abutment was given. The implants were embedded in a custom made jig made according to ISO 14801 standards.. An universal testing machine was used to load all the specimens at a cross head speed of 1mm/min. The maximum load was recorded and used as the failure load. The load (N) at which fracture occurred was recorded and statistically analyzed .

Results. One way analysis of variance (ANOVA) was performed as a parametric test to compare different sub groups within each group. Dunnet test was employed as post Hoc tool to compare the Mean value between the three groups with each other of the sub groups. Difference were considered to be significant at $P<0.05$.The internal hexagonal abutment group fractured at a mean (SD) load of 410.19±11.98 N , The morse taper abutment group fractured at a mean load of 343.12±16.92 N and the triconal abutment group fractured at a mean (SD) load of 503.87±12.19 N. The differences between the groups were statistically significant for mean load.

Conclusions. Within the limitations of this in vitro study, triconal connection (TC) exhibited higher fracture resistance when compared to internal hex (IH) and morse taper (MT). Morse taper abutments exhibited a significantly lower fracture resistance than internal hexagonal abutments.The mode of failure is specific to the abutment material and design.

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Introduction

Clinicians for many decades have attempted to replace missing teeth by implanting alloplasts into the bone. Scientifically based implant therapy, emerged at the end of the 1970s following groundbreaking studies with 10- year clinical results by Dr Per –Ingvar Brenemark. His studies showed that pure titanium integrates with bone tissue if it is carefully prepared surgically, and the transmucosal element (abutment) joined to the implant can retain an intra oral prosthesis. Implant-supported restorations that replace single or multiple teeth, have demonstrated high success rates (above 90%) [1, 2,3,5,9]. Success of implant-supported restorations depends largely on the biomechanical factors related to the integrity of the bone/implant interface and the stability of the mechanical connection between implant and restorative components. [3,5,6,7,8]

Despite the high clinical success of implant prostheses, several complications have also been reported[22,29]. Clinical observations have indicated that mechanical complications are among the major causes of the implant failures.[9,14,12]. The mechanical complications include, abutment screw loosening, screw fractures and abutment fracture.[1,2,,4,10,11,13,37]. The fracture of prosthetic components has different clinical consequences, depending on the component fractured and the location of the fracture. Along this line, the fracture of implant components may require treatment ranging from substitution of restorative components to surgical removal of osseo-integrated implants. Two-piece implants have separate implant body to which the abutment is connected via a small screw. The one piece implants may be stronger than the two piece systems, because they have an integral one piece without any connection, but little data is available to support this claim. Likewise, there are several situations that indicate the use of the two-piece systems in order to correct the emergence profile and the crown angulations. According to misch et al, the size of the implant is considered to be the most important factor for the implant resistance to fracture or deformation. The implant abutment connection design seems to also significantly influence the ultimate failure resistance of the complex. This design feature includes the geometrical shape of the connecting parts, length of the engaged part of the abutment and the thickness of the thinnest part of the implant collar.[2]

The implant / abutment interface connection, is generally described as an internal or external connection. The distinctive factor that separates the two groups is the presence or absence of a geometric feature that extends above the coronal surface of the implant. The joined surfaces may also incorporate a rotational resistance and indexing feature and / or lateral stabilizing geometry. This geometry is further described as octagonal, hexagonal, cone screw, cone hex, cylinder hex, cam, cam tube and pin / slot.

The external hex-systems was initially designed to provide a rotational torque transferring mechanism suited for surgical placement of the implant into the osteotomy. Main use of external hexagon was with the full mouth splinted reconstruction. But when the same was used in the single unit reconstruction it was a mechanical challenge as it imposed load mainly in the abutment screw.

To overcome some of the inherent design limitations of the external hexagonal connection a variety of alternative connections have been developed. The most notable are the cone screw, the cone hex, the internal octagonal, the internal hexagonal, the cylinder hex, the Morse taper, spline, internal spline and resilient connection. Such internal connections could dissipate load along the implant wall in contact with the abutment surface, thereby providing a shield for the abutment screw. The goals of new designs are to improve connection stability throughout function and placement, and simplify the armamentarium necessary for the clinician to complete the restoration. There are at least 20 different implant/abutment interface variations on dental implants, in that 15 cleared the marketing by the FDA.[53] Since the introduction of the internal connection concept, further design enhancements have been made in an attempt to enhance the implant /abutment connection. Included in such efforts is the “Morse” taper, wherein a tapered abutment post is inserted into the no threaded shaft of a dental implant with the same taper. Other internal connection designs have been developed with variations in their use of joint designs (e.g., bevel, butt), or the numbers of 'hexes' present for the restorative phase.[9, 29,31,32,37.]

Implants designed with Morse taper interface engage their abutments by using a five degree angulated friction fit internal wall into which an abutment with a rounded male extension is placed. The abutments achieve an anti rotational properties due to the cold-weld phenomenon that occurs after placing and torquing the abutment. Cold or contact welding is a solid state welding process in which joining takes place without fusion at the interface of the two parts to be welded. Cold welding is defined as an increase in loosening torque with respect to tightening torque and it has been suggested that this might occur and result in lack of retrievability, which is inherent in the 3-component system of the external hex design. Sutter et al.[1]demonstrated that the loosening torque was 124% of the tightening torque at a clinically relevant level of 25 Ncm, which was presented in a favorable light, with reduced 24 risk for loosening. When it is made accurately enough seal [13] can be a hermetic one, eliminating microbial leakage. The cone screw tapered connection originated with the ITI group in Switzerland (ITI Straumann). Although the connection is called a “Morse” taper, the mating angle between component parts is 8 degrees. A true Morse taper exist at 2 degree and 4 degree and has unique self-locking characteristic without threads. Interference fit components are free of displacement upon function. More significantly, such interfaces are also geometrically locked against potential displacement that results from functionally imposed bending movements. The combined interference from rotational displacement, the high surface area, and the geometric constraint to displacement from lateral loads creates an implant/abutment interface that is largely free of micro motion and resistant to clinical prosthetic 2 complications or failure.

The myriad –plus system feature the tri-cone 17 degree internal cone abutment connection. The conical connection form an engineering perspective is one of the most stable mechanical implant abutment connections. The tricone three position internal indexing allows for torque transfer during implant placement as well as facilitates indexing for crown and bridge abutments. The tri-cone conical connection provides a zero micro motion solid connection that virtually removes the risk of screw loosening and subsequent breakage. The tight bacteria proof seal minimizes stress induced resorption in the marginal bone by optimally distributing load and ensures inflammation free and healthy peri-implant soft tissue.

A new internal connection implant design (Osseotite Certain, 3i Implant Innovations, Inc., and Palm Beach Gardens, FL) incorporates an audible and tactile “click” when the components are properly seated. This unique feature eases placement for the clinician and may reduce the need for radiographs following placement of the restorative components. The implant's internal connection allows 4 mm of internal engagement, with contact along a significant length that provides lateral stability from off-axis forces. The deep, 4mm multilevel engagement zone of this internal connection achieves a precise, secure connection with low torque. No more than 20 Ncm is required to maintain screw retention without loosening. The design of the internal connection allows the height of the screw to be only 1.95 mm from the top of the screw to the seating surface, allowing flexibility in abutment preparation without damaging the head of the screw. This internal connection design incorporates a 6-point hex and a

12-point, double-hex internal design. The 6-point internal hex provides a stable base for the use of straight abutments. The 12-point, double-hex of the internal connection allows 30-degree increments of rotational flexibility for placement of machined pre angled abutments of 25^0 to correct the off-axis emergence of the implant.

Several reports emphasize the integrity of implant abutment; Berglundh *et al.* reported that implant fractures represent 5% to 20% of the lost implants during function. Earlier studies have compared the fracture strength and failure modes of the regular internal hexagonal diameter implants. These studies were performed on different implant-abutment connection systems. Norton et al compared the static bending strength between two implant abutment combination: Branemark and astra tech implant system . He conclude that superior strength was with the 11 degree internal conical interface design on comparison with hex-mediated butt joint and also reported that internal conical , favors resistance to bending moment in contrast to shallow one like the hex- mediated butt joint [6,29,31.]

The literature concerning the mechanical behavior of IH(Internal Hexagon), MT(Morse Taper) and TC(Triconal Connection) implant abutment connection is still sparse and may be contradictory most studies concerning the mechanical behavior of implant connections have been limited to static numerical simulation and only a few have considered the role of fatigue in the mechanism of failure. Thus the evaluation of reliability and failure mode could provide insight into the mechanical behavior of different configuration of implant abutment connections[9]. This study focused on the ultimate failure strength of different implant abutment connections.

In light of the above, the aim of the present in vitro study was to comparatively evaluate the effect of static loading on different implant abutment connections.

Aim and Objectives of the Study

The aim of this study was to obtain the in-vitro comparative evaluation of fracture resistance of pre fabricated dental implant abutment connections.

The objectives of the present study included the following:

1. To measure Fracture Resistance of hexogonal abutment at static loading.
2. To measure Fracture Resistance of morse taper abutment at static loading.
3. To measure Fracture Resistance of triconal abutment at static loading.
4. To compare the fracture resistance of hexagonal & morse taper abutment after static loading.
5. To compare the fracture resistance hexagonal & triconal abutment abutment after static loading
6. To compare the fracture resistance morse taper& triconal abutment after static loading.
7. To compare overall, the mean reverse torque values of hexagonal, morse taper, triconal abutment after static loading.

Review of Literature

Adell et al., (1981)[51] studied the Fracture Resistance and Analysis of Stress Distribution of Implant-Supported Single Zirconium Ceramic Coping Combination with Abutments Made of Different Materials in which is mentioned that dental implants and abutments where usually manufactured using pure titanium due to its well documented biocompatibility and mechanical properties and concluded that titanium abutment(1,454N) showed highest fracture resistances compared to groups with Al_2o_3(422.5N) and with ZrO_2(443.6N).

Dixon et al.,(1995)[26] compared screw loosening, rotation and deflection among three implant designs: external hexagon, internal hexagon and internal octagon.. Micro movements and torque levels required to loosen abutment screws were examined. The amount of torque necessary to loosen the abutment screws before and after cyclic loading were recorded and compared. Results showed no significant difference between the straight and angled abutments.

Rangert et al (1995)[56] in his retrospective clinical analysis studied the Bending overload and implant fracture . he analyzed 39 fractures of 10,000 Brånemark implants.

Levine et al (1997) [58] did A multicenter retrospective analysis of the ITI implant system used for single tooth replacements: preliminary results at 6 or more months of loading. For the internal conical implant-abutment interface, the ITI system with an 8-degree tapered connection and Reported 3 fractures among 157 single tooth implant restorations.

Mollersten et al.,(1997)[26] By comparing the strengths of 7 implant systems under static cantilever bending stated that implants with a deep implant/abutment joint, such as the internal conical connection, favor resistance to bending moments in contrast to shallow one like the hex-mediated butt joint.

Marinello et al., (1997)[52] studied the Fracture Resistance and Analysis of Stress Distribution of Implant-Supported Single Zirconium Ceramic Coping Combination with Abutments Made of Different Materials in which is mentioned that dental implants and abutments where usually manufactured using pure titanium due to its well documented biocompatibility and mechanical properties and concluded that titanium abutment(1,454N) showed highest fracture resistances compared to groups with Al_2o_3(422.5N) and with ZrO_2(443.6N).

Michael R Norton et al.,(1997)[25] compared the resistance of bending forces by this biconical designs of the astra tech implant systems and the standard butt design of the “benchmark” Branemark systems(nobel bio care) at 2 level; test 1: the fixture – abutment interface. Test 2: the abutment-bridge cylinder interface. He concluded that the incorporation of an internal conical interface at the fixture- abutment and abutment- bridge cylinder levels may be seen to dramatically enhance the ability of a dental implant unit to resist bending forces, to a statistically significant degree. Such improved biomechanical stability may have ramification on the clinical integrity of a prosthesis supported by intra osseous root form dental implants.

Declan Byrne et al.,(1998)[13] studied the fit of cast and premachined implant abutments in which he stated that A close fit between implants and abutments is considered important for several reasons. A relationship between plaque levels and inflammation was similar to that seen around natural teeth.4 Surface irregularities facilitated the colonization of putative pathogens. The presence of gaps that allow bacteria to congregate may result in inflammation of the peri-implant tissue. It is speculated that this could lead to compromised implant stability. The abutments were usually made of machined titanium designed to minimize potential gaps at the implant/abutment interface and to encourage a tight peri-implant cuff with hemidesmosomal attachments to the implant. The results of this study confirmed the suggestion that premachined abutments, which include those abutments that are modified in a laboratory, are superior in adaptation to those cast from burnout patterns.

Levine et al (1999) [57] did A multicenter retrospective analysis of the ITI implant system used for single tooth replacements: preliminary results at 6 or more months of loading. For the internal conical implant-abutment interface, the ITI system with an 8-degree tapered connection and Reported 3 fractures among 157 single tooth implant restorations.

Binon PP et al.,(2000)[29] Implants designed with Morse taper interface engage their abutments by using a five degree angulated friction fit internal wall into which an abutment with a rounded male extension is placed. The abutments achieve an antirotational properties due to the cold-weld phenomenon that occurs after placing and torquing the abutment. Cold or contact welding is a solid state welding process in which joining takes place without fusion at the interface of the two parts to be welded. Cold welding is defined as an increase in loosening torque with respect to tightening torque and it has been suggested that this might occur and result in lack of retrievability, which is inherent in the 3- component system of the external hex design. Sutter et al.1 demonstrated that the loosening torque was 124% of the tightening torque at a clinically relevant level of 25 Ncm, which was presented in a favourable light, with reduced 24 risk for loosening. When it is made accurately enough seal can be a hermetic one, eliminating microbial leakage.

Beat R. Merz et al.,(2000)[31] did a comparison between the 8-degree Morse Taper and the butt joint as connections between an implant and an abutment. Three-dimensional, non-linear finite element models were created to compare the 2 connection principles under equal conditions. The loading configuration was thereby modeled according to a test setup actually used for the dynamic long-term testing of dental implants as required for regulatory purposes. The results give insight into the mechanics involved in each type of connection and are compared to actual findings with the testing machine. The comparison indicates the superior mechanics of conical abutment connections and helps to explain their significantly better long-term stability in the clinical application.

