|| ISSN(online): 2589-8698 || ISSN(print): 2589-868X ||
International Journal of Medical and Biomedical Studies
Available Online at www.ijmbs.info
PubMed (National Library of Medicine ID: 101738825)
Index Copernicus Value 2018: 75.71
Original Research Article
Volume 3, Issue 8; August: 2019; Page No. 117-124

INFLUENCE OF DIFFERENT IMPLANT ABUTMENT CONNECTION DESIGNS ON ABUTMENT SCREW LOOSENING IN DENTAL IMPLANT SYSTEMS – A SYSTEMATIC REVIEW.

Dr. Prerna N Kulkarni[1], Dr. Nilesh S Bulbule[2], Dr. Dilip M Kakade[3], Dr. Shalu S Mondal[4], Dr. Akanksha Bhandari[5]

[1]MDS Student, Dept. of Prosthodontics and Crown & Bridge, Dr. D.Y. Patil Dental College and Hospital, Dr. D.Y Patil Vidyapeeth. Pimpri, Pune, Maharashtra, India

[2] MDS, Professor & PG Guide, Dept. of Prosthodontics and Crown & Bridge, Dr. D.Y. Patil Dental College and Hospital, Dr. D. Y. Patil Vidyapeeth Pimpri, Pune, Maharashtra, India

[3]MDS, HOD and Professor, Dept. of Prosthodontics and Crown & Bridge, Dr. D.Y. Patil Dental College and Hospital, Dr. D. Y Patil Vidyapeeth, Pimpri, Pune, Maharashtra, India

[4]MDS Student, Department of Prosthodontics and Crown & Bridge, Dr. D.Y. Patil Dental College and Hospital, Dr. D.Y. Patil Vidhyapeeth, Pimpri, Pune, Maharashtra, India

[5]MDS Student, Department of Prosthodontics and Crown & Bridge, Dr. D.Y. Patil Dental College and Hospital, Dr. D.Y Patil Vidhyapeeth, Pimpri, Pune, Maharashtra, India

Article Info: Received 13 July 2019; Accepted 04 August. 2019

DOI: https://doi.org/10.32553/ijmbs.v3i8.467

Address for Correspondence: Dr. Prerna N Kulkarni, MDS Student, Department of Prosthodontics and Crown & Bridge, Dr. D.Y. Patil Dental College and Hospital, Dr. D.Y Patil Vidyapeeth. Pimpri, Pune, Maharashtra, India

Conflict of interest: No conflict of interest.

Abstract

Background: Dental implants have provided an alternative method of prosthetic rehabilitation with high long-term success rates. However, mechanical or biological complications may occur with implants amongst which loosening of the screw is very common. Loosening of the screw might cause misfit of implant–abutment interface and may occur due to preload loss subsequent to inadequate initial torque, distortion of the screw, wear of the screw, overloading, and micro-movements because of functional loading. The implant-abutment connection design like internal hex, external hex and morse taper may affect the screw stability. The effect of various implant-abutment connections on the stability of abutment screw has been discussed in this systematic review.

Aim: The aim of this review is to assess and compare effect of different abutment connections on loosening of the screw.

Data Sources: An online search was made for the articles using Google Scholar and PubMed.

Study Eligibility Criteria: Articles published in English language or those articles that have a detailed summary in English language were included. Articles published between 1st January 2000 and 30th September 2018 was selected. Scientific research papers, Randomized controlled trials were included with data on the effect of various implant abutment connections on the loosening of the screw.

Results: Out of 449 articles that were identified through electronic database searching. 19 articles were selected. These articles were screened for duplicates and 7 articles were obtained after eliminating the duplicates. None were excluded after screening of the duplicate articles. This review provides an understanding of effect of various abutment connections on loosening of the screw.

Limitations: Few articles do not give concrete conclusions due to smaller sample sizes, differences inter-study sample population, variety of groups compared**.**

Conclusions: Out of all studies that were evaluated few stated that internal hex connection design had least screw loosening compared to external hex and morse taper while the other studies were inconclusive.

