Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

CAUSES OF IMPLANT CONNECTION FRACTURES AND HOW TO AVOID THEM

Madrid, academic year 2024/2025

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RESUMEN

Introducción: Menos del 5% de los implantes fracasan, lo que puede atribuirse al uso de mejores materiales biocompatibles y a la tecnología de fabricación. Empero, todavía existen dudas entre los profesionales sobre qué materiales, qué métodos de fabricación, qué tipos de conexión e qué tipo de fijación utilizar para que los implantes tengan las mayores posibilidades de éxito y el menor riesgo de fractura; **Objetivos:** Los objetivos de este trabajo son conocer las causas de fractura de las conexiones de implantes y proporcionar recomendaciones útiles para los profesionales sobre cómo evitar las fracturas de conexiones de implantes; **Métodos:** Se utilizaron dos bases de datos electrónicas para encontrar un total de 53 fuentes que incluyen trabajos primarios así como libros y revisiones literarias, la mayoría de los cuales son de 2015 a 2025 referenciando fractura de pilar o fractura de tornillo en implantes; **Resultados:** Las conclusiones de los artículos primarios que hacían referencia a cementado frente a atornillado, stock frente a colado/fresado, externo frente a interno, con encaje frente a sin encaje, titanio frente a circonio, pilares de dos piezas frente a una pieza y el efecto de la altura de la corona en las resistencias a la fractura de las conexiones de los implantes se organizaron en tablas para evaluar qué opción era mejor en cada caso; **Conclusión:** Hay menor riesgo de fractura de la conexión si se utilizan dos piezas, de titanio, cementadas, con menor altura de corona. En cuanto a los demás criterios, no se encontraron pruebas suficientes.

PALABRAS CLAVE

Odontología, implante, fractura de conexión de implante, fracaso de implante.

ABSTRACT

Introduction: Currently less than 5% of implants fail, which can be attributed to the use of better biocompatible materials and technology in regard to fabrication. However, there are still doubts amongst professionals on which materials, which fabrication methods, which connection types and even which fixation type to use to give the implants the best chances of success and the lowest risk of fracture; **Objectives:** The objectives of this work are to learn about implant connection fracture causes and provide useful recommendations for dental practitioners on how to avoid implant connection fractures; **Methods:** Two electronic databases were used to find a total of 53 sources including primary work as well as books and literary reviews, the majority of which are from 2015 to 2025 referencing either abutment fracture or screw fractures in implants; **Results:** Conclusions of primary articles referencing cemented versus screwed, stock versus cast/milled, external versus internal, engaging versus non-engaging, titanium versus zirconia, two-piece versus one-piece abutments and the effect of the crown height on the fracture resistances of implant connections were organized into tables to evaluate which option was better in each case; **Conclusion:** There is a lower risk of connection fracture if using cemented, titanium two-piece with lower crown height. Regarding the other criteria, not enough evidence was found to make a definitive conclusion.

KEYWORDS

Odontology, implant, implant connection fracture, implant failure.

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1. INTRODUCTION

1.1. Theoretical framework

1.1.1. Definitions

An implant is defined as an artificial structure that is placed in the bone to either repair, support or replace a biological structure (tooth) that is either missing or damaged. A dental implant is composed of a dental implant body (with an implant platform) that is fixed into the bone, an abutment that supports the crown or any dental prosthesis, and a screw which can either fix the abutment to the implant body or the crown/dental prosthesis to the abutment (1).

The crown or dental prothesis is not part of the dental implant and will not be considered when talking about the different types of fractures in this work. Implants can either be presented in “one-piece” (“one-phase”) or “two-pieces” (“two-phase”). This refers to the implant body/abutment connection. In “one-piece” implants, the implant body and abutment come together, as one-piece. In “two-piece” implants, the implant body and abutment come as two sperate pieces (2).

1.1.2. History of Implants

The introduction of dental implants as we know them today (cylindrical and with threads) was done by Per Ingvar Branemark. He also introduced the notion of osteointegration with dental implants, which is a fundamental concept in the understanding and success to a favorable implant (1,3).