Ameen Khraisat et al.,(2002)[6] studied the fatigue resistance of two implants/abutment joint designs that is Brenemark and ITI in which a hex mediated-butt joint and 8-degree internal conical implants abutment interface are used, respectively and concluded that the effect of joint design on the fatigue strength and failure mode of the ITI single tooth implant systems was significantly ($p>.001$) than the barnemark single tooth implant .

Perriard J et all (2002) [62], studied Fatigue resistance of ITI implant-abutment connectors – a comparison of the standard cone with a novel internally keyed design.and concluded that on comparision of the fracture resistance of internal hexagon and morse taper connections . morse taper connection provides greater resistance to deformation and fracture than internal hexagon .

Joerg R. Strub et al.,(2003)[22] The purpose of this study was to evaluate the fracture strength and mode of failure of five different single-tooth abutment-implant combinations before and after cyclic loading in the artificial mouth. Where the testing was done in universal testing machine until failure, which was defined as a deviation from linearity.

Dincer Bozkaya et al.,(2003)[32] studied two types of connection method a)screw and b)a tapered interference fit(also called as morse taper) are commonly used for securing the abutment to the implant. They evaluated the long term success of a dental implant, the reliability and the stability of the implant-abutment interface and concluded that Tapered interference fits provide a reliable connection method between the abutment and the implant.

Yilidrim m ,Fisher h, et al.,(2003)[41] To investigate the effect of implant-abutment connection types on reliability and failure modes of anterior single unit crowns. Fifty-four implants were divided in 3 groups (n=18 each): external hexagon (EH), internal hexagon (IH), and Morse taper (MT) connection. Abutments were screwed to the implants, and maxillary central incisor metal crowns were cemented and subjected to step-stress accelerated life testing. Reliability was higher for the EH and MT relative to IH groups, whereas the characteristic strength was significantly higher for implants with MT connection.

Asbjorn Jokstad et al.,(2004)[1] did a quality research data collection to decide which dental implant should be selected for patient treatment. in this implant abutment connection has been compared as external vs internal connection, hexagonal vs octagonal vs morse taper, rotational vs non rotational,added non rotational feature ,butt vs bevel joint, slip fit vs frictional fit joints, resilience vs non resilience.and also conluded that the scientific literature does not provide any clear directives to claim of alleged benefits of specific morphological characteristic of dental implant.

UNI EN ISO 14801 et al.,(2005)[8] Dentistry Fatigue test for endosseous dental implants. This International Standard specifies a method of fatigue testing of single-post endosseous dental implants of the transmucosal type. It is most useful for comparing endosseous dental implants of different designs or sizes. While it simulates the functional loading of an endosseous dental implant body and its premanufactured prosthetic components under “worst-case” conditions, this International Standard is not applicable forpredicting the *in vivo* performance of an endosseous dental implant or prosthesis, particularly if multiple endosseous dental implants are used for a prosthesis. The bone-anchoring part of the specimen shall be fixed in a rigid clamping device. If an embedding material is used, it shall have a modulus of elasticity higher than 3 GPa. The geometry of the clamping device shall be such that the testing geometry specified in 5.2 is achieved. The clamping device shall be designed so as not to deform the test specimen. The device shall clamp the specimen at a distance 3, 0± mm0,1 mm apically from the nominal bone level as specified in the manufacturer’s instructions for use. For many endosseous dental implants, it is known that the marginal bone will retract following implantation to a steady-state ±level. The distance 3,0 mm is chosen to provide a worst case with respect to bone retraction.

Gehrke Peter (2005)[16] studied the effect of cyclic loading on Zirconium abutment screw loosening in his laboratory study he did according to the International Standards (ISO/14801, International Organization for Standardization) simulating the functional loading of an endosseous dental implant body and its abutment components under worst case conditions that is top of the implant extended 3mm above the level of the surrounding material. The static loading test was done at the crosshead speed of 0.05inches per minute and fatigue test(15Hz)

F. BUTZ et al., (2005)[19] studied the Survival rate, fracture strength and failure mode of ceramic implant abutments after chewing simulation in which all the specimens were loaded until fracture or deflection of 4 mm in a universal testing machine with a cross-head speed of 1-5 mm /min. Loads were applied with anangle of 130, 3 mm below the incisal edge using a 0-8 mm thick tin foil to ensure even stress distribution. The fracture loads were recorded and analysed using Zwicktest Xpert software. The mode of failure was then recorded and classified into screw fracture, abutment fracture, and deflection.

Att W, kurum s Gerds t , strub j et al.,(2006)[43]To investigate the effect of implant-abutment connection types on reliability and failure modes of anterior single unit crowns. Fifty-four implants were divided in 3 groups (n=18 each): external hexagon (EH), internal hexagon (IH), and Morse taper (MT) connection. Abutments were screwed to the implants, and maxillary central incisor metal crowns were cemented and subjected to step-stress accelerated life testing.

Reliability was higher for the EH and MT relative to IH groups, whereas the characteristic strength was significantly higher for implants with MT connection.

Peter Gehrke et al.,(2006)[17] studied the fracture strength of zirconia implant abutment which was done according to ISO 14801 simulating the functional loading of an endosseous dental implants and its abutments and used static loading. Research has extensively focused on the bite forces occurring during mastication. Apart from individual anatomic and physiologic characteristics, it has been shown that maximal bite forces vary according to the region in the oral cavity. While the greatest bite force was found in the first-molar region, incisors bear only about one-third to one-fourth of that force in the posterior region. Mean values varying from 216 to 847 N for the maximum force level could be shown, whereas smaller values ranging from 108 to 299 N have been reported for the incisal region. After intensive investigation, Körber and Ludwig presumed that posterior fixed partial dentures should be strong enough to withstand a mean load of 500 N. It appears feasible to expect a similar minimum permissible value for posterior implant abutments and their restorations.

Y. MAEDA et al.,(2006)[35] studied the In-Vitro difference of stress concentrations for internal and external hex implants-abutment connections in which they concluded that fixtures with external-hex showed an increase in strain at the cervical area under horizontal load, while in internal-hex fixtures the strain was at the fixture tip area. The internal hex system has advantages such as (i) ease in abutment connection, (ii) suited for one stage implant installation, (iii) higher stability and antirotation because of a wider area of connection and suited for single tooth restoration, (iv) higher resistance to lateral loads because of the lower centre of rotation and

(v) Better force distribution; while its disadvantages are (i) thinner lateral fixture wall at the connecting part and (ii) difficulty in adjusting divergences in angles between fixtures. Taper joint connections with a conical seal, or Mouse's taper, have advantages of better sealing capabilities in closing the micro-gap on top of those in an internal hex system.

Rudi c Van Studen et al.,(2008)[3] The aim of this study is to clarify the difference
in the stress distribution patterns between implants with internal and external-hex connections with the crown using the Finite Element Method (FEM).concluded that the magnitude of the stress produced by the internal hex implant system is generally lower than that of the external - hex system. The geometrical design of the external – hex system tends to induces stress concentration in the crown at a distance of 2,89 mm from the apex.

Aramoni P, Zeboni E et al.,(2008)[45] To investigate the effect of implant-abutment connection types on reliability and failure modes of anterior single unit crowns. Fifty-four implants were divided in 3 groups (n=18 each): external hexagon (EH), internal hexagon (IH), and Morse taper (MT) connection. Abutments were screwed to the implants, and maxillary central incisor metal crowns were cemented and subjected to step-stress accelerated life testing. Reliability was higher for the EH and MT relative to IH groups, whereas the characteristic strength was significantly higher for implants with MT connection.

Neil Meredith et al.,(2008)[18] studied the Survival rate, fracture resistance and mode of failure of titanium implants in clinical function and dynamic loading. In that its discussed that mechanism of failure for implant components, fixtures, abutments and screws is fatigue failure. This occurs as a result of cyclic functional loading; the magnitude of which may be well below the ultimate strengths of the components. Good clinical practice and adherence to sound biomechanical principles of prosthesis design should minimize the risks of fatigue failure, although component design may play a role. Catastrophic failure can be modeled in-vitro with some confidence by the application of a single load cycle applied by a calibrated testing system until failure occurs. Fatigue loading is much more complex to model in-vivo and it can be difficult to extrapolate to clinical behavior from such findings. Clinical study of failure specimens may be helpful in identifying possible contributory factors. An international standard (ISO 14801:2003) exists for fatigue testing of endosseous dental implants. It is most useful for comparing implants of different designs or sizes. The published standard carries an important caveat not included in the similar standard for the testing of orthopedic prostheses: ‘Whilst it simulates the functional loading of an endosseous dental implant body and its pre-manufactured prosthetic components under ‘worst case’ conditions, the standard is not applicable for predicting the *in-vivo* performance of an endosseous dental implant or prosthesis. a simple uniaxial loading regimen can be useful in comparing implant performance .

Lars Steinebrunner et al.,(2008)[33] evaluated the implant abutment interface design which affect the fracture strength of implants in which they concluded that Implant systems with long internal tube-in-tube connections and cam–slot fixation showed advantages with regard to longevity and fracture strength compared with systems with shorter internal or external connection designs.

Adatia ND, B ayne SC, cooper LF, Thompson JY etb al.,(2009)[46] To investigate the effect of implant-abutment connection types on reliability and failure modes of anterior single unit crowns. Fifty-four implants were divided in 3 groups (n=18 each): external hexagon (EH), internal hexagon (IH), and Morse taper (MT) connection. Abutments were screwed to the implants, and maxillary central incisor metal crowns were cemented and subjected to step-stress accelerated life testing. Reliability was higher for the EH and MT relative to IH groups, whereas the characteristic strength was significantly higher for implants with MT connection.

Irena Sailer et al.,(2009)[34] did the In-Vitro study to find the influence of the type of connection on the fracture load of zirconia abutment with internal and external implant abutment in which sample were mounted in a steel holder of the universal testing machine at an angle of 30 degrees, according to ISO norm 14801.To ensure an even distribution of the static force tin foil was applied between the Sample and the indenter and they concluded that internal connection has been associated with a more favorable load distribution in the connection area.

Abílio Ricciardi Coppede et al., (2009)[24] did An In Vitro Study comparing the Fracture Resistance of the Implant-Abutment Connection in Implants with Internal Hex and Internal Conical Connections Under Oblique Compressive Loading: The objective of this study was to determine if the different design, dimensions, and mechanical properties of the abutments and implant-abutment connections. The implants were embedded in a 21.3-mmdiameter by 25.6-mm-high stainless steel cylinder. The embedded depth was 10 mm to simulate a 3-mm bone resorption. Oblique compressive loading tests were made in a universal testing machine (DL-2000, EMIC). Loading was performed with the specimens positioned at a 45-degree angle, utilizing a 500 kgf load cell with 1 mm/min dislocation. The loading point was at a distance of 11 mm from the cylinder surface (lever arm length). Two values were analyzed in each test: the maximum deformation force (MDF) and the fracture force (FF) of each implant-abutment assembly under 5-degree compressive loading. All results were analyzed using statistical software (JMP for Windows version 5.1, SAS Institute). MDF values were assessed using the Student *t* test ($P < .05$).

kim s , kim hi, brewer JD, Monaco EA et al.,(2009)[47], To investigate the effect of implant-abutment connection types on reliability and failure modes of anterior single unit crowns. Fifty-four implants were divided in 3 groups (n=18 each): external hexagon (EH), internal hexagon (IH), and Morse taper (MT) connection. Abutments were screwed to the implants, and maxillary central incisor metal crowns were cemented and subjected to step-stress accelerated life testing. Reliability was higher for the EH and MT relative to IH groups, whereas the characteristic strength was significantly higher for implants with MT connection.

Pines M ,Stappert C et al.,(2010)[48] in which all groups were subjected to static loading until fracture using universal testing machine(Z010/TN2s, Zwick) at a cross head speed of .5mm until fracture testing an implants crown to failure it provides valuable information to the design engineer and is recommended prior to designing the foundation . And also used original implants instead of implants analogue.

Pessoa S, Muraru L, Júnior EM,et al (2010) [59] studied Influence of implant connection type on the biomechanical environment of immediately placed implant CT-based nonlinear, three-dimensional finite element analysis for instance, has shown improved stability for the abutment and the lowest stress concentration in the abutment screw for MT connections relative to EH and IH. Conversely, a recent study by Ribeiro CG, Maia ML, Scherrer SS, et al [60] studied Resistance of three implant-abutment interfaces to fatigue testing comparing the EH, IH, and MT implants showed that EH presented significantly higher fatigue resistance than IH and MT.

In an attempt to reduce prosthetic and biological complications, different implant-abutment connection designs have been developed and are available for use. However, the literature concerning the mechanical behavior of EH, IH, and MT implant-abutment connections is still sparse and may be contradictory. Most studies concerning the mechanical behavior of implant connections have been limited to static numerical simulations, and only a few have considered the role of fatigue in the mechanisms of failure.

Sutter f weber et all (2010) [61.] the authors in the journal new restorative concept of the ITI dental implant system: design and engineering. Has described that superior strength and security offered by the 8 degree conical interface designs of the ITI systems and postulated that this designs might be clinically superior to that of a butt joint or flat coupling designs.

Tsunemichi Kanbara et al., (2011)[7] studied influence of tetragonal zirconia polycrystal (TZP) on the two-body wear behavior of titanium (Ti). Two-body wear tests were performed using TZP, two grades of cp-Ti or Ti alloy in distilled water, and the cross-sectional area of worn surfaces was measured to evaluate the wear behavior. In addition, the surface hardness and coefficient of friction were determined and an electron probe microanalysis performed to investigate the underlying mechanism of wear. The hardness of TZP was much greater than that of Ti. The coefficient of friction between Ti and Ti showed a higher value than the Ti/TZP combination. Ti was more susceptible to wear by both TZP and Ti than TZP, indicating that the mechanism of wear between TZP and Ti was abrasive wear, whereas that between Ti and Ti was adhesive wear. No remarkable difference in the amount of wear in Ti was observed between TZP and Ti as the opposite material, despite the hardness value of Ti being much smaller than that of TZP.

Cleide Gisele RIBEIRO et al.,(2011)[37] studied the resistance of three implant abutment interface to fatigue testing.(external hexagon, internal hexagon and cone-in-cone) and concluded that though internal connections present a more favorable design, this study did not show any advantage in terms of strength. The external hexagon connector used in this study yielded similar results to those obtained in a previous study with Nobel Biocare and Straumann systems. However, the internal connections (cone-in-cone and internal hexagon) were mechanically inferior compared to previous results.