Keywords: Dental Implant, Implant-Abutment Connection, Screw Loosening

Introduction:

The screw is a crucial part of implant prosthesis. Screw loosening might cause displacement of prosthesis leading to loss of function.[1] It may also cause misfit of implant abutment interface,[2] causing bio-mechanical complications like microleakage of bacteria, fractures of the screw and/or the framework.[3]

Screw loosening may occurs due to inadequate preload, loss of preload subsequent to inadequate initial torquing, deformation of screw, wear of the screw, over-loading, and micro-movements due to functional loading.[2] Various designs of implant abutment connection have been put forth to reduce the microgap.[4]

Incidents of screw loosening are more common with single-tooth implant restorations. However, it occurs in multiple-unit cases as well.[5]

A tight screw connection can be maintained by including anti-vibrational threads, mechanical interlocks, changing the design and mechanism of the screw to control torque.[6]

These methods help in minimizing the screw loosening problem. However, they don't eliminate the problem completely.[7]

Various implant–abutment connections that have been proposed include - External Hexagon, Internal Hexagon, and Conical or Morse Taper[8].

Screw loosening in immediate implant loading cases might transfer harmful stresses to the alveolar bone before osseointegration, thus causing failure of the osseointegration.[9]

METHODS

ELIGIBILITY CRITERIA:

Inclusion Criteria:

1. Articles that are in English language or the articles that can be translated to English.
2. All full text articles.
3. Articles mentioning implant/abutment connections.
4. Scientific research papers, Randomized controlled trials with data on implant abutment connections and abutment screw loosening.
5. Articles published from 1st January 2000 to 30th September 2018.

Exclusion Criteria:

1. Articles that are in a language other than English.
2. Articles with full text not available.
3. Review articles.
4. Letters to editors
5. Case reports.

PCOS:

Component	Description
Product	Different Implant Abutment connections
Comparison	Endosteal implants with implant abutment connections - Internal Hex, External Hex, Morse Taper, Internal conical
Outcome	Screw loosening
Study Design	Randomized controlled trials

INFORMATION SOURCES:

PubMed and Google scholar were the two databases used to complete the search for all full text articles available. Lists of the cross reference of the selected articles were checked for papers that might meet the eligibility criteria of the study. The search was done for studies published from 1st January 2000 to 30th September 2018.

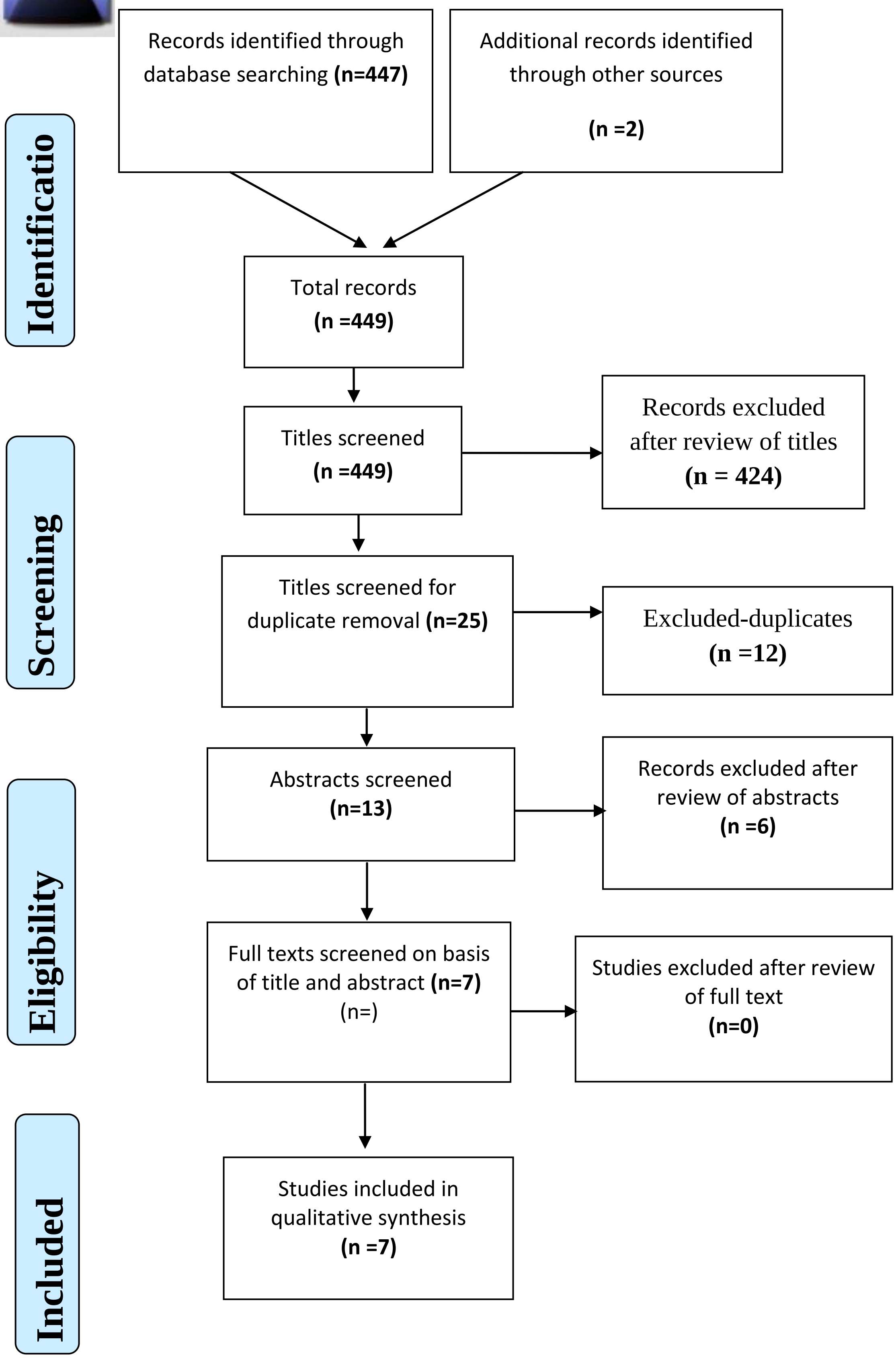
SEARCH STRATEGY:

The comprehensive data search was done on PubMed and Google scholar. Articles published from January 1st 2000 till September 31st 2018 were included. Articles in English language were selected. Filters for full text and for study designs were not applied. The keywords used for searching articles in PubMed are given in table 1.

Table 1: Search Strategy

Sr. No	Search Strategy	Total Number of Articles	Number of Selected Articles	Number of articles after duplicate removal
1	Implant abutment **AND** implant abutment connection design **AND** screw loosening	59	4	4
2	Implant abutment connection **OR** implant abutment attachment **OR** implant abutment Joint **AND** screw loosening	92	5	1
3	Implant abutment connection **OR** implant abutment Fixture **OR** implant abutment interconnection **AND** screw loosening	72	2	0
4	Implant abutment connection **AND** screw loosening **OR** screw detachment **OR** screw disconnection	144	3	0
5	Implant abutment connection **AND** screw loosening **OR** screw disconnection	80	3	0
6	Others	2	2	2
	Total	**449**	**19**	**7**

PRISMA 2009 Flow Diagram



SEARCH ENGINES

Pub Med, Google Scholar, Institutional Library

STUDY SELECTION:

All articles were searched using the above mentioned search strategy. For screening of articles, initially, titles and abstracts were used to identify full articles concerning the effect of various connection designs on abutment screw loosening. After the articles were identified, duplicates from the respective searches were removed. In the final step, these articles were subjected to exclusion and inclusion criteria for the review.

Data was extracted independently by first author and the data extraction was confirmed by other review authors. Any difference of opinion between the reviewers was resolved with discussion. After this a data extraction sheet was prepared.

DATA COLLECTION PROCESS:

Significant data from the selected articles was recorded for screw loosening depending on connection design. A standard pilot form in excel sheet was used. Data extraction was first done for one of the selected articles according to the form and was evaluated by an expert and finalized. Data extraction was then done for all the remaining articles.

DATA ITEMS:

Selected articles were read thoroughly and the data was segregated under the following headings in an excel sheet.

1. Study ID – Serial number.
2. Author – Author name.
3. Publication Year – When the article was published.
4. Location – Where the study was conducted.
5. Comparison Groups –Different implant-abutment connections.
6. Sample Size of implants – Number of implants placed.
7. Brand Of Implant
8. Method of Loading – the method used for loading of implant
9. Outcome Assessment – the value measured after loading of implant.
10. Outcome – Amount of torque loss that occurred
11. Results - Which group had the highest screw loosening.
12. Remarks - Comments of the author (NB, DK, PK).
13. Other Observations

STUDY SELECTION:

The guidelines in PRISMA statement (Preferred Reporting Items for systematic Reviews and Meta-analysis) were followed for the systematic review. (Flowchart 1)

Preliminary screening consisted of 449 studies. The studies were screened and 430 studies were excluded for not meeting the eligibility criteria. Out of the remaining 19 studies, 12 were removed for being duplicates. Out of the remaining 7 studies, none were excluded after reading the abstract. Thus, total 7 studies were included in qualitative synthesis.