Implant designs have greatly evolved since their introduction. For instance, they were originally cylindrical in shape with a constant diameter from the coronal part of the implant body to the apical portion. Their external surface was smooth and non-threaded. Nowadays, implant bodies are tapered incrementally from coronal to apical to simulate the anatomy of a natural tooth root which permits an easier placement of the implant body into the prepared site. Their surface is also rough with micro-designs achieved with sandblasting or acid etching in order to reach greater biocompatibility and osteointegration with the surrounding bone. They are also threaded with different designs (square, v-thread, vertical slot,…) which increases the functional surface area of the implant body and provides better force distribution into the bone, favoring a greater implant stability and long-term success (1).

1.1.3. Indications and contraindications

Before considering dental implants for a patient, it is important to look at a variety of factors to know whether the patient is a good candidate for this treatment. First and foremost, a thorough medical history is necessary to know if the patient suffers from any condition that would be an absolute contraindication to the procedure. For example, poorly controlled diabetes, pregnancy and transmissible hepatitis are absolute contraindications. If the patient is deemed medically healthy enough to undergo the procedure it is important to evaluate their mental status. Do they have unrealistic expectations? If so, the patient needs to be informed of what results they should expect from dental implants and offered alternative restoration methods (4).

Then, the status of the remaining teeth in the dental arch (if the patient is not completely edentulous) should be evaluated. Their periodontal status and restorability need to be considered as it will affect the treatment plan. The quantity of bone remaining in the sites where we desire to place an implant also needs to be evaluated by means of radiographs and CTs (Computerized Tomography). Areas with not enough bone to place an implant either in height or width, or presenting bony undercuts need to be corrected by performing either bone regeneration or bone remodeling before placing the implant. Additionally, anatomical features such as the mental foramen need to be considered before placing the implant to avoid injuring the nerve present. Once bone quantity has been deemed sufficient, bone quality should also be considered. Bone quality is classified into four classes. In the mandibular anterior ridge, we will find dense cortical bone (Class I), which is the most favorable type of bone to place an implant. However, in the maxillary posterior region we will find thin cortical loose trabecular bone (Class IV), which is the least favorable to place an implant. Typically, patients with sites with bone quality of Class III or IV will need bone augmentation surgery before placing an implant (4).

1.1.4. Implant connection designs

Implant connection refers to the way the implant body connects to the abutment. It can either be internal or external. In an internal connection implant, the implant body has the female part, and the abutment has the male part. For external connection implants it is the opposite, the implant body has the male part and the abutment has the female part. Typically, external connection implants have a hexagonal design as it provides more stability to the implant. According to the literature, internal connection implants provide a better long-term stability, less screw loosening and fractures, than external connection implants as there is a greater contact surface which increases the friction between the abutment and the implant body (5).

Additionally, the connection of the abutment with the implant platform can either be engaging or non-engaging. An example of an engaging connection would be a hexagonal shape as it would provide a great resistance to rotational forces of the abutment in regard to the implant platform. However, a non-engaging connection would be smooth and circular, providing the least resistance to rotational forces. This is important as the forces applied in the abutment screws will vary depending on the connection design (6).

1.1.5. Abutment types

Depending on the manufacturer of implants, there may be over 10 different options of abutments for the implant body. Dental abutments can be manufactured using different methods. They can be stock, cast or custom-made. Stock abutments are prefabricated by the manufacturer. Cast abutments are prefabricated and used to make custom abutments. An example of a castable abutment is the UCLA (Universal Castable Long Abutment) (7).

Custom-made abutments are usually lab-milled and are fabricated using CAD/CAM (computer-aided design/computer-aided manufacturing). The abutment can then either be straight, angled or preparable, whether they are stock or custom (8–10).

1.1.6. Materials

Prosthetic dental abutments can be manufactured with a variety of techniques and in different types of materials. Generally speaking, abutments are either made of metal and metal alloys (such as titanium, gold and their alloys), ceramics (such as zirconia and lithium disilicate), polymers (such as composite or fiber reinforced composite) or hybrid materials (titanium-zirconia, titanium-polymer, ceramics-polymer). Each come with their different advantages and drawbacks. For instance, metallic and zirconia abutments have higher mechanical strength resistance, whereas ceramic abutments are more esthetic and hybrid abutments permit for greater angle correction (2).