Ahmad mohamoud et al.,(2012)[2] studied the implant – abutment interface in which he has compared the ultimate force to cause failure between small diameter implant systems. In his study , each sample was secured in a rigid clamping device 3.0mm apically from the bone level at 30 degree angulation according to ISO 14801and static loading is used. The study is concluded that zimmer tapered screw-vent showed higher amount of load to fracture in comparision to other groups tested in this study.

Hendrik Jacob santing et al., (2012)[27] studied the fracture strength implant supported crowns. In which the testing was done in the universal testing machine. In order to simulate the clinical situation as close as possible, the specimen were mounted in a metal base and load was applied at 137 degree at a crosshead speed o0f 1 mm/ min. the spherical load was used. Commercially available aluminium foil was folded to achive a thickness of approximately 1 mm and was placed between the loading cell and the crown to avoid slipping of the load cell. The force applied was graphically recorded on the x-t recorder.

Izabela Cristina Mauricio Moris et al.,(2012)[30] evaluated the mechanical analysis of convectional and small diameter conical implant(morse taper) under oblique compressive loads. In which implant abutment assembly were subjected to static compressive test, performed in a universal testing machine with 1mm/min displacement, at 45 degree angulation. The maximum deformation was determined and he concluded that Abutment measuring 3.8 mm in diameter (reduced) presented mechanical properties similar to 4.8 mm (conventional) abutments, enabling its clinical use as indicated.

Amilcar C. Freitas et al.,(2012)[36] studied reliability and failure modes of anterior single-unit implant-supported restorations For mechanical testing, the specimens were subjected to 30° off-axis loading. Three specimens of each group underwent single-load-to fracture (SLF) testing at a cross-head speed of 1 mm/min in a universal testing machine (INSTRON 5666, Canton, MA, USA) with a flat tungsten carbide indenter applying the load at the incisal edge of the crown.

Kadir Firidinoglu et al.,(2012)[14] studied the Fracture Resistance and Analysis of Stress Distribution of Implant-Supported Single Zirconium Ceramic Coping Combination with Abutments Made of Different Materials in which is mentioned that dental implants and abutments where usually manufactured using pure titanium due to its well documented biocompatibility and mechanical properties and concluded that titanium abutment(1,454N) showed highest fracture resistances compared to groups with Al_2o_3(422.5N) and with ZrO_2(443.6N).

Spiridon-Oomvertos Koutayas et al.,(2012) To investigate the effect of implant-abutment connection types on reliability and failure modes of anterior single unit crowns. Fifty-four implants were divided in 3 groups (n=18 each): external hexagon (EH), internal hexagon (IH), and Morse taper (MT) connection. Abutments were screwed to the implants, and maxillary central incisor metal crowns were cemented and subjected to step-stress accelerated life testing. Reliability was higher for the EH and MT relative to IH groups, whereas the characteristic strength was significantly higher for implants with MT connection.

Jamie K. W. Foong et al.,(2013)[11] In thier In-Vitro study they studied fracture resistance of internal connection titanium and zirconia abutments where the abutments where attached to customized brass device in such a way that long axis of the crown was angulated 30 degrees to the loading platon. The rounded metal loading platen was positioned on the palatal surface of the crown 2mm from the incisal edge. Failure was determined by an audible crack or by automatic software detection and it was concluded that the meam number of cycles until failure of the titanium abutment group was three times that of the Zirconia abutment group.

Jae Seon Kim et al.,(2013)[12] studied three types of Zirconia implant abutment under static load. In this In-Vitro study they used custom-made positioning device to standardize the test implants within the acrylic resin. The platforms of the test implants where 3.0mm away from the acrylic resin to simulate 3.0mm of bone loss according to ISO 14801 standard. A preload of 35Ncm was applied to all the abutments to anchor them to the test implant, according to the manufactured instructions. The universal testing machine(instron model 5500R Instron corporation, Norwood, Mass) made contact with the specimen 2.0mm from the incisal tip at the 30 degree angle to simulate maxillary anterior tooth contact. Multiple limitations of the study need to be addressed for proper clinical correlation. The first was that only static loading was used. Static loading may only be one type of force among many that can be applied to the abutment-coping complex; thus different results may be demonstrated when fatigue loading is applied. However, to design a fatigue loading test, static loading is essential to provide a starting point and calculate the load that will be applied to the abutment-coping complex. Therefore, this static loading test may be considered a preliminary study for future fatigue loading projects. Second, the precision of the fit of the abutments from different manufacturers to the test implants was not compared. This factor was a variable that may have contributed to the difference in the maximum load capacity or the fracture behavior of the abutments. Third, non anatomic copings were used rather than anatomically contoured crowns. Thick zirconia copings (2.0 mm) were used to concentrate the forces being applied to the specimens to the cervical region and to prevent any coping fractures, which may introduce another variable and complicate the data analysis. In addition, this study used only one type of implant system with a specific connection type and diameter; thus the results may not be applicable to other implant systems. Additional clinical studies are needed to conducted to identify the mode of failure of such implant abutments and to provide guidelines for the use of zirconia abutments with different connections and different implant platform designs.

Luigi CANULLO et al.,(2013)[20] studied Mechanical testing of thin-walled zirconia abutments according to ISO 14801:2007, for mechanical testing, single load to fracture (SLF) was performed with metal clamping device. testing methods available for the evaluation of different implant-abutment system configuration, several have described, such as the single load to fracture1, the use of fatigue followed by the application of a static load until fracture, the staircase method16, fatigue limit (ISO 14801:2007), step-stress accelerated life testing, and others. While the ISO 14801 was created in 2003 and revised in 2007, with the aim of standardizing the testing procedures and data presentation in the fatigue of dental implants, it has been shown that the results produced by such a method should be interpreted with caution.

Eun-Sook Kim et al.,(2013) [23] examined the effects of the abutment types and dynamic loading on the stability of implant prostheses with three types of implant abutments prepared using different fabrication methods. In which they have used thecustomized jig according to ISO standards 14801 for dentistry- fatigue test for endosseous dental implants. The jig was designed to apply a force to the abutment at 30 degree t the long axis.

Lucas S. Machado et al.,(2013)[9] To investigate the effect of implant-abutment connection types on reliability and failure modes of anterior single unit crowns. Fifty-four implants were divided in 3 groups (n=18 each): external hexagon (EH), internal hexagon (IH), and Morse taper (MT) connection. Abutments were screwed to the implants, and maxillary central incisor metal crowns were cemented and subjected to step-stress accelerated life testing. Reliability was higher for the EH and MT relative to IH groups, whereas the characteristic strength was significantly higher for implants with MT connection.

Manoj Shetty et al.,(2014)[10] studied implant abutment connection in biomechanical Perspectives in which he stated that the implant/abutment interface determines joint strength, stability, and lateral and rotational stability. One of the first internally hexed implants was designed with a 1.7 mm-deep hex below a 0.5-mm wide, 45° bevel. Its features were intended to distribute intraoral forces deeper within the implant to protect the retention screw from excess loading, Internally connected implants also provide superior strength for the implant/abutment connection. Since the introduction of the internal connection concept, further design enhancements have been made in an attempt to enhance the implant /abutment connection. Included in such efforts is the “Morse” taper, wherein a tapered abutment post is inserted into the non threaded shaft of a dental implant with the same taper. Other internal connection designs have followed, frequently with variations in their use of joint designs (eg, bevel, butt), or the numbers of 'hexes' present for the restorative phase.

Rubén Agustín-Panadero et al., (2014)[28] studied the mechanical behavior of provisional implant prosthetic abutments. When the study groups and sample sizes had been decided, the specimen/test design was conceived following UNE-ISO 14801 specifications for fatigue testing of single post endosseous dental implants with straight abutments and their prosthetic components, whereby specimens must be angled along an axis that forms a 30º±2º angle to the direction of the force exercised by the test machine. The specification also states that all materials must be used according to the instructions provided by their manufacturers. The compression test was performed with a static load universal test machine (Instron ® model 4202, Instron®, Barcelona, Spain) fitted with a load cell of 5000 N. The force direction was the same for all samples and the load was applied by means of a flat-surfaced antagonist. The load applicator made a vertical motion descending onto the sample, applying a continuous vertical force onto the abutment with a crosshead speed of 0.5 mm/min. The test machine was stopped when it had produced the first abutment fracture and the force provoking the fracture was registered in Newtons (N). During compression strength testing, elastic deformation of the abutments at the point of maximum loading was registered. Deformation was interpreted as displacement (in millimeters) of the Instron machine's load applicator from the initial test position to the moment of abutment failure.

Materials and Methods

MATERIALS & METHODS

The Present In-Vitro study was conducted to evaluate and compare the fracture resistance of different pre-fabricated Dental Implants abutment connection

The following materials, instruments and equipments are used for the study:

MATERIALS USED:

1. Prefabricated Titanium Dental Implant and its Abutment (internal hexagon).
   (Adin dental Implants ltd.Israel).
2. Prefabricated Titanium Dental Implant and its Abutment (morse taper).
   (Adin dental Implants ltd.Israel).
3. Prefabricated Titanium Dental Implant and its Abutment (triconal connection).
   (equinox).

INSTRUMENTS USED:

1. Adin dental Implants touareg-s (internal hexagon connection) hex driver.
2. Adin dental Implants touareg-s (internal hexagon connection)Torque rachet.
3. Adin dental Implants touareg-s (morse taper) hex driver.
4. Adin dental Implants touareg-s (morse taper)Torque rachet.
5. Equinox Dental Implant myriad plus(triconal connection) hex driver.
6. Equinox Dental Implant myriad plus(triconal connection) Torque rachet.
7. Custom made stainless steel Jig to hold Implant at 30^0

EQUIPMENTS USED:

1. The UNIVERSAL Testing Machine 3345(Instron model, Instron Copt norwood, Mass).

METHODOLOGY

I. COLLECTION OF SPECIMENS.
   1. prefabricated titanium implant & abutment with internal hexogon.
   2. prefabricated titanium implant & abutment with morse taper.
   3. prefabricated titanium implant & abutment with internal tricone

II. TORQUING THE ABUTMENTS ON THE IMPLANTS AT 35 N .

III. CUSTOM- MADE MOUNTING JIG FABRICATION ACCORDING TO ISO14801 .

IV. MOUNTING THE SAMPLES IN THE SPECIMEN HOLDER .

V. EVALUATION OF FRACTURE RESISTANCE OF DIFFERENT PREFABRICATED DENTAL IMPLANT ABUTMENTS USING UNIVERSAL TESTING MACHINE (INSTRON MODEL 3345).

VI. TABULATION OF THE RESULTS WITH MAXIMUM FORCE APPLIED IN NEWTON (N).

VII. STATISTICAL ANALYSIS DONE WITH ONE WAY ANOVA APPLIED FOR ANALYSIS.

Methodology- Overview:

COLLECTION OF SPECIMENS

↓

TORQUING THE ABUTMENT ON THE IMPLANT

↓

CUSTOM- MADE MOUNTING JIG FABRICATION ACCORDING TO ISO 14801

↓

MOUNTING THE SAMPLES IN THE SPECIMEN HOLDER .

↓

EVALUATION OF FRACTURE RESISTANCE EACH SAMPLES

↓

TABULATION OF RESULTS

↓

STATISTICAL ANALYSIS

SPECIMEN FABRICATION

Specimens used in this study consisted of implant-abutment assemblies mounted in a specimen holder made of a stainless steel jig. The details of specimen fabrication are explained below and it is comprised of the following steps:

1. COLLECTION OF SPECIMENS.
2. TORQUING THE ABUTMENT ON THE IMPLANT.
3. MOUNTING JIG FABRICATION ACCORDING TO ISO 14801.
4. EVALUATION OF FRACTURE RESISTANCE OF DIFFERENT PREFABRICATED DENTAL IMPLANT ABUTMENT DONE USING UNIVERSAL TESTING MACHINE (INSTRON MODEL 3345) ACCORDING TO ISO 14801.

I. COLLECTION OF SPECIMENS.

Study design group	No of samples	Implants	Abutment connection designs
1	6	ADIN pvt ltd,.Touareg-s. D 3.75 *L 11.5.	Internal hexogon Connection.
2	6	ADIN pvt ltd,.Touareg-close fit. D 3.5 *L 13.	Morse taper Connection.
3	6	EQUINOX, Myraid plus. D 3.8 *L 13.	Internal triconal Connection.

Table-1: collection of specimens.

(Ref fig 1,2 4,5,7,8 ,22)

II. TORQUING THE ABUTMENT INTO THE IMPLANT

All dental implant components were tested as assembled according to its manufacture's recommendation statement. A preload of 35 N (± 5%) was applied to all abutments using their respective hex driver (fig 3,6, 9)and Torque rachet (fig-9,10) to anchor them to the implants. All specimens were stored in artificial saliva before testing.