DISCUSSION

Several studies have been conducted to assess the effect of different implant abutment connection designs such as internal hexagon, external hexagon and morse taper on screw loosening**.** This systematic review has been attempted to find the best available evidence to determine which connection design has a better effect on the stability of the screw. However, it is difficult to draw conclusions from the articles selected as they cannot be compared directly due to the diversity of eligibility criteria's, assessment methods, population in which study was done and outcomes. Seven papers were identified and included.

Katsuhiro Tsuruta et al (2018) conducted a study to assess the effect of implant–abutment connection on loosening of screw and microleakage. Three types of Nobel Biocare implants were utilized in the study. One compressive and tensile load was applied every second and loading was done for 2000 cycles. Removal Torque Value (RTV) of abutment screw was tested. No notable difference was seen between the groups.[10]

Hakimeh Siadat et al (2018) evaluated the effect of different connection designs on screw loosening and microleakage following cyclic loading effect of implants. 12 samples were divided into two groups: internal and external hexagon. Two implants were used as control. Five minutes after tightening the abutment, the initial torque loss (ITL) was evaluated using a torque wrench. Metal crowns were placed on abutments before loading was carried out. Secondary torque loss (STL) was evaluated. ITL was more than the STL in both groups.[11]

Eun-Sook Kim et al (2013) evaluated the effect of various abutment designs on initial loosening of screw. Three groups of abutments were fabricated with different fabrication methods. A dynamic load was applied and removal torque value before and after loading was evaluated. There was no notable difference in removal torque value amongst the groups. The abutment types did not have a notable influence on screw loosening.[12]

Hyon-Mo Shin et al (2014) evaluated the effect of various abutment connection designs and the diameter on stability of screw joint. Regular diameter and wide-diameter implants with different types of connection designs were used. Initial removal torque values of screw was evaluated with a torque gauge. Postload removal torque value was evaluated after cyclic loading was done. The post-load removal torque value was highest in two-stage internal cone and least in external butt joint systems.[13]

Jack Piermatti et al (2006) evaluated the torque loss with external hexagon and internal hexagon connection design. Ten samples of each system were utilized. Screws were tightened and loading was done. The Bio-Lok samples lost about 10% of torque, almost all torque of Astra Tech group was lost and it loosened, whereas 50% of the torque was lost of Nobel Biocare and Zimmer samples but it did not loosen. This study did not indicate advantage of internal connection over external hex connection related to loosening of the screw.[14]

Yasuhiro KATSUTA et al (2015) evaluated the screw loosening of dental implant-abutment joint by cyclic torsional loading. 36 samples, 6 samples from each different abutment systems available commercially were utilized. Internal connection system (four groups) and external connection system (two groups) were used. The screw was tightened for every system and the loosening torque was evaluated by a digital torque meter. Cyclic torsional loading was performed and the loosening torque was evaluated. It was concluded that the abutment screw loosened due to cyclic torsional loading, and the amount of loosening differed with every system.[15]

Abílio Ricciardi Coppedê et al (2013) conducted a study to evaluate the loosening torque in different connection designs. Abutments were tightened and loosening torque was evaluated. Abutments were retightened and mechanically loaded. The loosening torque was again measured. Significant differences between the groups were observed before mechanical cycling. No significant differences were seen among the groups after mechanical cycling. Within the same group, significant differences were observed before and after mechanical cycling loading.[16]

RESULTS

Out of 7 studies, three studies stated that internal hex connection design had least screw loosening compared to external hex and morse taper (one study stated that external hex had the highest screw loosening whereas the other two studies stated that morse taper connection had higher incidence of screw loosening) while the other studies were inconclusive (Table 2).