When looking at materials, it is also important to note that the screws can come in either gold or titanium alloys when referring to final prosthetic screws, or stainless steel when referring to laboratory screws. It is important to note that screws in gold or titanium alloys present less fracture risks than stainless steel screws and are therefore recommended to be used over stainless steel screws in order to avoid connection fractures (5).

1.1.7. Implant to Prosthesis fixation options

There are two main options to fix the crown or dental prosthesis to the abutment/implant body. It can either be screwed or cemented. Regarding cemented restorations, the abutment is first screwed to the implant body and the crown is then cemented to the abutment. This generally provides a better sealing of the implant at the junction of the abutment and the prosthetic crown and is preferred in posterior area as it can sometimes be difficult to reach with a screw. However, there is the significant drawback that when failure of the implant does happen in any part (either screw, implant body or abutment) it is difficult to repair as most often times the complete destruction of the crown/abutment will be necessary to access the implant body. Regarding screwed restorations, the prosthetic crown will be fixed to the abutment not with cement, but with a screw. This provides the opportunity that if any complications were to arise that needed access to the implant body or platform for repairs, they could simply be accessed by unscrewing the crown to the abutment. This is usually done in anterior restorations as there is sufficient vertical space to access with a screwdriver (5).

1.1.8. Types of fractures

Implant connection refers to 3 separate parts of the implant. This includes the abutment, the screw connecting the abutment to the implant and the coronal part of the implant body that encases the aforementioned screw. Any of those parts can fail by either deforming, loosening or fracturing, causing the need to replace only one part of the implant or the whole depending on the case (11). A physical representation of those parts can be observed in Figure 1 below (Figure 1).

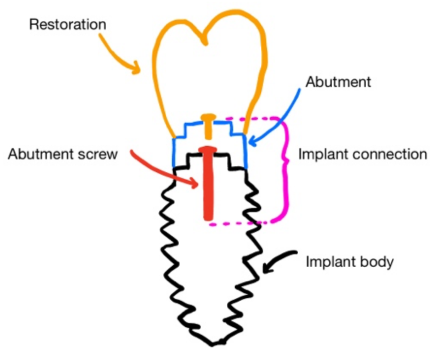


Figure 1: Implant design

Screw loosening is often the initial stage of a screw fracture, which happens as the outside forces surpass the internal forces maintaining the screw in place (11).

1.2. Current state of the subject

Implants have greatly evolved since their first introduction in the 1960s by Per Ingvar Branemark. Nowadays, over 95% of implants survive, whether it is measured across a period of 10 or 23 years. The use of biocompatible materials such as titanium and the advancement of digital technology for not only impression-taking but also manufacturing through CAD/CAM have greatly contributed to making implant failure a more and more rare phenomenon with less than 5% of implants suffering from implant failure (3). This is why it is so important that dental practitioners are correctly informed on ways to avoid, limit and prevent implant connection fracture.

1.3. Justification

At present less than 5% of implants result in failure. This can be attributed by the advances in technology and the use of more biocompatible materials. However, now more than ever with the incredible amount of options when designing an implant, clinicians are often confused on how to choose the connection types and materials in order to provide a better chances of success to their implants. This can go from choosing to use a zirconia or titanium abutment or a 2-piece or 1-piece abutment or even an internal or external connection design.

By combining the use of literary reviews and case study reports, this thesis aims to provide a reference-based text that dental practitioners can refer to in order to make better informed decisions on the connection types and materials used when plasing an implant to reduce risks of implant connection fractures.

2. OBJETIVE

The aim of this thesis is to gain knowledge on implant fractures. To satisfy this purpose, the objectives of this thesis are:

- Learn about implant connection fracture causes
- Provide useful recommendations for dental practitioners on how to avoid implant connection fractures

3. MATERIAL AND METHODS

The purpose of this thesis is to find out about the implant connection fractures and how to avoid them. For this purpose, electronic databases such as Medline Complete and Biblioteca CRAI Dulce Chacon were used to find a total of 53 scientific articles and reviews, as well as literary books relevant to the topic. The majority of scientific articles and literary books were from between 2015 to 2025. One of the literary books was published in 2003 but was included as it provided an abundance of useful information to establish a basic theoretical knowledge on the subject. One of the scientific articles was also published at a sooner date (2011) but was kept in because of the useful insight it provided on cemented versus screwed restorations.