III. MOUNTING JIG FABRICATION ACCORDING TO ISO 14801 .

The purpose of the mounting jig is to help mount all the samples in a consistent and predictable manner. Custom made implant holders were fabricated for the research project. The testing protocol was based on the UN EN ISO 14801 Dentistry [8] — Fatigue test for endosseous dental implants as follows…

Key

1 loading device

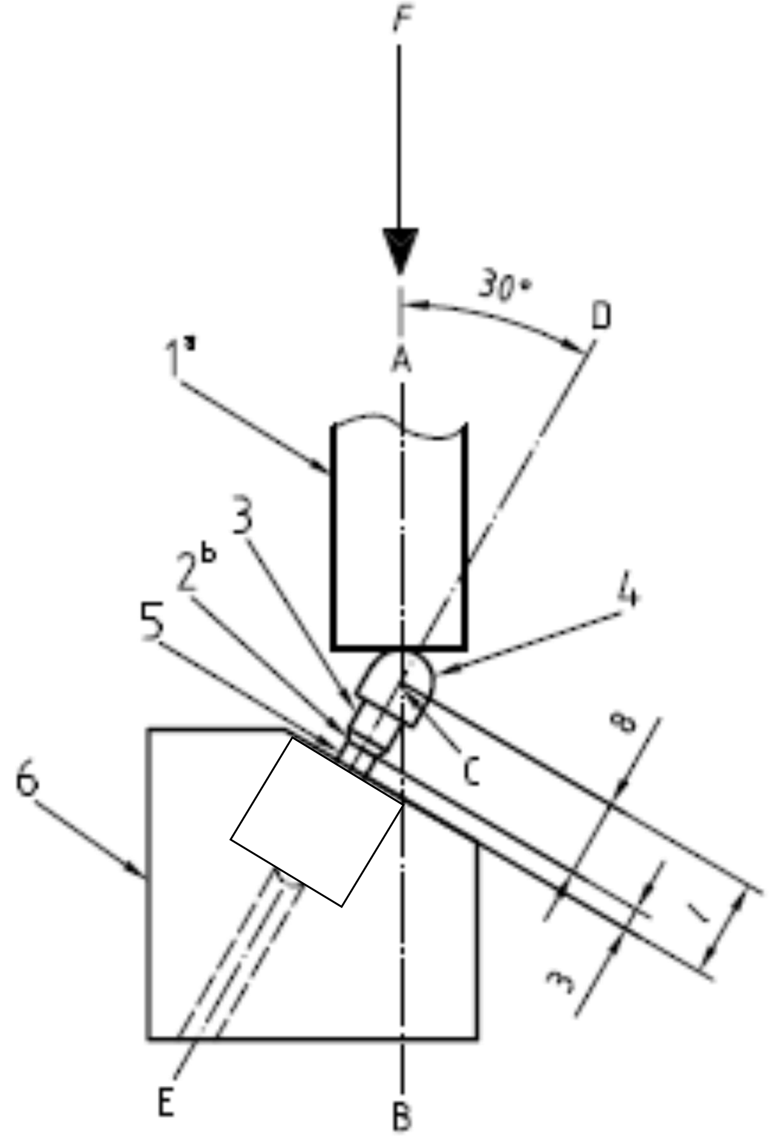
2 nominal bone level

3 abutment

4 hemispherical loading member

5 dental implant body

6 specimen holder



Dia 1 Line diagram of Custom made stainless jig for positioning in the static loading machine

Specimen holder: (fig 12, 13)

The bone-anchoring part of the specimen was fixed in a rigid clamping device. The endosseous dental implant was clamped such that its axis makes a 30° ± 1° angle with the loading direction of the testing machine. The clamping device was designed so as not to deform the test specimen.

Custom-made jig for the implant abutment fixture assembly consisted of two stainless steel blocks-one major stainless steel block and one minor stainless steel block. The purpose of fabricating the blocks in two parts was to eliminate the need to refabricate the entire jig in case of damage or distortion during testing. The major stainless steel block serves two purposes: first it acts as a base to hold on to the instron machine , secondly it holds the minor stainless jig at an angle of 30°according to the ISO 14801 standard. The minor stainless jig was secured in placed with the help of a screw. The dimension of major block are as follows height 50 mm; width 12mm ;length 50 mm.

The minor stainless steel block was designed to hold the endosseous dental implant. It had the following dimensions: height 20 mm, width 10 mm and in the center it had a slot with the diameter of 3.8 mm at one end to hold the implant of diameter 3.75 and 2 mm diameter on the other end to facilitate easy removal of implant in an event of fracture. The difference in the diameter at both ends of the slot serves as a vertical stop allowing the endosseous dental implants to be positioned 3.0mm apically from the nominal bone level as specified in the manufacturer’s instruction for use. For many endosseous dental implants, it is known that the marginal bone will retract following implantation to a steady-state level. The distance 3.0 mm was chosen to provide a worst case with respect to bone retraction.

IV EVALUATION OF FRACTURE RESISTANCE OF DIFFERENT PREFABRICATED DENTAL IMPLANT ABUTMENT DONE USING UNIVERSAL TESTING MACHINE (INSTRON MODEL 3345). (FIG14, 15)

The International Standard specified a method of fatigue testing of single-post endosseous dental implants of the transmucosal type. It is most useful for comparing endosseous dental implants of different designs or sizes. It simulates the functional loading of an endosseous dental implant body and its premanufactured prosthetic components under "worst-case" conditions.

General principles followed

1. Finished-device testing

Testing was performed on specimens that were representative of the finished device (i.e. components that have undergone the same manufacturing process as the device that is to be marketed). All test specimens used in the study was supplied in sterile packs by the manufacturer which eliminated the need to sterilize the specimens before testing.

2. Testing environment

The testing was carried out according to ISO 3696 ,in normal saline. The test specimens were kept at 37º C ± 2ºC during the testing.

3. Test method

Testing machine

The testing machine possessed the following characteristics:

a) capable of applying the specified load with an error not exceeding ± 5 % at maximum load (in accordance with ISO 7500-1 and ISO 4965);

b) capable of applying the load at the specified frequency;

c) includes instrumentation to monitor the values of maximum and minimum loads and loading frequency and to detect failure of the specimen;

d) capable of recording the number of loading cycles during the test.

Loading geometry (ref diagram 1)

The loading force (*F*) of the testing machine was applied in such a way that

a) no lateral constraint occured,

b) the loading centre (Point C), being the intersection of the loading axis (Line AB) with the axis of the endosseous dental implant (Line DE), is well defined.

Schematic of test set-up

The endosseous dental implant was clamped such that its axis makes a 30° ± 1° angle with the loading direction of the testing machine (see Figure 1)

Procedure (Fig 16, 17 ,18)

Thus three implant systems were used namely: Adin Implant System with internal hex(IH), Adin Implant System with morse taper connection(MT) and Equinox Implant System with triconal connection(TC). Six Implant –abutment assemblies were used for each system. Installation torques of 35 Ncm for each abutment was given. The implants were embedded in a custom made jig made according to ISO 14801 standards.

The specimen of each group were subjected to compressive loading in a random order in universal testing machine (Instron model 3345). The jig was used to standardized the position of specimen at the base of the apparatus so that the load could be applied at the angle of 30^{o} in relation to long axis of the implant. The indenter was positioned about 2mm from the edge. Prior to testing, the load cell was calibrated to zero load, Off-axial loading with round terminus was performed with the vertical piston at a rate of 1.00 mm/min and the test commenced by applying a load in displacement control until fracture occurred which was detected by an audible crack and a sudden drop in the force as seen in the graph. An appropriate starting load was 80 % of the load to failure in a static test performed using the same test geometry. The critical failure point and the location of failure initiation were identified. Failure is defined as material yielding, permanent deformation or fracture of any component. A computered generated load-cycle diagram of testing specimens at a series of loads until a lower limit is reached was recorded.

Force versus time data was captured via an attached computer.The test was carried out until the implant fractured or underwent obvious deformation after obtaining the peak load value. Load and displacement values were recorded throughout the loading with Test works (Software Research Inc., San Francisco, CA) computer software. The data were used to create load displacement curves and analyze maximum load levels..

6 Test report (Fig – 19, 20, 21)

In the test report, the following shall be addressed: Specimens were divided into three groups. Prefabricated Titanium Dental Implant Abutments with internal hexagon (Adin dental Implants ltd.Israel) is denoted as (IH), Prefabricated Titanium Dental Implant Abutment with morse taper. (Adin dental Implants ltd.Israel) is denoted as (MT), Prefabricated Titanium Dental Implant Abutment with triconal connection (equinox) is denoted as (TC).

Specimens of each group were subjected to load to fracture in universal testing machine (Instron model 3345) and the maximum load at failure was recorded, tabulated and statistically analyzed.

FIGURES

Fig.1: Prefabricated Titanium Dental Implant with internal hexagon connection. (Adin dental Implants ltd,Israel) (3.75mm diameter, 13mm length

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Fig.2: Prefabricated Titanium Dental Implant Abutment with internal Hexagon connection (Adin dental Implants ltd.Israel) .

Fig.3: Adin dental Implants touareg-s (internal hexagon connection) hex driver.

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Fig.4 **Prefabricated Titanium Dental Implant with morse taper connection (Adin dental Implants ltd,Israel) 3.75mm diameter, 13mm length**

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Fig.5: **Prefabricated Titanium Dental Implant Abutment with morse taper connection (Adin dental Implants ltd.Israel) .**

.

Fig.6: **Adin dental Implants touareg-s (morse taper connection) hex driver.**

Fig.7 Prefabricated Titanium Dental Implant with triconal connection (Equinox Dental Implant myriad plus) 3.8mm diameter, 13mm length

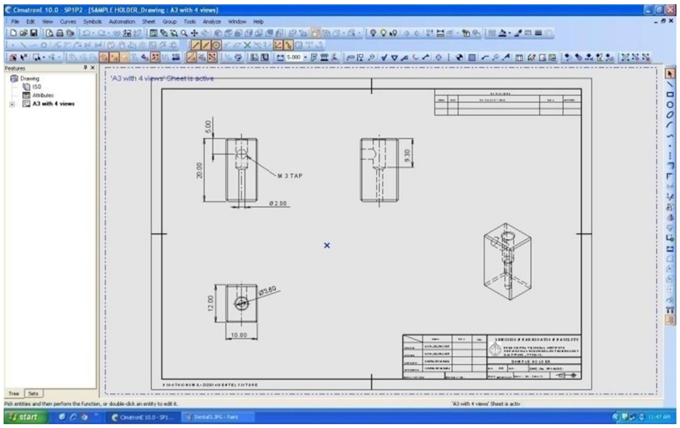
.

Fig.8: Prefabricated Titanium Dental Implant Abutment with triconal connection ((Equinox Dental Implant myriad plus)) .

Fig.9: Equinox dental Implants Myraid plus (triconal connection) hex driver

Fig.10: Adin dental Implants touareg-s (internal hexagon & morse taper connection) Torque rachet.

Fig.11: Equinox Dental Implant myriad plus(triconal connection)Torque rachet.



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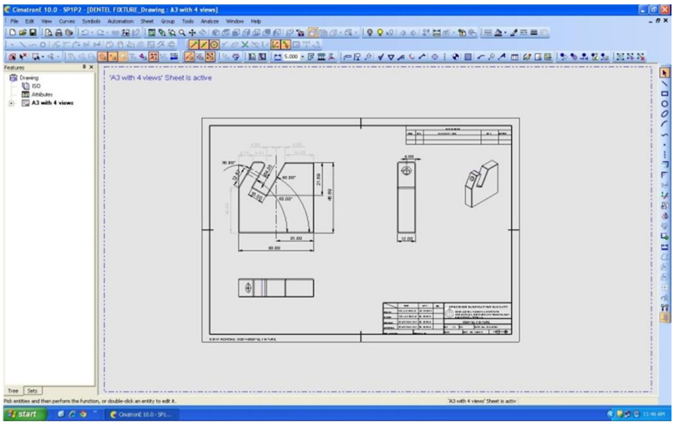

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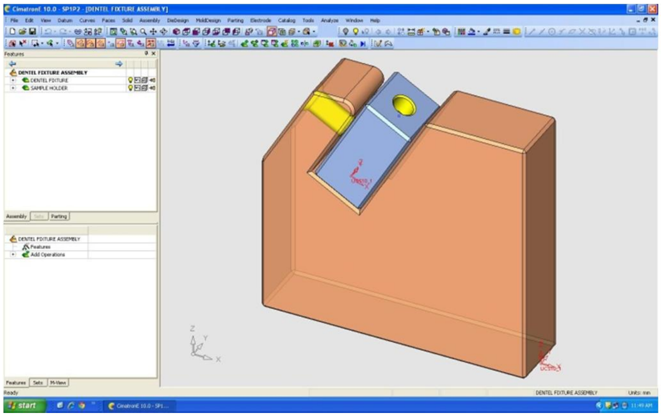

CimatronE 10.0 - SP1P2 - [DENTEL FIXTURE ASSEMBLY]

Fig.12: Line diagram of Custom made stainless jig

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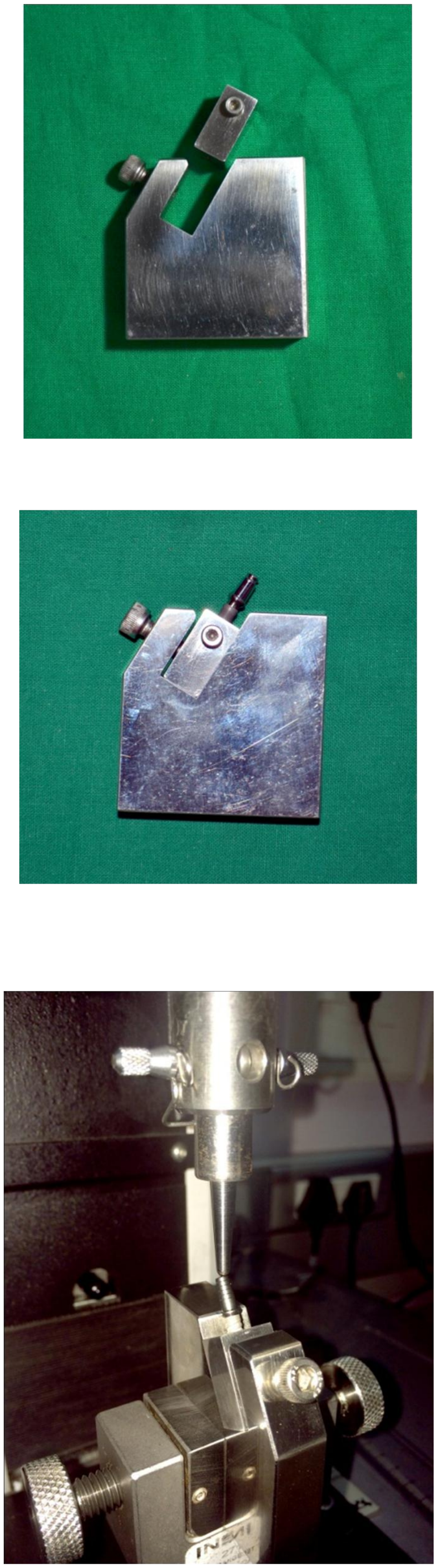


Fig.13 : **Custom made stainless jig which holds the implant unit .**

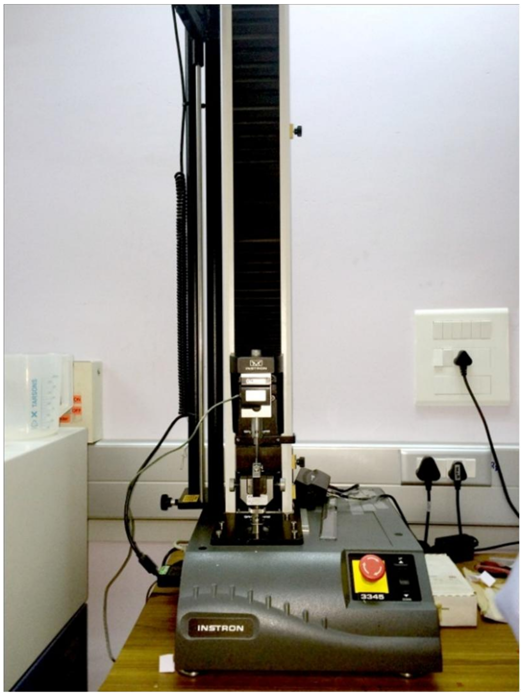


Fig.14: **Custom made stainless jig positioning in static loading machine - instron 3345**

Fig15: **The universal Testing Machine 3345 (Instron model, Instron Copt norwood, Mass).**

Fig16. After loading Adin internal hex implants in UTM 3345 with jig.