Table 2:

Study ID	Authors	Year of publication	Location	Comparison Groups	Sample Size (N)	Brand of Implant	Method of Loading	Outcome Assessment	Outcome	Results	Remarks	Other Observations
1	Katsuhiro Tsuruta, et al.	Apr-18	Japan	Group A(External Parallel) Group B (Internal Parallel) Group C (Conical)	7	Nobel biocare	One Compressive and One Tensile 10N load was applied per second for 2000 Cycles	Removal Torque value (RTV)	Group A (External Parallel): 25.83±5.19 Group B (Internal Parallel): 23.70±2.86 Group C (Conical): 23.88±1.98	There were no statistical differences in the Removal Torque Value among three groups	Different implant abutment connections have no significant difference on loosening of the screw.	Along with checking for screw loosening, microleakage has been checked.
2	Hakimeh Siadat et al.	2018	Iran	Group A (External Hex) Group B (Conical Internal Hex)	12	Branemark, Nobel Active	The cyclic loading test was performed with a force of 50 N perpendicular to the occlusal surface with 500000 cycles	Initial Torque Loss (ITL), Secondary Torque Loss (STL)	ITL - Group A (External Hex): 7.40±1.82 Group B (Internal Hex): 8.60±2.07 STL - Group A (External Hex): 21.40±22.70 Group B (Internal Hex): 12.00±3.67	Internal connection exhibited better torque maintenance compared to the external hexagon connection	Screw loosening with external hex implant abutment connection is more as compared to internal hex connection	Along with checking for screw loosening, microleakage has been checked.

3	Eun-Sook Kim et al.	2013	korea	Group A (Stock Abutment) Group B (Gold cast abutment) Group C (CAD/CAM custom abutment)	7	Osstem Co., Raphabio	A sine curved dynamic load was applied for 100000 cycles between 25 and 250 N at 14 Hz	Removal Torque value (RTV)	Group A (Stock Abutment): 17.67±2.60 Group B (Gold cast abutment): 16.10±1.56 Group C (CAD/CAM custom abutment): 15.20±2.25	Removal torque value before loading and after loading was the highest in stock abutment, which was then followed by gold cast abutment and CAD/CAM custom abutment, but there were no significant differences	Screw loosening with stock abutment was the least and that with CAD/CAM abutment was the highest	
4a	Hyon-Mo Shin et al.	2014	korea	Group A (External Hex Butt Joint) Group B (8° Morse Taper) Group C (11° Morse taper)	5	Osstem System	100,000 cycles of a 150 N and a 10 Hz cyclic load had been applied	Postload Removal Torque Value	Group A (External Hex Butt Joint): 24.6±1.5 Group B (8° Morse Taper): 20.8±0.7 Group C (11° Morse taper): 12.5±0.6	the external butt joint and one-stage internal cone systems showed lower postload removal torque loss rates than the two-stage internal cone system	Screw loosening with two-stage internal cone connection was higher than external butt joint and one-stage internal cone system	Influence of the implant-abutment diameter on the screw joint stability
4b	Hyon-Mo Shin et al.	2014	korea	Group A (External Hex Butt Joint) Group B (External Hex Butt Joint) Group C (8° Morse taper)	5	Osstem System	100,000 cycles of a 150 N and a 10 Hz cyclic load had been applied	Postload Removal Torque Value	Group A (External Hex Butt Joint): 25.6 ± 1.6 Group B (External Hex Butt Joint): 24.2 ± 0.7C Group C (8° Morse taper): 19.5 ± 2.6	the external butt joint showed lower postload removal torque loss rates than the one-stage internal cone system	Screw loosening with one-stage internal cone connection was higher than external butt joint	Influence of the implant-abutment diameter on the screw joint stability
5	Jack Piermatti et al.	Jun-05	Newark	Group A (Bio-lok: External hex connection) Group B (Zimmer: Internal Connection) Group C (Nobel Biocare: External Connection) Group D (Astra Tech: Internal Connection)	10	Bio-lok, Zimmer, Nobel Biocare, Astra Tech	Samples were loaded vertically with 200 N at a rate of 10 Hz. Torque audits were done at 250,000, 500,000, 750,000, and 1,000,000 cycles	Postload Torque Value	Group A (0 Cycles): 32.04 (0.08) (250,000 cycles): 31.00 (1.33) (500,000 cycles): 31.00 (1.33) (750,000 cycles): 32.10 (0.32) (1,000,000 cycles): 28.30 (6.62) Group B (0 Cycles): 32.0(0) (250,000 cycles): 28.80 (5.53) (500,000 cycles): 24.20 (6.48) (750,000 cycles): 18.20 (8.96) (1,000,000 cycles): 16.10 (7.82) Group C (0 Cycles): 32.0 (0) (250,000 cycles): 28.40 (4.45) (500,000 cycles): 22.70 (6.53) (750,000 cycles): 21.10 (6.70) (1,000,000 cycles): 16.90 (8.76) Group D (0 Cycles): 29.29 (9.02) (250,000 cycles): 25.30 (5.60) (500,000 cycles): 5.80 (8.03) (750,000 cycles): 3.40 (7.23) (1,000,000 cycles): 2.70 (5.74)	The Bio-Lok samples lost an average of 10% of the original torque values, the Astra Tech group lost almost all of the torque and loosened, while the Zimmer and Nobel Biocare samples lost an average of 50% of the torque but did not loosen	Screw loosening did not occur with Zimmer and Nobel Biocare systems.	
6	Yasuhiro KATSUTA and Fumihiko WATANABE	2015	Japan	Group A (Internal/ 8° Taper) Group B (Internal/ 11° Taper) Group C (Internal/ "Tube in tube" with cam-slot) Group D (Internal/ "Tube in tube" with cam-slot) Group E (External/ Hex) Group F (External/ Hex - UCLA abutment)	6	Straumann	A cyclic torsional loading test with 100,000 cycles was performed at a velocity of 10º/min	Removal Torque value	Removal torque before cyclic torsional loading (Ncm) Group A: 38.6 [−10.2] Group B: 16.5 [17.5] Group C: 19.0 [5.0] Group D: 30.8 [12.0] Group E: 28.7 [18.0] Group F: 26.3 [12.3] Removal torque after cyclic torsional loading (Ncm) Group A: 34.8 [0.6] Group B: 14.3 [28.5] Group C: 17.2 [14.0] Group D: 29.3 [16.3] Group E: 28.0 [20.0] Group F: 25.1 [16.3]	The values for removal torque after cyclic torsional loading indicated that with all the systems, the abutment screw was looser after cyclic torsional loading test	Screw loosening occurred with all the systems after cyclic tortional loading	
7	Abílio Ricciardi Coppedê et al.	2013	Brazil	Group A (Flat-head Screw EH Connection) Group B (Flat-head screw IT Connection) Group C (Conical head screw ET Connection) Group D (Conical head screw IT Connection)	11	Dérig System	Abutments were tightened at 32 Ncm of torque; after 10 minutes, loosening torque was measured. The same abutments were then retightened with 32 Ncm of torque; after 10 minutes, they were mechanically loaded for 300,000 cycles and loosening torque was again measured.	Removal Torque (before and after loading)	Before Cycling (t0) Group A (EH): 76.01±3.36 Group B (EHCS):91.37±3.67 Group C (IT): 77.25±6.03 Group D (ITCS): 92.25±3.64 After Cyclic (t1) Group A(EH): 68.02±10.55 Group B (EHCS): 74.82±6.9 Group C (IT): 61.81±11.25 Group D (ITCS): 78.28±5.43	Measurement of initial torque (t0) showed higher loosening torques for groups EHCS and ITCS than for groups EH and IT. EH and IT connections showed similar loosening torque values. Final torque measurements (t1) after mechanical loading also showed higher loosening torques for groups EHCS and ITCS. EH and IT connections again showed similar loosening torque values	screw loosening was the highest with EHCS and ITCS groups before and after cyclic loading	