The keywords and Bolean operators used were “Dental implant connection fracture” AND “Abutment” NOT “systematic reviews or meta-analysis” NOT “removing or retrieval”.

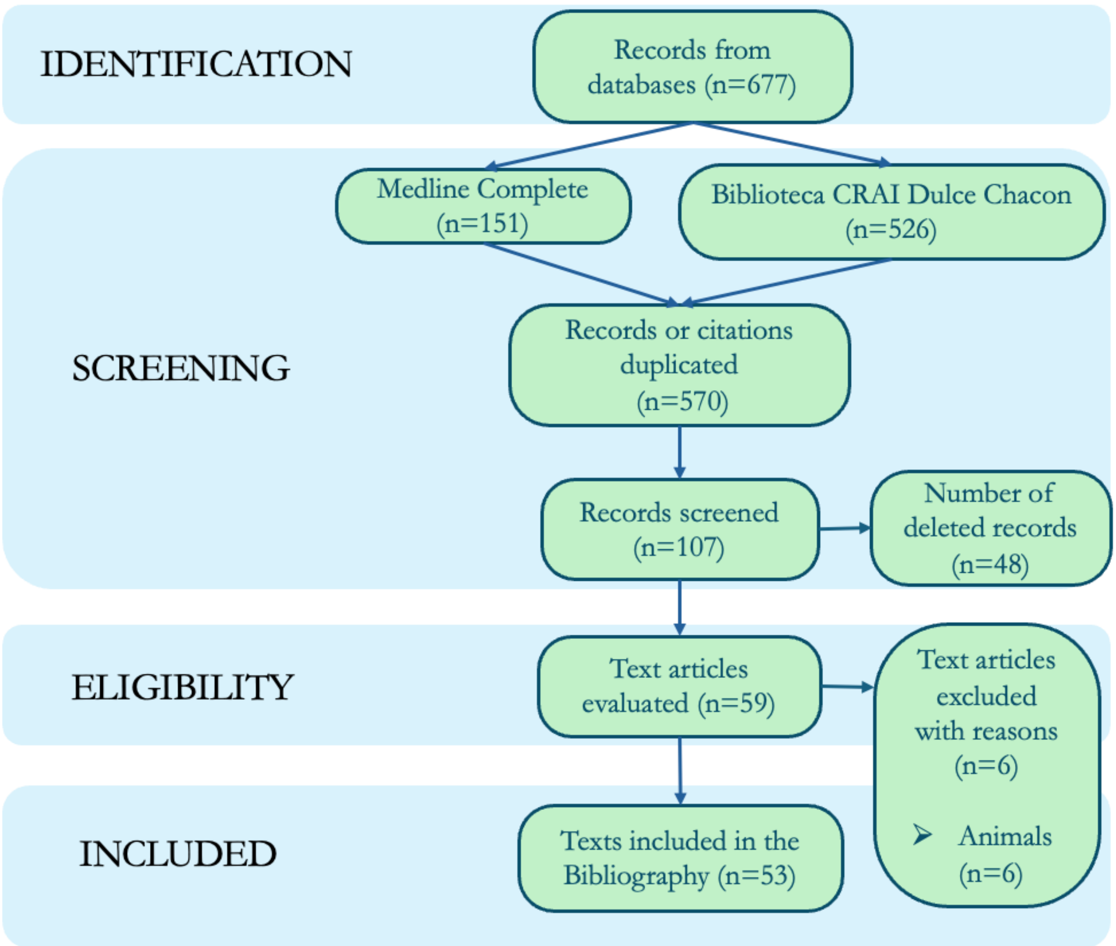
In the electronic database Medline Complete, this resulted in 686 results before the english inclusion criteria was applied, which then yielded 526 articles. All of this is shown in the PRISMA diagram below.

We also excluded any article that focused on either the fracture of the implant body in the bone or the fracture of the implant around the connection in order to better focus on either the abutment or the screw fractures as those were seen as more easily modifiable subjects when looking into the prevention of implant connection fractures.