Fig.17: After loading Adin Morse taper implants in UTM 3345 with jig.

Fig18: After loading Equinox internal triconal implants in UTM 3345 with jig.

.

Fig.19: Group I test Samples (internal hexagon connection abutment)

Fig.20: Group II test Samples(morse taper connection abutment)

Fig.21: Group III test Samples(triconal connection abutment)

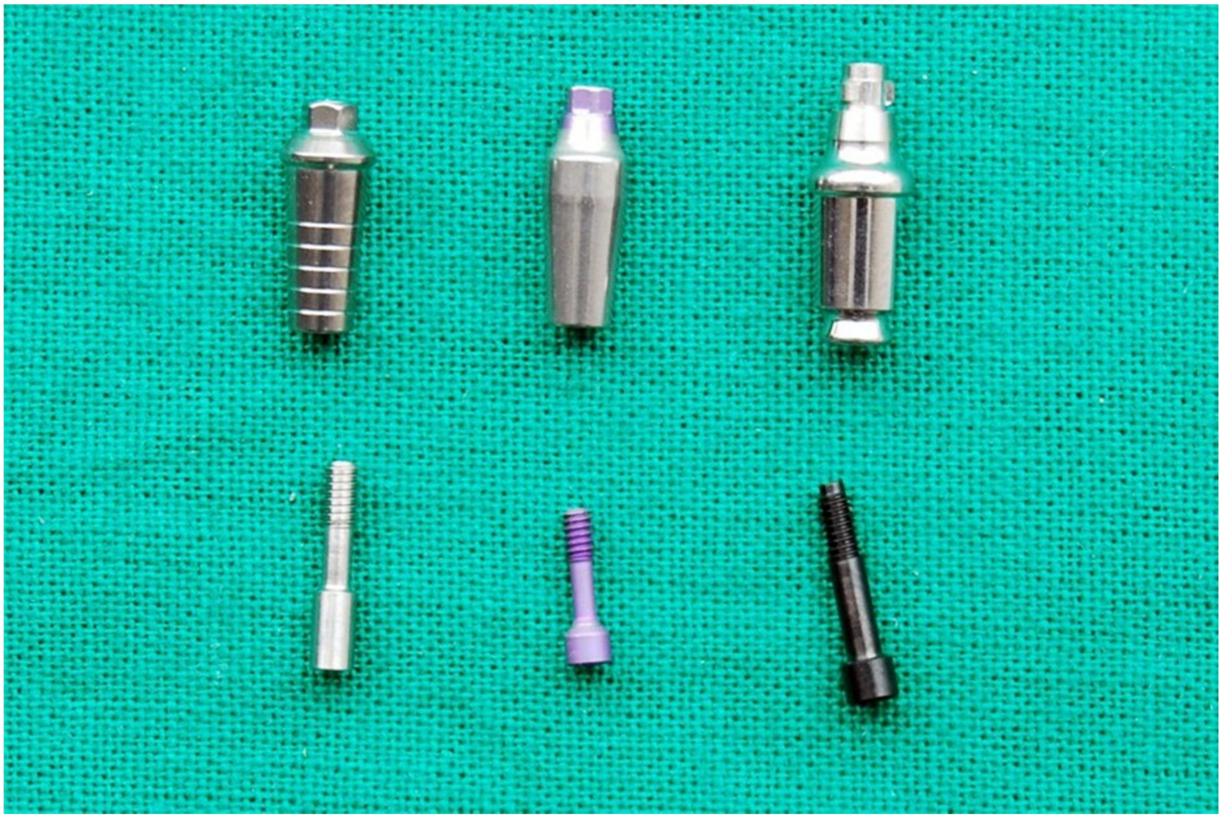


Fig.22: comparasion of three group abutment with their screw.

Results

The data was analyzed using computer software, Statistical Package for Social Sciences (SPSS) version 16.0 (SPSS, Inc. Chicago IL). Data was expressed in its Mean±SD (Standard Deviation). One way ANOVA was applied for analysis. Post Hoc followed by Dunnet t test was used to find statistical significance between and within the groups. P value less than 0.05 ($P<0.05$) consider statistically significant at 95% confidence interval.

Specimens were divided in to three groups. Prefabricated Titanium Dental Implant Abutment with internal hexagon. (Adin dental Implants ltd.Israel) is denoted as (IH), Prefabricated Titanium Dental Implant Abutment with morse taper. (Adin dental Implants ltd.Israel) is denoted as (MT), Prefabricated Titanium Dental Implant Abutment with triconal connection (equinox) is denoted as (TC).

Specimen of each group were subjected to load to fracture in universal testing machine (Instron model 3345) and the maximum load at failure was recorded and tabulated as shown in the tables 1 to 4. The Mean value ±SEM of fracture resistance of groups were calculated from the test values. In group I **Max load (N) values of Group-I (Titanium + Internal hexagon**) showed $MEAN \pm$ SD=410.19 $\pm$11.98 N (TABLE 2) , **Max load (N) values of Group-II (Titanium + Morse taper)** $MEAN \pm$ SD=343.12 $\pm$16.92 N (TABLE 3),AND **Max load (N) values of Group-III (Titanium + Triconal)** $MEAN \pm$ SD=503.87 $\pm$12.19 N (TABLE 5)

Comparison of different internal connection abutment:

Table-2: Max load (N) values of samples of different groups

S. No	**Group-I (Titanium + Internal hexagon)**	**Group-II (Titanium + Morse taper)**	**Group-III (Titanium + Triconal)**
1.	410.36	341.41	510.86
2.	424.27	360.23	490.95
3.	390.12	320.34	520.92
4.	410.34	326.45	510.04
5.	420.13	350.12	500.23
6.	405.94	360.19	490.23
(MEAN±SD)	**410.19±11.98**	**343.12±16.92**	**503.87±12.19**

Table-3: Mean max load (N) of different groups

Groups	Type of material	Max. Load (N) (MEAN±SD)
Group-I	**Titanium + Internal hexagon**	410.19±11.98
Group-II	**Titanium + Morse taper**	343.12±16.92
Group-III	**Titanium + Triconal**	503.87±12.19

Table-4: Comparison of mean Max. Load of Group-I with other groups

Groups	Max. Load (N) (MEAN±SD)	F value	P value
Group-I	410.19±11.98		
Group-II	343.12±16.92*	**1.51**	**0.001**
Group-III	503.87±12.19*	**0.25**	**0.001**

(*P<0.001 significant compared group-I with other groups)

Table-5: Comparison of mean Max. Load of Group-II with other groups

Groups	Max. Load (N) (MEAN±SD)	F value	P value
Group-II	343.12±16.92		
Group-I	410.19±11.98*	**1.51**	**0.001**
Group-III	503.87±12.19*	**0.91**	**0.001**

\(*P<0.001 significant compared group-II with other groups)

Table-6: Comparison of mean Max. Load of Group-III with other groups

Groups	Max. Load (N) (MEAN±SD)	F value	P value
Group-III	503.87±12.19		
Group-I	410.19±11.98*	**0.25**	**0.001**
Group-II	343.12±16.92*	**0.91**	**0.001**

(*P<0.001 significant compared group-III with other groups)

Table -7: Multiple comparison of mean Max. Load of between the groups

Groups	Type of material	Max. Load (N) (MEAN±SD)	F value	P value
Group-I	**Titanium + Internal hexagon**	410.19±11.98		
Group-II	**Titanium + Morse taper**	343.12±16.92*	202.68	0.001
Group-III	**Titanium + Triconal**	503.87±12.19*,#		

(*P<0.001 significant compared group-I with other groups,

#P<0.001 significant compared group-II with other groups)

Table – 8: ANOVA table for comparison between groups

ANOVA					
Comparison	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	78228.083	2	39114.042	202.684	.000
Within Groups	2894.704	15	192.980		
Total	81122.788	17			

Table-9: Post hoc multiple Comparisons test table for comparison

Multiple Comparisons						
Groups						
(I) groups	**(J) groups**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
G-I	**G-II**	67.07000*	8.02040	.000	45.3044	88.8356
	G-III	-93.67833*	8.02040	.000	-115.4440	-71.9127
G-II	**G-I**	-67.07000*	8.02040	.000	-88.8356	-45.3044
	G-III	-160.74833*	8.02040	.000	-182.5140	-138.9827
G-III	**G-I**	93.67833*	8.02040	.000	71.9127	115.4440
	G-II	160.74833*	8.02040	.000	138.9827	182.5140

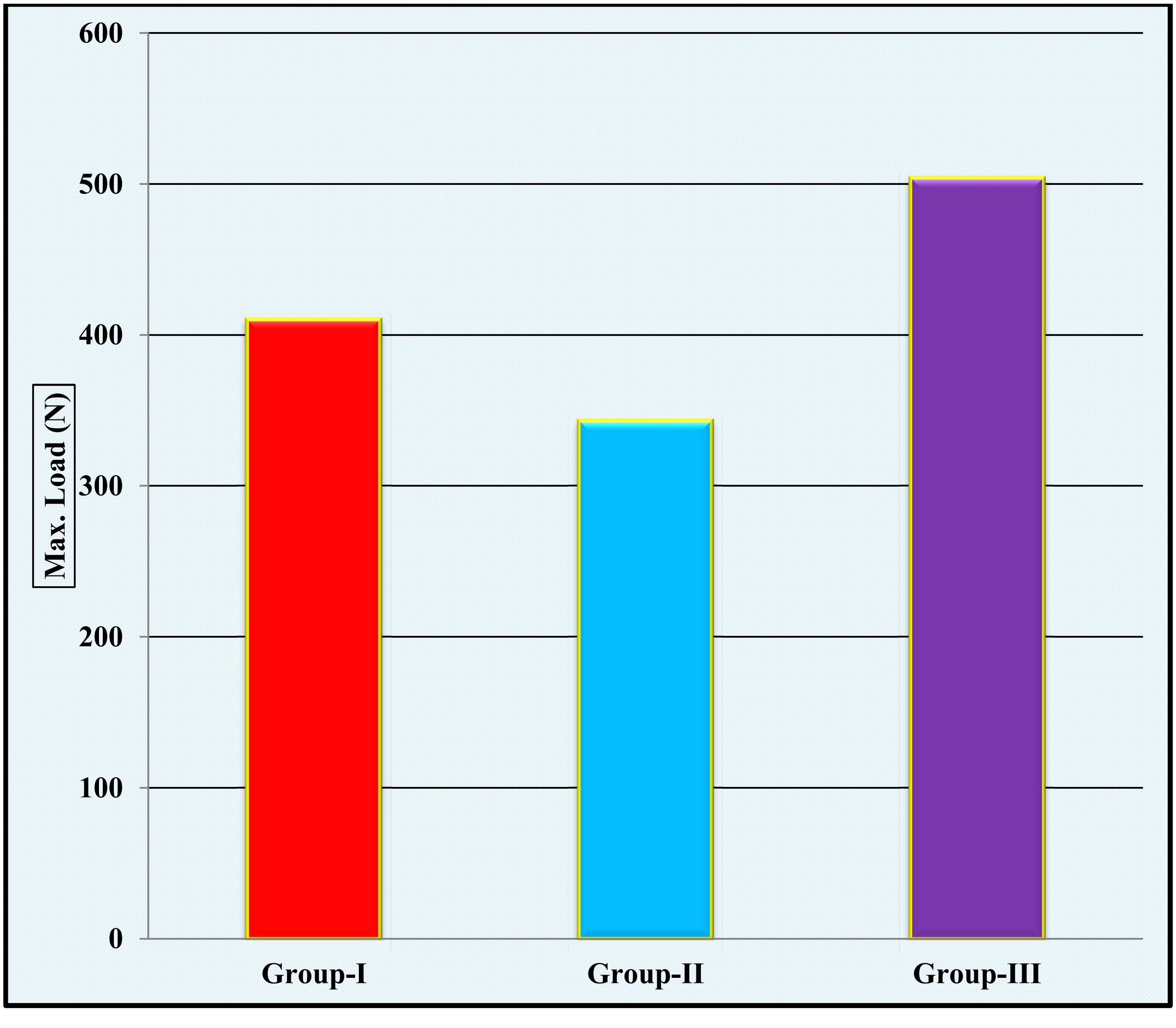
***. The mean difference is significant at the 0.05 level.**