LIMITATIONS:

Some studies don't give a definite conclusion because of the smaller sample sizes, differences in implant system used for the study, variety of groups compared, and relevant articles being available in languages other than English. Only one of the studies selected compared all the types of implant abutment connections i.e. Internal Hex, External Hex and Morse Taper connections at one time.

CONCLUSION:

Screw loosening is a common complication of implant treatment. The abutment screw stability is affected by implant-abutment connection design. Various connection designs such as internal hexagon, external hexagon and morse taper are available. Therefore, it is important to study the effect that the different connections may have on the screw stability. Various studies showed that screw loosening occurred to some extent irrespective of the connection design used.Out of 7 studies, three studies stated that internal hex connection design had least screw loosening compared to external hex and morse taper. Two other studies stated that there was no difference in the screw loosening associated with different implant abutment connection designs whereas the other studies were inconclusive. It is difficult to draw conclusions at this stage relating to the eligibility criteria, different implant-abutment connection designs. Clinical trials with bigger sample size where the confounding factors are controlled are necessary to evaluate the findings.

FUTURE IMPLICATIONS:

Studies with larger sample size and long term follow up; studies pertaining to all different kinds of connections in same sample may be carried out to evaluate which amongst the implant abutment connections i.e. Internal Hex, External Hex and Morse Taper have the least screw loosening associated with it.