- Inclusion criterias:
  - Language: English
  - Type of sources: Literary books, Scientific articles
  - Year of publication: From 2015 to 2025
  - Full text available

- Exclusion criterias:
  - Language: Any other language than English
  - Scientific articles or Books without a complete available free text
  - Not related to dental implants
  - Systematic reviews and meta-analyses
  - Fractures on implant body
  - Studies conducted on animals

- PICO question:
  - P (Population): Dental implants
  - I (Intervention): Internal connection, Screw retained, Engaging, Zirconia, Stock abutments
  - C (Comparison): External connection, Cemented, Non-Engaging, Titanium, Cast or Milled abutments
  - O (Outcome): Reduce the incidence of implant connection fracture and screw loosening
  - In dental implants, does using an internal, screw retained, engaging, zirconia, or stock abutment versus an external, cemented, non-engaging, titanium, cast or milled abutment reduce the incidence of implant connection fracture and screw loosening?



4. RESULTS

Table 1: Screwed versus cemented

Year, Author	Study type	Sample	Conclusion
2011, Freitas AC Jr and al. (12)	In vitro study	N= 84	Cemented-internal connection higher stability
2015, Ugurel CS and al. (13)	In vitro study	N= 64	Internal screw-retained > Screwless morse taper
2016, Anchieta RB and al. (14)	In vitro study	N= 168	Regular cemented > Regular screwed > Switch-platform cemented > Switch-platform screwed (fracture)
2023, Del Castillo R and al. (15)	Prospective Case series study	N= 22	Screw-retained internal connection zirconia abutment. After 1 year, no abutment fracture
2021, Fonseca M and al. (16)	Prospective cohort study	N= 40	Screw-retained 1 piece zirconia abutment with conical connection. Only one abutment fracture over 6 years. → Good clinical performance
2022, Lemos CAA and al. (17)	In silico study (3D Models)	N= 8	Screw-retained > Cemented

Table 2: Crown height ratio

Year, Author	Study type	Sample	Conclusion
2015, Gehrke SA (18)	In vitro study	N= 60	Higher crown height: more resistant (14 > 12 > 10 > 8 mm)
2022, Yilmaz B and al. (19)	In vitro study	N= 21	Internal connection implants with crown height 6mm > 10mm > 14mm. Higher: More fracture
2021, Yilmaz B and al. (20)	In vitro study	N= 21	Internal hexagonal connection of titanium screw-retained crowns. Crown height: 14mm < 10mm < 6mm

Table 3: Stock, cast or milled abutment

Year, Author	Study type	Sample	Conclusion
2024, Hendi and al. (8)	In vitro study	N= 64	Stock 4mm abutment with less screw loosening (lowest RTL)
2017, Jarman JM and al. (21)	In vitro study	N= 20	OEM (stock) abutments more fracture resistant
2023, Gehrke SA and al. (7)	Retrospective study	N= 120	UCLA less abutment fractures BUT more screw loosening than solid titanium abutment
2023, Ahmad Waled Mohammed (10)	In vitro study	N= 20	Higher fracture resistance in preparable abutments than titanium bases
2016, Patankar A and al. (22)	In vitro study	N= 30	Abutment Manufactured > prepared 1mm apical > prepared 1.5mm apical
2023, Ma R and al. (23)	In vitro study	N= 72	Restored hybrid abutments more fracture resistance than un-restored abutments
2015, Yilmaz B and al. (23)	In vitro study	N= 15	Manufacturer's abutment > Aftermarket brands (screw fracture)
2018, Moris ICM and al. (24)	In vitro study	N= 18	Zirconia customized > Titanium > Zirconia non-customized
2015, Shabanpour R and al. (25)	In vitro study	N= 140	Bigger abutment diameter: more resistant
2023, Alberti A and al. (26)	In vitro study (numeric)	N= 2	2.9mm versus 3.3mm diameter implant with conical connection. No clinical difference. Conical connection increases fracture resistance.