Data normally distributed

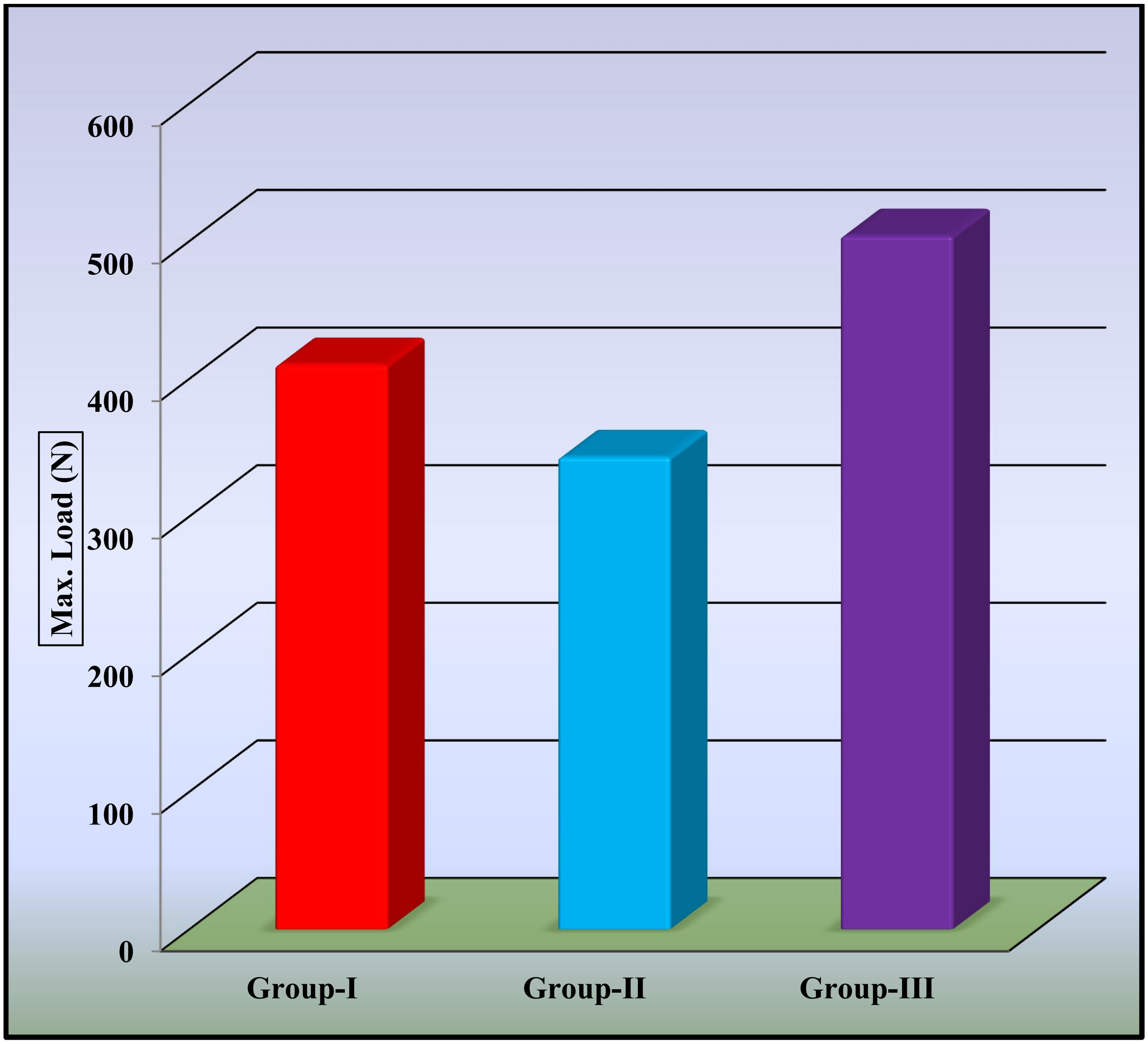
Three groups

The multiple comparisons, multiplicity or multiple testing problems occurs when one considers a set of statistical inferences simultaneously or infers a subset of parameters selected based on the observed values.

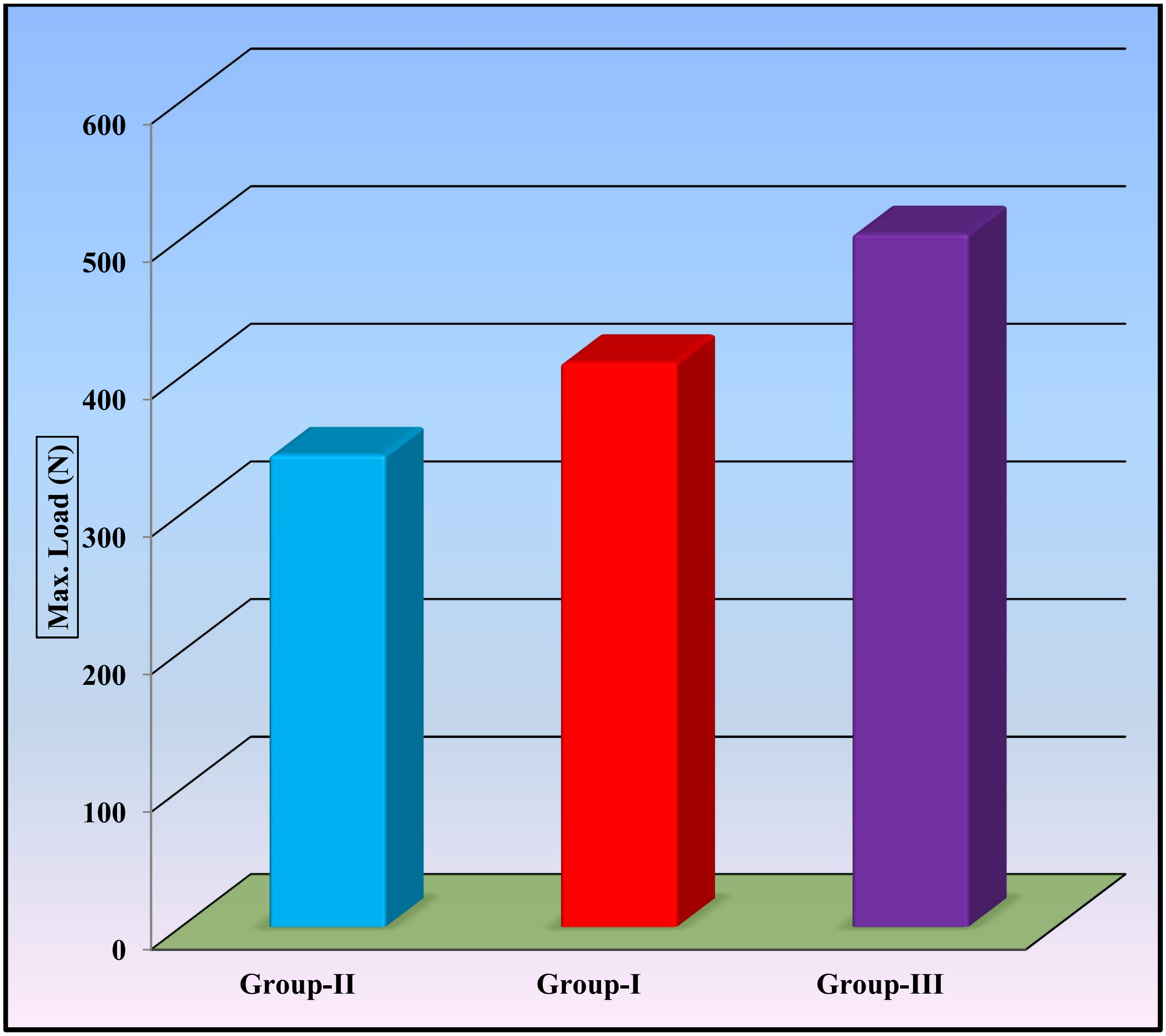
Graph-1: Mean max load (N) of different groups



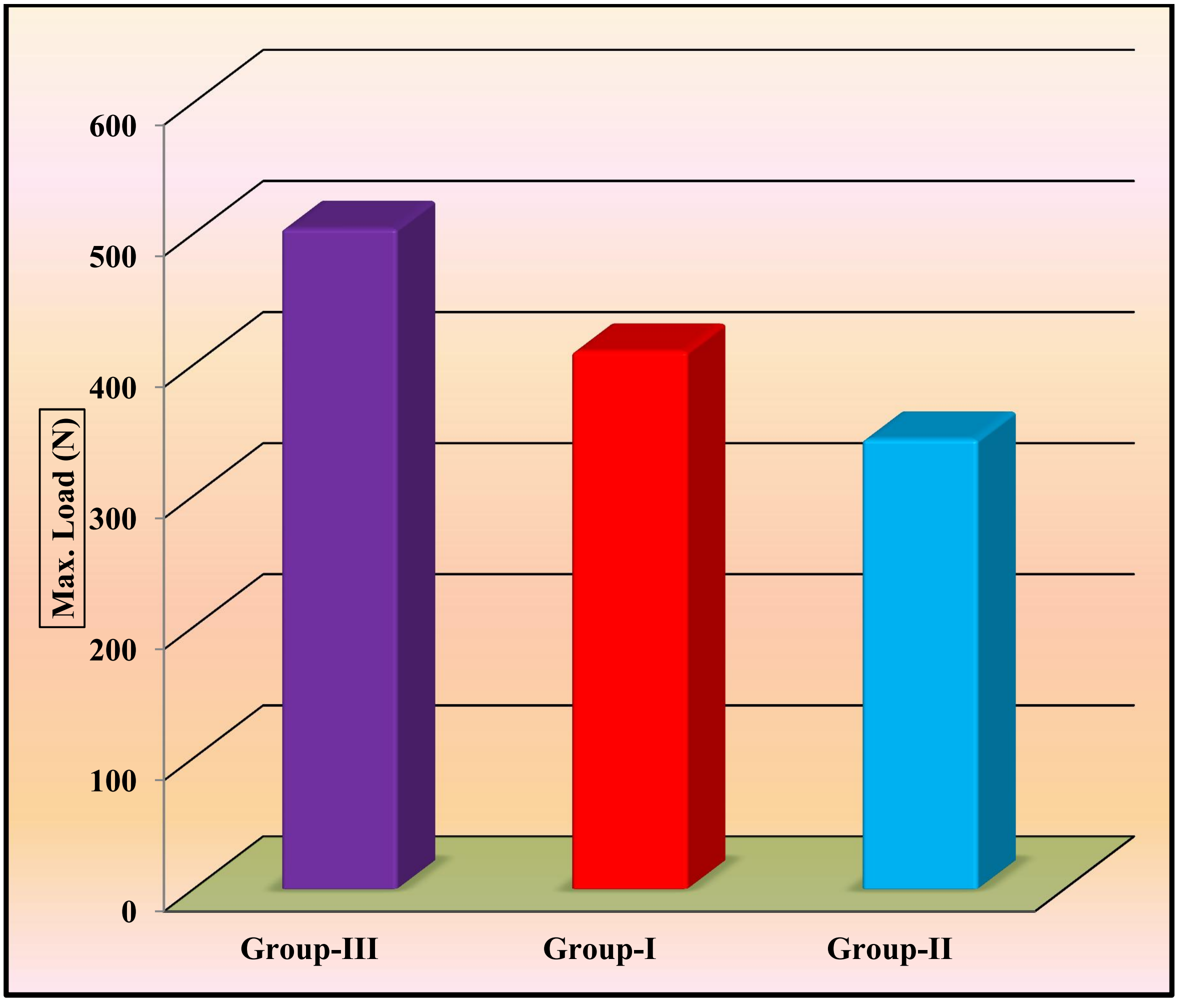
Graph-2: Comparison of mean Max. Load of Group-I with other groups



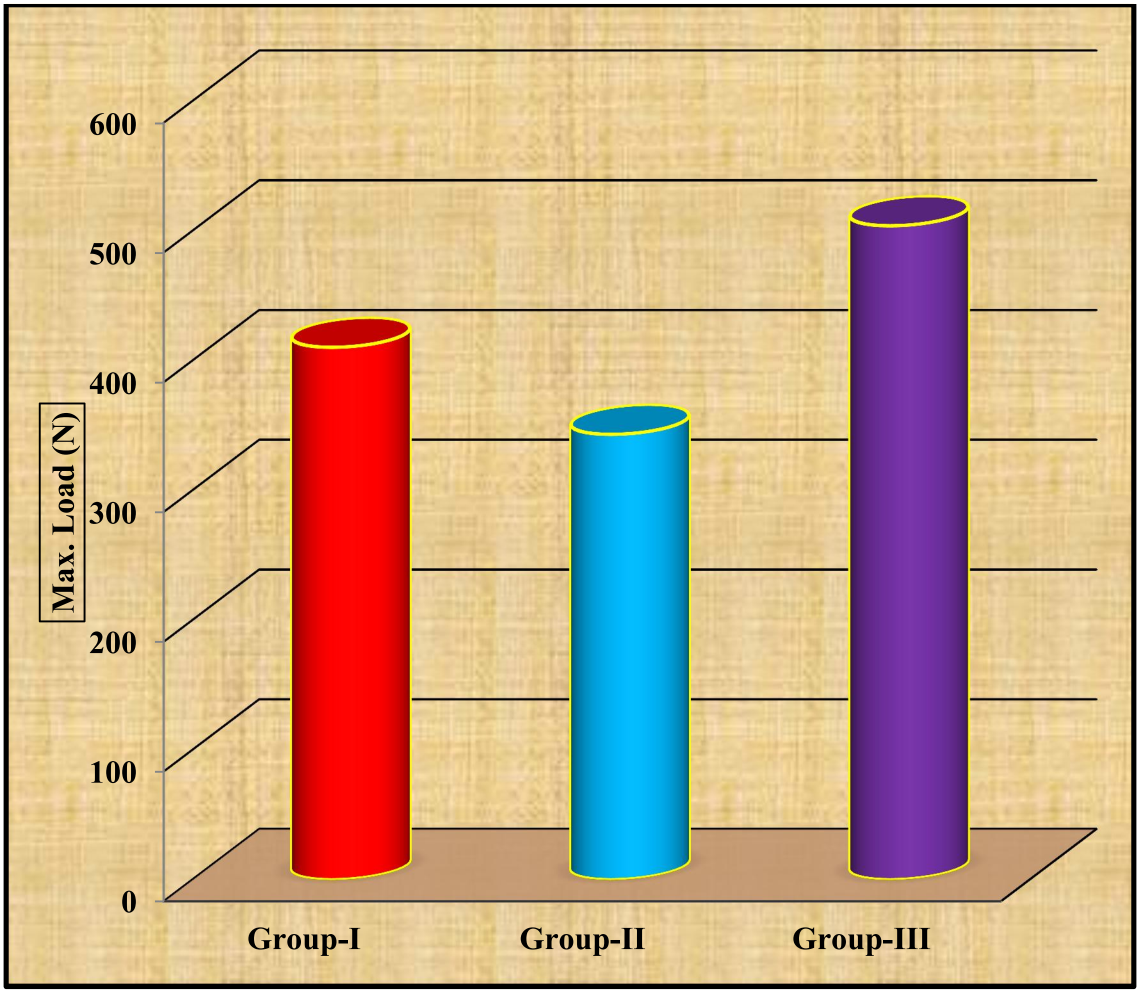
Graph-3: Comparison of mean Max. Load of Group-II with other groups



Graph-4: Comparison of mean Max. Load of Group-III with other groups



Graph-5: Multiple comparison of mean Max. Load of between the groups



Discussion

DISCUSSION

Clinicians should always consider the long-term success of treatment. The potential mode of implant failure is important to consider, even at the treatment planning stage. Patients seeking dental implants often ask about the longevity of dental implant supported prosthesis. Dental implant fracture is one of the most common catastrophic long-term failures. The implant abutment connection design has a significant influence over the ultimate failure resistance of the complex. This design feature includes the geometrical shape of the connecting parts, length of the engaged part of the abutment and the thickness of the thinnest part of the implant collar.