ACKNOWLEDGEMENTS

We place on record, our sincere gratitude to the HOD and professors, Department of Prosthodontics and Crown & Bridge, for their constant help and encouragement. We also thank them for their expert, sincere and valuable guidance extended to us.

We acknowledge the immense help received from the scholars whose articles are cited and included in references of this manuscript. We are also grateful to authors / editors / publishers of all those articles, journals and books from where the literature for this article has been reviewed and discussed.

We would also like to extend my sense of gratitude to one and all who, directly or indirectly, have lent their helping hand in this venture.

REFERENCES:

1. Jemt T, Laney WR, Harris D, et al. Osseointegrated implants for single tooth replacement: A 1-year report from a multicenter prospective study. Int J Oral Maxillofac Implants.1991;6:29-36.
2. Guzaitis, KL, Knoernschild KL, Viana, AG. Effect of repeated screw joint closing and opening cycles on implant prosthetic screw reverse torque and implant and screw thread morphology. J Prosthet Dent 2011; 106:159–69.doi:10.1016/S0022-3913(11)60115-7.
3. Kim SK, Koak JY, Heo SJ, Taylor TD, Ryoo S, Lee SY. Screw loosening with interchangeable abutments in internally connected implants after cyclic loading. Int J Oral Maxillofac Implants 2012; 27: 42–7.
4. Ekfeldt A, Carlsson GE, Börjesson G. Clinical evaluation of single-tooth restorations supported by osseointegrated implants: a retrospective study. Int J Oral Maxillofac Implants 1994;9:179-83.
5. Jemt T, Pettersson P. A 3-year follow-up study on single implant treatment. *J Dent*. 1993;21:203-208.
6. Shigley JE, Misonke CR. In: The Design of Screws, Fasteners and Connections in Mechanical Engineering Design. 5th ed. New York, NY: McGraw-Hill, Inc.;1989:325-381.
7. Scheller H, Urgell P, Kultje C, et al. A 5-year multicenter study on implant supported single crown restorations. Int J Oral Maxillofac Implants.1998;13: 212-218.
8. Liu Y, Wang J. Influences of microgap and micromotion of implantabutment interface on marginal bone loss around implant neck. Arch Oral Biol. 2017;83:153–60.
9. Misch CE, Wang HL, Misch CM, Sharawy M, Lemons J, Judy KW. Rationale for the application of immediate load in implant dentistry: Part I. Implant Dent 2004;13:207-17.
10. Katsuhiro Tsuruta, YasunoriAyukawa* , Tatsuya Matsuzaki, MasafumiKihara and Kiyoshi Koyano. The influence of implant–abutment connection on the screw loosening and microleakage International Journal of Implant Dentistry (2018) 4:11.
11. HakimehSiadat, HossainNajafi, MarziehAlikhasi, BabakFalahi, ElahehBeyabanaki, FaridZayeri. Effect of lateral oblique cyclic loading on microleakage and screw loosening of implants with different connections. J Dent Res Dent Clin Dent Prospect 2018; 12(3):183-189.

12. Eun-Sook Kim, Soo-Yeon Shin.Influence of the implant abutment types and the dynamic loading on initial screw loosening. J AdvProsthodont 2013;5:21-8.
13. Hyon-Mo Shin1, Jung-Bo Huh1, Mi-Jeong Yun1, Young-Chan Jeon1, Brian Myung Chang2, Chang-Mo Jeong. Influence of the implant-abutment connection design and diameter on the screw joint stability. J AdvProsthodont 2014;6:126-32.
14. Jack Piermatti, HodaYousef, Allyn Luke, Richard Mahevich, Saul Weiner. An In Vitro Analysis of Implant Screw Torque Loss With External Hex And Internal Connection Implant Systems. Implant Dentistry 2006; 4:15.
15. Yasuhiro KATSUTA and Fumihiko WATANABE. Abutment screw loosening of endosseous dental implant body/abutment joint by cyclic torsional loading test at the initial stage. Dental Materials Journal 2015; 34(6): 896–902.
16. AbílioRicciardiCoppedê Et Al. Mechanical Comparison Of Experimental Conical-Head Abutment Screws With Conventional Flat-Head Abutment Screws For External-Hex And Internal Tri-Channel Implant Connections: An In Vitro Evaluation Of Loosening Torque. The Int J of Oral & Maxillofacial Implants. 2013;28(6):321-29.