Table 4: Internal versus External connection

Year, Author	Study type	Sample	Conclusion
2018, Yi and al. (27)	Retrospective study	N= 1289	External connection: screw fracture / Internal connection: abutment fracture
2017, Jarman JM and al. (21)	In vitro study	N= 20	External hexagon connection stronger (468N)
2011, Freitas AC Jr and al. (12)	In vitro study	N= 84	Cemented-internal connection higher stability
2020, Camps-Font O and al. (28)	In vitro study	N= 48	External hexagon connection more fracture resistant after implantoplasty than internal hexagon or conical connection
2015, Gehrke SA (18)	In vitro study	N= 60	More resistant to deformation Morse taper connection than external or internal hexagon connection
2016, Vigolo P and al. (29)	Retrospective study	N= 1431	No difference between internal or external connection
2020, Nicolas-Silvente AI and al. (30)	In vitro study	N= 54	External connection > Internal connection. Smaller platform diameter: Lower resistance to fracture.
2023, Del Castillo R and al. (15)	Prospective Case series study	N= 22	Screw-retained internal connection zirconia abutment. After 1 year, no abutment fracture
2016, Carneiro Tde A and al. (31)	In vitro study	N= 30	Regular hexagon and internal connection > Narrow internal hexagon
2018, Bordin D and al. (32)	In vitro study	N= 84	Internal conical > External hexagon and internal hexagon connection

2015, Chae SW and al. (33)	Retrospective study	N= 2651	External > Internal. Loosening and fracture of abutment more frequent in internal connection
2017, Fabbri G and al. (34)	Retrospective study	N= 965	Internal metal connection > External or Internal zirconia
2022, Lemos CAA and al. (17)	In silico study (3D Models)	N= 8	Morse taper > External hexagon.
2016, Gehrke SA and al. (35)	In vitro study	N= 60	External hexagon, Internal hexagon, Morse taper abutments. All less resistant after implantoplasty. Morse taper handle it better.
2022, Yang F and al. (36)	Retrospective study	N= 945	Platform-switching Morse tapper connection fracture more frequent in single crowns in molars.
2021, Giner S and al. (37)	In vitro study	N= 60	Internal conical > tube in tube connection (internal) (mechanical performance)
2023, Alberti A and al. (26)	In vitro study (numeric)	N= 2	Conical connection increases fracture resistance.

Table 5: Engaging versus Non-Engaging

Year, Author	**Study type**	**Sample**	**Conclusion**
2021, Savignano and al.	In vitro study	N= 47	Most balanced in mE-pmE (engaging connection in both implant pillars)

Table 6: Zirconia versus Titanium

Year, Author	Study type	Sample	Conclusion
2020, AlAmar M and al. (38)	In vitro study	N= 21	1 piece zirconia abutment more fracture resistant than titanium
2022, Korkmaz and Kul (9)	In vitro study	N= 3	Low Angled (17º > 25º) titanium based abutment: less stress on bone and implant (compared to zirconia)
2023, Zhai Z and al. (39)	In vitro study	N= 30	For narrow diameter: one piece zirconia abutment more resistant
2025, Schäfer T and al. (40)	In vitro study	N= 50	Titanium more resistant. Abutment design insignificant
2018, Sailer I and al. (41)	In vitro study	N= 120	Internal connection titanium abutment stronger than zirconia abutment
2017, Stimmelmayr M and al. (42)	In vitro study	N= 30	1 piece zirconia abutment: less fracture resistance
2022, Watanabe S and al. (43)	In vitro study	N= 3	Zirconia abutment with titanium base > Simple Zirconia abutment
2015, Joda T and al. (44)	In vitro study	N= 20	Titanium > Zirconia abutment (fracture)
2023, Del Castillo R and al. (15)	Prospective Case series study	N= 22	Screw-retained internal connection zirconia abutment. After 1 year, no abutment fracture
2023, Yi Y and al. (45)	Retrospective study	N= 898	Titanium screw > Gold screw (fracture). Narrow diameter: higher fracture risk