Various geometrical designs for implant abutment connections such as internal/ external hex have been proposed over the decade for clinical use. The implant/abutment interface determines joint strength, stability, and lateral and rotational stability. The main challenge in the development of implant-abutment connection designs relies on reducing or eliminating the incidence of mechanical failures in the implant-prosthetic devices and improving the response of bone and soft tissues. Though it has been proposed that different implant-abutment connections will present advantages and disadvantages in clinical and laboratory practice; connection failure is a common factor. Thus the present study compared the fracture resistance of internal hex, morse taper and triconal connections under static loading.

One of the first internally hexed implants was designed with a 1.7 mm-deep hex below a 0.5-mm wide, 45° bevel . Its features were intended to distribute intraoral forces deeper within the implant to protect the retention screw from excess loading. Internally connected implants also provide superior strength for the implant/abutment connection. Implants designed with Morse taper interface engage their abutments by using a five degree angulated friction fit internal wall into which an abutment with a rounded male extension is placed. The abutments achieve anti rotational properties due to the cold-weld phenomenon that occurs after placing and torquing the abutment. Cold or contact welding is a solid state welding process in which joining takes place without fusion at the interface of the two parts to be welded. Cold welding is defined as an increase in loosening torque with respect to tightening torque. It has been suggested that this might occur and result in lack of retrievability, which is inherent in the 3-component system of the external hex design. The cone screw tapered connection originated with the ITI group in Switzerland (ITI Straumann). Although the connection is called a “Morse” taper, the mating angle between component parts is 8 degrees. A true Morse taper exist at 2 degree and 4 degree and has unique self-locking characteristic without threads. Interference fit components are free of displacement upon function. More significantly, such interfaces are also geometrically locked against potential displacement that results from functionally imposed bending movements. The combined interference from rotational displacement, the high surface area, and the geometric constraint to displacement from lateral loads creates an implant/abutment interface that is largely free of micro motion and resistant to clinical prosthetic complication or failure. Studies which compared the fatigue resistance and strength of morse taper or internal conical connection with hex mediated butt joint revealed that morse taper connection were significantly better regardless of taper angulations (11º or 8º) [2,6,9,24,29.30,31.] Conversely, only one recent study by Ribeiro CG et al [60] comparing the fatigue resistance of three implant-abutment interfaces (EH, IH, and MT), showed that EH presented significantly higher fatigue resistance than IH and MT. In the present study morse taper abutments ($P < 0.001$) showed least fracture resistance when compared to internal hex and triconal connections. This finding is in contrast to the results of the previous studies. Ablio et al studied the fracture resistance of the implant-abutment connection in implants with internal hex and internal conical connections under oblique compressive loading. Maximum deformation force for IC implants (90.58 ± 6.72 kgf) was statistically higher than that for IH implants (83.73 ± 4.94 kgf) (P = .0182). They concluded that friction-locking mechanics and the solid design of the IC abutments provided greater resistance to deformation and fracture under oblique compressive loading when compared to the IH abutments

Perriard J et al studied the fatigue resistance of the standard cone with a novel internally keyed design concluded that morse taper connection provides greater resistance to deformation and fracture than internal hexagon. Another study by Lucas S. Machado et al observed the reliability and failure modes implant-abutment connection designs (external hexagon (EH), internal hexagon (IH), and Morse taper (MT) connection) for anterior crowns. Abutments were screwed to the implants, and maxillary central incisor metal crowns were cemented and subjected to step-stress accelerated life testing. The characteristic strength was not significantly different between EH (290 N) and IH (251 N) but significantly higher for MT (357 N). They concluded that reliability was higher for the EH and MT relative to IH groups, whereas the characteristic strength was significantly higher for implants with MT connection.

Triconal connection incorporates an audible and tactile “click” when the components are properly seated. This unique feature eases placement for the clinician and may reduce the need for radiographs following placement of the restorative components. The implant's internal connection allows 4 mm of internal engagement, with contact along a significant length that provides lateral stability from off-axis forces. The deep, 4mm multilevel engagement zone of this internal connection achieves a precise, secure connection with low torque. No more than 20 Ncm is required to maintain screw retention without loosening. The design of the internal connection allows the height of the screw to be only 1.95 mm from the top of the screw to the seating surface, allowing flexibility in abutment preparation without damaging the head of the screw. This internal connection design incorporates a 6-point hex and a 12-point , double-hex internal design. The 6-point internal hex provides a stable base for the use of straight abutments. The 12-point, double-hex of the internal connection allows 30-degree increments of rotational flexibility for placement of machined pre angled abutments to correct the off-axis emergence of the implant. Interestingly the connection design of equinox implant system has (TC) triangular connection design with the thin rim connection at the apex makes it stable. The myriad –plus system feature the tri-cone 17 degree internal cone abutment connection. The conical connection from an engineering perspective is one of the most stable mechanical implant abutment connections. The tricone three position internal indexing allows for torque transfer during implant placements as well as facilitates indexing for crown and bridge abutments. The tri-cone conical connection provides a zero micromotion solid connection that virtually removes the risk of screw lossening and subsequent breakage. The tight bacteria proof seal minimizes stress induced resorption in the marginal bone by optimally distributing load and ensures inflammation free and healthy peri-implant soft tissue. Studies comparing the fracture/fatigue resistance of triconal connection with other implant abutment connection designs were none (as per the author’s knowledge). So it did not allow for comparison of results with other studies. In the present study triconal connections showed higher resistance to fracture when compared to internal hex and morse taper which was statistically significant ($p< 0.001$).

Implant-abutment connection could be a controlling factor when it comes to the location of fracture, the mode of the fracture and the possible fracture resistance of a particular abutment. Previous study by Sailer et. al. concluded that the type of connection significantly influenced the strength of zirconia abutments. Essentially the implant's internal or external connection geometry controls the abutment design in terms of morphology and dimensions. Thus the configuration of an abutment that is designed to fit a shorter internal hex is quite different than one that is designed to fit an implant with a conical internal connection or an external connection. For example, in a previous study by Adita et.al where they tested the fracture strength of zirconia abutment with a conical connection, the force values and the fracture mode were different. The fracture location seemed to be comparable to this study where the fracture occurred at the thinnest portion of the abutment at the abutment-implant interface. In this study an internal shorter hex implant was used, not only did the hex portion break off but the portion slightly above the implant platform also broke off in majority of the samples. This could be attributed to the geometrical differences between the abutment designs due to the implant-abutment connection differences. It is important to note that the same study did not use a full crown on the abutment but the force values were higher than the force values obtained in this study. Again this could be because of the difference in stress transfer mechanism from the abutment on to the implant from one connection design to the other.

Merz et.al elaborated on the merits of conical connections and suggested that in conical connection, lateral loading is resisted mainly by the taper interface, which prevents the abutment from titling off, even when the connection between the taper section and the hex of the abutment is lost, for example because of a fracture. In another comparable study where they examined the fracture resistance of zirconia abutment using abutments with conical connection, the force values for the straight and the angulated abutment came out higher than the force value in this study which again leads to the speculation that the abutment with long conical connections may outperform abutments with short hexagonal connection in terms of fracture strength. The fracture location in the above mentioned study was much below the implant platform in the region of the internal hexagon where the abutment is thinnest. This is different from the fracture location in this study, which was either at the hex or both at the hex portion and slightly above the platform. Thus the commonality of this study and the previous studies is that in all the studies the fracture location is always at the weak portion of the abutment where it is the thinnest, but the location and the fracture strength varied from one study to another.

Dental implants vary in material, dimension, geometries, surface properties and interface geometry, so today the dentists needs to select from more than 2000 different dental implants and abutments in a specific treatment situation. Certain manufactures alone offer more than 100 different implants in varying shapes and materials. Other manufactures focuses on significant advantages in implant In addition to the implant size and design the type of metal used to manufacture the implant must be taken into consideration. Implant abutments made up of commercially pure titanium are well documented to be bio compatible and have sufficient mechanical property to support long term fixed implant supported dental prostheses. The fatigue limit and the ultimate tensile strength of both titanium and titanium alloy are related. Under fatigue testing, titanium and titanium alloy specimen fractures approximately after 106 load cycles at 50% of the ultimate force required to break the same specimen under static loading. Previous studies and laboratory investigation have demonstrated this relationship between titanium ultimate fracture/fatigue strength. Kadir Firidinog lu et all studied the fracture resistance and analysis of stress distribution of implant-supported single zirconium ceramic coping combination with abutments made of different materials , and concluded that fracture resistances for titanium and zirconium abutment groups were 525.65 N and 514.05 N, respectively.In the present study, all the samples employed were made of titanium.

Fatigue testing is considered to be the most accurate test to produce data of clinical relevance. However, according to general engineering principles and laws of mechanics, using static loading tests can also generate clinical relevant data.

Although in-vitro studies should be as clinical relevant as possible and use standardized specimen, the present study present study was designed to limit the variables solely to the abutment materials. Therefore the crown was not made which should be commonly placed clinically [1,7,11,14] .Although most clinical failure results from fatigue loading , static loading test may model situation such as a person occluding into a hard object or receiving trauma to the implant abutment complex[12] . Static loading [15,16,18,20,27,28,41,42,43,45.46.47.48,49,50]as used for testing in the current study is the most definitive method to determine the load capacity (maximum allowable load) of the restoration. In-vitro testing on implant abutment to failure provides valuable information regarding the design engineering and is recommended for future research and development.

Limitation of this study was that it was an in vitro study and result obtained may not be comparable to in-vivo situations. In order to the limit the variables solely to the abutment materials, present study was designed not to include the superstructure crown which would be commonly placed clinically. Whether inclusion of crown would alter the outcome of the result was not known. Lastly, the present study did not employ cyclic loading testing which is considered to be the most accurate test to produce data of clinical relevance. Future scope would be to evaluate the fracture resistance of implant abutment connections using a larger sample size and under cyclic loading testing.

The requirements for an optimal implant abutment connection can be summarized as follows:-
The misfit between abutment and implant interface has many clinical implications such as:

abutment overload, screw loosening or fracture of abutment or even of the implant itself, incorrect transmission of force to implant and marginal bone and microbial proliferation. These factors can lead to a persistent inflammation around peri-implant tissue. It is important to say that the force applied in torque tightening the screw is only valid ,if the machining and adjustment degree between abutment and implant were proper because high levels of tightening torque will be achieved if only the components mortise perfectly. Decisions regarding dental implant abutments are essential aspects of clinical dental implant excellence.[10, 9, 29,31,32,37]

Summary and Conclusion

SUMMARY

The present In-Vitro study was conducted to comparatively evaluate the fracture resistances of different pre-fabricated implant abutments.

This study used eighteen implants of three different implants systems; Adin Implant System with internal hexagon(IH), Adin Implant System with morse taper connection(MT) and Equinox Implant System with triconal connection(TC). Six Implants –abutment assemblies where used for each system. Installation torques of 35 Ncm for each abutment were given, according to manufacture's instruction. The implants were embedded in a stainless steel custom made jig made according to ISO 14801 standards, where the platform of the test implants were 3.0mm away from the surface to simulate bone loss and also to hold at 30 degree angulation. Universal testing machine was used to load all the specimens at a cross head speed of 1mm/min. The maximum load was recorded and used as the failure load. The load (N) at which fracture occurred were tabulated and statistically analyzed.

For successful restoration, dentists need knowledge and understanding of the different materials and products available on the market and their behavior. Strength, elastic behavior and bond capacity to coverage materials of implant-prosthetic abutments will determine their survival rate in the mouth. Furthermore, a detailed study of abutment fracture pattern could be beneficial to improve the abutment design.

Testing an implant abutment to failure provides valuable information to the design engineer and is recommended prior to designing the foundation.

CONCLUSION

An In-Vitro study was conducted to comparatively evaluate the fracture resistances of different pre-fabricated implant abutments. Within the limitations of the study the following conclusions were drawn:

1. The mean Fracture Resistance of Internal hexagonal abutment at static loading was found to be 410.19±11.98 N
2. The mean Fracture Resistance of morse taper abutment at static loading was found to be 410.19±11.98 N
3. The mean Fracture Resistance of triconal abutment at static loading was found to be 503.87±12.19 N
4. Statistically significant difference in the mean values was observed in the fracture resistance between internal hexagon and morse taper connections. The fracture resistance of internal hex was higher than morse taper connection.
5. Statistically significant difference in the mean values was observed in the fracture resistance between internal hexagon and triconal connection. The fracture resistance of triconal connection was higher than internal hexagon connection.
6. Statistically significant difference in the mean values was observed in the fracture resistance between triconal and morse taper connection. The fracture resistance of triconal connection was higher than morse taper connection. .
7. On overall comparison, the mean fracture resistance of triconal abutments was slightly higher than hexagonal abutment and morse taper connections and this difference was statistically significant. **(*P<0.001 significant while comparing group-I with other groups, $^{\#}$P<0.001 significant while comparing group-II with other groups).**

Bibliography

BIBLIOGRAPHY

1. **Asbjorn J,Urs Braegger, John BB et all,** Quality of Dental Implants. The International Journal of Prosthodontics, vol 17, number 6, 2004;607-641.

2. **Huang H-M, Tsai, C.-M., Chang, C.-C., Lin, C.- T. & Lee, S.-Y**. Evaluation of loading conditions on fatigue-failed Implants by fracture surface analysis. International Journal of Oral & Maxillofacial Implants 2005;20: 854–859.

3. **Rudi C. Van Staden , Hong Guan , Yew-Chaye Loo , Newell W. Johnson & Meredith Nell** Comparative analysis of internal and external hex.crown connection systems - a finite element Study.J. Biomedical Science and Engineering, 2008, 1, 10-14.

4. comparative measurement of fracture resistance of various kind internal connection systems. presented at the 20th annual scientific meeting of the european association of osseointegration 10-13 October 2012, Copenhagen, Denmark.

5. **Donna m. hacker, dads, ms, Steven e. eckert, dds, ms, and Yong-geun choi, dds**, cyclic loading of implant-supported prostheses: Comparison of gaps at the prosthetic-abutment interface when cycled abutments are replaced with as-manufactured abutments. the journal of prosthetic dentistry volume 95 number 1, page no 26- 32.

6. **Ameen Khraisat, DDS, Roxana Stegaroiu, DDS, PhD,Shuichi Nomura, DDS, PhD,andOsamu Miyakawa, BE, PhD**,Fatigue resistance of two implant/abutment joint designs.J Prosthet Dent 2002;88:604-10.

7. **Tsunemichi Kanbara, Yasutomo Yajima and Masao Yoshinari.**Wear behavior of tetragonal zirconia polycrystal versus titanium and titanium alloy. iop publishing ,biomedical materials, published 11 march 2011.

8. INTERNATIONAL STANDARD; Dentistry — Fatigue test for endosseous dental implants ISO 14801:2003.

9. **Lucas S. Machado, DDS, MS, Estevam A. Bonfante, DDS, MS, PhD,. Rodolfo B. Anchieta, DDS, MS,Satoshi Yamaguchi, PhD and Paulo G. Coelho, DDS, BS, MS,, PhD**
implant-abutment connection designs for anterior crowns: reliability and failure modes. implant dentistry / volume 0, number 0 2013.

10. **Manoj shetty , Krishna prasad d. ,Naresh h. G. Shetty & Raghavendra jaiman**.Implant abutment connection: biomechanicalPerspectives,(nitte university journal of health science, nujhs vol. 4, no.2, june 2014.)

11. **Jamie K. W. Foong, BDSc, DCD, Roy B. Judge, BDS, LDS, RCS,MDSc, PhD, Joseph E. Palamara, BDSc, PhD,and Michael V.Swain, BSc, PhD.** Fracture resistance

of titanium and zirconia abutments: An in vitro study. (J Prosthet Dent 2013;109:304-312).

12. **Jae Seon Kim, DDS, Ariel J. Raigrodski, DMD, MS, Brian D. Flinn, PhD, Jeffrey E. Rubenstein, DMD, MS,Kwok-Hung Chung, DDS, PhD,and Lloyd A. Mancl, PhD.** In vitro assessment of three types of zirconia implant abutments under static load. (J Prosthet Dent 2013;109:255-263).

13. **Declan Byrne, MSc, Frank Houston, BDS, Richard Cleary, MSD, and Noel Claffey,Dent.**the fit of cast and premachined implant abutments. The journal of prosthetic dentistry volume 80 number 2.

14. **Kadir lu,Suna Toksavul,Muhittin Toman,Mehmet Sarıkanat, and I˙ Firidinog brahim Nergiz.** Fracture Resistance and Analysis of Stress Distributionof Implant-Supported Single Zirconium Ceramic CopingCombination with Abutments Made of Different Materials*Journal of Applied Biomechanics*, 2012, 28, 394-399.

15. **Spiridon-oumvertos koutayas, CDT,DDS, Dr Med Dent et all**. Influence of preparation mode and depth on the fracture strength of zirconia ceramic abutments restored with lithium disilicate crowns.Int J Oral Maxillofac Implants 2012;27;839-848.

16. **Gehrke Peter, Gunter Dhom,Wolf Dietrich** et all, Effect of cyclic loading on zirconia abutment screw loosening. presented at the14 annual scientific meeting of the european association of osseointegration , sep 22-24 2005, munich ,Germany.

17. **Peter Gehrke/Günter Dhom/Jochen Brunner/Dietrich Wolf/Marco Degidi/Adriano Piattelli** Zirconium implant abutments: Fracture strength and influence of cyclic loading on retaining-screw loosening. (Quintessence Int 2006;37:XX–XX).

18. **Neil Meredith , Fredrik Engman et all.**Survival rate, fracture resistance and mode of failure of titanium implants in clinical function and dynamic loading. Applied Osseointegration Research - Volume 6, 2008.

19. **F. Butz, G. Heydecke, M. Okutan & J. R. Strub** .Survival rate, fracture strength and failure mode of ceramic implant abutments after chewing simulation. Journal of Oral Rehabilitation 2005 32; 838–843.

20. **Luigi Canullo, Paulo G Coelho et all.**Mechanical testing of thin-walled zirconia Abutments. J Appl Oral Sci,2013;21(1);20-4.

21. **Rocio Velázquez-Cayón, Cristina Vaquero-Aguilar et all .** Mechanical resistance of zirconium implant abutments: A review of the literature. Med Oral Patol Oral Cir Bucal. 2012 Mar 1;17 (2):e246-50.

22. **Joerg R. Strub, DMD, PhD Thomas Gerds, Dipl Math,.et all.,** .Fracture Strength and Failure Mode of Five Different Single-Tooth Implant-Abutment Combinations. Int J Prosthodont 2003;16:167–171.

23. **Eun-Sook Kim, DDS, MS, Soo-Yeon Shin*, DDS, MS, PhD.,**Influence of the implant abutment types and the dynamic loading on initial screw loosening. J Adv Prosthodont 2013;5:21-8.

24. **Abílio Ricciardi Coppedê, DDS, MSca/Edmilson Bersani, DDS, MSc et all**.,Fracture Resistance of the Implant-Abutment Connection in Implants with Internal Hex and Internal Conical Connections Under Oblique Compressive Loading: An In Vitro Study. Int J Prosthodont 2009;22:283–286.

25. **Norton MR.** An in vitro evaluation of the strength of an internal conical interface compared to a butt joint interface in implant design. Clin Oral Implants Res 1997;8:290-8.

26. **Mollersten L, Lockowandt P, Linden LA**. Comparison of strength and failure mode of seven implant systems: an in vitro test. J Prosthet Dent997;78:582-91.

27. **Francisco Martinez-Rus DDS, Alberto Ferriroa DDS et all .**Fracture strength and failure mode of maxillary implant- supported provisional single crown ; a comparison of

composite resin crowns fabricated directly over peek abutments and solid titanium abutments.Clinical implant dentistry and related research, voiume14, number 6, 2012.

28. **Rubén Agustín-Panadero, Blanca Serra-Pastor, Ana Roig-Vanaclocha, Juan-Luis et all.**
Mechanical behavior of provisional implant prosthetic abutments**.** Med Oral Patol Oral Cir Bucal. (2014), doi:10.4317/medoral.19958.

29. **Binon PP**. Implants and components: Entering the new millennium. Int J Oral Maxillofac Implants 2000;15:1;76-94

30. **Izabela Cristina Maurl′cio Moris, MSc, Adriana Cla′udia Lapria Faria, PhD, Maria da Gloria Chiarello de Mattos, PhD**.Mechanical analysis of conventional and small diameter conical implant abutments. J Adv Prosthodont 2012;4:158-61.

31. Beat R. Merz, Dr sc techn, MBA/Stephan Hunenbart, Dipl Eng TU/ Urs C. Belser, DMD, Prof Dr med dent,Mechanics of the Implant-Abutment Connection:An 8-Degree Taper Compared to a Butt Joint Connection Mechanics of the Implant-Abutment Connection: An 8-Degree Taper Compared to a Butt Joint Connection . (int j oral maxillofac implants 2000;15:519–526).

32. **Dincer Bozkaya, Sinan Muftu. Et all**.Mechanics of the tapered interference fit in dental implants. Journal of Biomechanics 36 (2003) 1649–1658.

33. **Lars Steinebrunner,Stefan Wolfart,Klaus Ludwig,Matthias Kern et all.**Implant–abutment interface design affects fatigue and fracture strength of implants. Clin. Oral Impl. Res. 19, 2008; 1276–1284.

34. **Irena Sailer, Dr med Dent,Thomas sailer et all**., In Vitro study of the influence of the type of connection on the fracture load of zirconia abutments with internal and external implant- abutment connections. int j oral maxillofac implants,vol 24 no 5 2009.

35. **Y. Maeda, T. Satoh & m.** SOGO etall,.In vitro differences of stress concentrations for internal and external hex implant–abutment connections: a short communication. Journal of Oral Rehabilitation 2006 33; 75–78.

36. **Amilcar C. Freitas Jr,Estevam A. Bonfante,Leandro M. Martins et all .**Reliability and failure modes of anterior single-unit implant-supported restorations. Clin. Oral Implants Res. 23, 2012 / 1005–1011.

37. **Cleide gisele ribeir1, maria luiza cabral maia, usanne s. scherrer3, antonio carlos et all,.** Resistance of three implant-abutment interfaces to fatigue testing. j appl oral sci. 2011;19(4):413.

38. **Amilcar C. Freitas-Junior,Erika O. Almeida,Estevam A. Bonfante,Nelson R.F.A. ilva,Paulo G. Coelho** .,Reliability and failure modes of internal conical dental implant connections. Clin. Oral Impl. Res. 24, 2013, 197–202.

39. **Ameen Khraisat, BDS, PhD**.,Stability of Implant-Abutment Interface with a Hexagon-Mediated Butt Joint: Failure Mode and Bending Resistance . Clinical Implant Dentistry and Related Research, Volume 7, Number 4, 2005.

40. **Charles J. Goodacre, DDS, MSD,a Joseph Y.K. Kan, DDS,b and Kitichai ,ET ALL. , Clinical complications of osseointegrated implants.** (J Prosthet Dent 1999;81:537-52.)

41. **Yilidrim m ,Fisher h, et all** , In vivo fracture resistance of implant supported all ceramic restoration, j prostho dent 2003;90;325-331.

42. **Butzf, Heydeckeb G, Okutan m, et all,.** Survival rate, fracture strength and failure mode of ceramic implant abutments after chewing stimulation, J Oral rehabilitation 2005 ;32;832-843.

43. **Att W, kurum s Gerds t , strub j** ., fracture resistance of single –tooth implant supported all ceramic restorations: an in vitro study,. J Prosthet Dent 2006:111-116.

44. **Att W, kurum s Gerds t , strub j** ., fracture resistance of single –tooth implant supported all ceramic restorations after exposure to artificial mouth. J Oral Rehabil 2006:33:380-386.

45. **Aramoni P, Zeboni E et all** .Fracture resistance and failure location of zirconia and metallic implant abutments,J Contemp Dent Pract 2008;9;41-48.

46. **Adatia ND, B ayne SC, cooper LF, Thompson JY**. Fracture Resistance Of Yttrium-Stabilized Zirconia Dental Implant Abutments. J Prosthodont 2009;18; 17-22.

47. **kim s , kim hi, brewer JD, Monaco EA et all**., Comparision of fracture resistance of pressable metal ceramic custom implant abutments with CAD/CAM commercially fabricated zirconia implant abutments.J prostho Dent 2009; 101;226-230.

48. **Mitsis ME, Saliva NR, Pines M ,Stappert C et all** ., Reliability and fatigue damage modes of zirconia and titanium abutments . Int J Prosthodont 2010 ;23;56-59.

49. **Dittmer MP, Dittmer S, Borchers L, Kohorst P, Stiesch M.et all.,** G.influence of the interface design on the abutment complex before and after cyclic mechanical loading. J Prosthodont Res. 2012;56:19-24.

50. **Kohal RJ, Wolkewitz M, Tsakona A et all .** The effects of cyclic loading and preparation on the fracture strength of irconiumdioxide implants: an *in vitro* investigation. Clin Oral Implants Res. 2011;22:808-14.

51. **Adell, R., Lekholm, U., Rockler, B., & Branemark, P.I. (1981).** A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *International Journal of Oral Surgery, 10,* 387–416.

52. **Marinello, C.P., Meyenberg, K.H., Zitzmann, N., Luthy, H.,Soom, U., & moberdorf, M. (1997).** Single tooth replacement some clinical aspects. *Journal of Esthetic Dentistry, 9,* 169–178.

53. **Israel M. Finger et al**; The evolution of external and. Internal implant/abutment connections; Pract Proced Aesthet Dent 2003;15;8:625-632

54. **Norton MR**. An in vitro evaluation of the strength of an internal conical interface compared to a butt joint interface in implant design. Clin Oral Implants Res 1997;8:290-8.

55. **Mollersten L, Lockowandt P, Linden LA**. Comparison of strength and failure mode of seven implant systems: an in vitro test. J Prosthet Dent 1997;78:582-91.

56. **Rangert B, Krogh PH, Langer B, Van Roekel N.** Bending overload and implant fracture: a retrospective clinical analysis. Int J Oral Maxillofac Implants 1995;10:326-34

57 . **Levine RA, Clem DS 3rd, Wilson TG Jr, Higginbottom F, Solnit G.** Multicenter retrospective analysis of the ITI implant system used for single-tooth replacements: results of loading for 2 or more years. Int J Oral Maxillofac Implants 1999;14:516-20.

58 . **Levine RA, Clem DS 3rd, Wilson TG Jr, Higginbottom F, Saunders SL**. A multicenter retrospective analysis of the ITI implant system used for singletooth replacements: preliminary results at 6 or more months of loading. Int J Oral Maxillofac Implants 1997;12:237-42

59**.** **Pessoa RS, Muraru L, Júnior EM,et al**. Influence of implant connection type on the biomechanical environment of immediately placed implants CT-based nonlinear, three-dimensional finite element analysis. Clin Implant Dent Relat Res. 2010;12:219–234.

60**.** **Ribeiro CG, Maia ML, Scherrer SS, et** al. Resistance of three implant-abutment interfaces to fatigue testing. J Appl Oral Sci. 2011;19:413–420.

61. **Sutter f weber et all** .The new restorative concept of the ITI dental implant system: design and engineering, international journal of periodontics and restorative dentistry.13:409-431

62. **Perriard J, Wiskott WA, Mellal A, Scherrer SS, Botsis J, Belser UC**. Fatigue resistance of ITI implant-abutment connectors – a comparison of the standard cone with a novel internally keyed design. Clin Oral Implants Res 2002;13:542-9.