2015, Chun HJ and al. (46)	In vitro study	N= 15	Titanium insert reinforces Zirconia abutment (Ti abutment-Ti screw / Zr abutment- Ti screw / Zr abutment- Ti insert- Ti screw)
2018, Moris ICM and al. (24)	In vitro study	N= 18	Zirconia fractures. Titanium deforms plastically. Zirconia customized > Titanium > Zirconia non-customized
2021, Giner S and al. (47)	In vitro study	N= 22	Zirconia > Titanium abutment. Screw is the weakest point
2022, Saravi B and al. (48)	In vitro study (ex vivo simulator model)	N= 48	PEEK abutment better load-bearing than zirconia abutments
2021, Fonseca M and al. (16)	Prospective cohort study	N= 40	Screw-retained 1 piece zirconia abutment with conical connection. Only one abutment fracture over 6 years. → Good clinical performance
2020, Lin YT and al. (49)	Retrospective study	N= 42	Two-piece zirconia abutment with bonded titanium inserts > without titanium insert
2017, Fabbri G and al. (34)	Retrospective study	N= 965	Internal metal connection > External or Internal zirconia
2016, Ferrari M and al. (50)	Randomized Control Trials	N= 89	Titanium, titanium nitride, zirconia abutment. Zirconia abutments more fractures after 3 years.

Table 7: 1-piece versus 2-piece abutment

Year, Author	Study type	Sample	Conclusion
2020, AlAmar M and al. (38)	In vitro study	N= 21	1 piece zirconia abutment more fracture resistant than titanium
2017, Stimmelmayr M and al. (42)	In vitro study	N= 30	1 piece zirconia abutment: less fracture resistance
2021, Fonseca M and al. (16)	Prospective cohort study	N= 40	Screw-retained 1 piece zirconia abutment with conical connection. Only one abutment fracture over 6 years. → Good clinical performance
2020, Lin YT and al. (49)	Retrospective study	N= 42	Two-piece zirconia abutment with bonded titanium inserts > without titanium insert
2017, Jeng MD and al. (51)	In vitro study	N= 96	Two-piece abutment (with screw) / 1 piece abutment. Higher torque = less screw loosening
2022, Zhang F and al. (52)	In vitro study	N= 16	One-piece: fracture in the implant body. Two-piece: fracture in the abutment in full ceramic zirconia implants

5. DISCUSION

5.1. Causes of implant fractures

5.1.1. Screwed versus Cemented

A restoration upon an implant can either be screwed or cemented. The choice is usually made by the practician based on the accessibility of the restauration-implant complex. Usually, restorations are screwed in the anterior region as we have ample vertical space to access the restoration with the screwdriver. This also offers the opportunity to easily access the implant complex whenever maintenance or reparations are needed without having to destroy the crown. Following the same reasoning, restorations are usually cemented in the posterior region as we do not have good enough access and space to pass with the screwdriver in the vertical plane. This presents the disadvantage of not being able to easily access the implant below the restoration without have to destroy the crown in most cases as de-cementation is not easy (5).

When looking at the failure rate and fracture risk of screwed versus cemented, it appears that cemented restorations generally have a better stability and suffer less risks of fractures when evaluated through in vitro studies (12–14).

However, one study realized with a virtual model on a simulation program did demonstrate a better result of stability in screw-retained than in cemented restorations (17).

It could also be observed that in screw-retained restorations, the fracture majorly occurs at the abutment and that in cemented restoration, the failure lies in the screw for both external and internal connection implants (12).

Overall, it does seem that cemented would be the favored option, but studies have shown that over the period of 1 year and 6 year there was no abutment fracture observed or only one respectively in screw-retained abutments (15,16).

5.1.2. Crown height ratio

The characteristics of the restoration that goes on the implant are very important as they will greatly influence the forces applied on the implant abutment and implant body which will determine the degree of screw loosening suffered by the abutment or even the risk of fracture incurred by that same abutment. This is demonstrated in the two in vitro studies conducted by Yilmaz B and al. in both 2021 and 2022 that a higher crown height will result in a greater risk of fracture for the abutment, independently of the material used for the abutment (19,20). However, one study conducted in 2015 goes to show the exact opposite, affirming that a greater crown height would result in more resistance to fracture and deformation (18).

This goes to show that more research is needed on the topic to establish a clear guideline on crown height ratio for implants. Although logic would dictate that with a lower crown height, less lateral force would be exserted on the implant crown and implant connection and therefore would present less screw loosening and less fractures.

5.1.3. Stock, cast or milled abutment

There exist different types of manufacture methods for dental implant abutments. They can be stock (prefabricated), cast (using a lost wax technique) or milled (using CAD/CAM technology). Both cast and milled abutments are specifically made for the case of the patient, whereas stock abutments are fabricated prior to the patient’s case and therefore not specifically adapted to it (8).

A majority of sources indicated that stock abutments where stronger than their customized counterparts to fracture and less subjected to screw loosening (8,21–23). However, some studies did find that preparable abutments and restored abutments were more fracture resistant after they underwent modifications (7,10,24,53). It is also important to note that using a bigger abutment diameter or a conical connection will offer greater fracture resistance as it will provide a more stable and resistant base to loading forces (25,26).

5.1.4. Internal versus External connection

There are two main types of connection between the abutment and the implant body: external connection and internal connection. The most common type of fracture we will encounter in external connection will be a screw fracture. Whereas in internal connection, the more often fracture is of the abutment. This can be explained by the fact that in internal connection, the retention of the crown and abutment is obtained though the friction of the abutment and the inner surface of the implant and screw. Whereas in external connection, that retention is resting solely on the screws. Therefore when loading forces are applied on the implant superstructure, those forces are exserted mainly on those screws, causing them to fracture more often than in internal connection designs (27).

In multiple studies, we can observe that external connection is generally stronger and suffers less overall fractures of the connection than internal connection design (21,28,30,33). Similarly, one study realized in 2018 found that internal type connections will generate more overall fractures (27).

However, as shown in the literature and one study realized in 2011, internal connections offer more stability, less screw loosening and therefore fractures than their external connection counterparts (5,12).

Finally, we can also observe that in a lot of cases, a Morse taper will handle better the occlusal loads or mechanical changes suffered by the abutment as, thanks to its unique connection design, it presents a friction free connection therefore greatly limiting the risks of screw loosening and therefore fracture (17,18,35).

5.1.5. Engaging versus Non-engaging connection

Very little evidence was found on the benefits of engaging versus non-engaging abutments. Typically, when working with single crown restorations, an engaging connection would be preferred. Whereas when working in bridges over implants, two non-engaging connections would be favored as it would facilitate the work of the dentist by giving him a bigger margin of error to work with (5,6).

However, in the unique in vitro study found, it was shown that in dental implant bridges including replaced molars and premolars, a combination of engaging abutments on both the molar and the premolar yielded the least screw loosing of the bridge as it offered an environment with less friction between the abutment and implant platform and therefore limited the possibilities of screw loosening (6).

More evidence is required to determine a definite benefit to using engaging abutments to reduce connection fracture and screw loosening.

5.1.6. Zirconia versus Titanium

Both implant bodies and implant abutments can be made of zirconia or titanium. Zirconia presents certain advantages such as better aesthetic, corrosion resistance and fracture toughness (5,21).

Although the literature varies, when looking at the results collected in this systematized review, it can be seen that titanium is stronger against fractures than zirconia (7:4 ratio). This can be explained by the fact that, when put under high loading stress, zirconia will break, whereas titanium will deform plastically first before breaking (34,40–42,44,48,50).

However, some articles do present findings where zirconia abutments were considered more fracture resistant then their titanium counterparts which could be justified by the fact that the screw of the abutment is the weakest part and that metal to metal friction could cause damage to the components, therefore rendering both the screw and titanium abutment more prone to fractures (24,38,39,47).

It was also observed that zirconia reinforced with titanium at the base was stronger than a monolithic zirconia abutment as it combined the strengths of both zirconia and titanium (43,46,49).

Finally, it is also important not to consider only the material of the abutment but also that of the screw. A study realized in 2023 compared using titanium screws and gold screws and found that titanium screws were less prone to fractures (45).

5.1.7. 1-piece versus 2-piece abutment

Any implant-restoration complex can either be made of 2 parts (implant body + direct restoration and abutment complex) and it is therefore called 1-piece abutment or of 3 parts (implant body + abutment + restoration) and called a 2-piece abutment. The 3 part implant can also be referred to as platform switching (52). This is illustrated in Figures 2, 3 and 4.

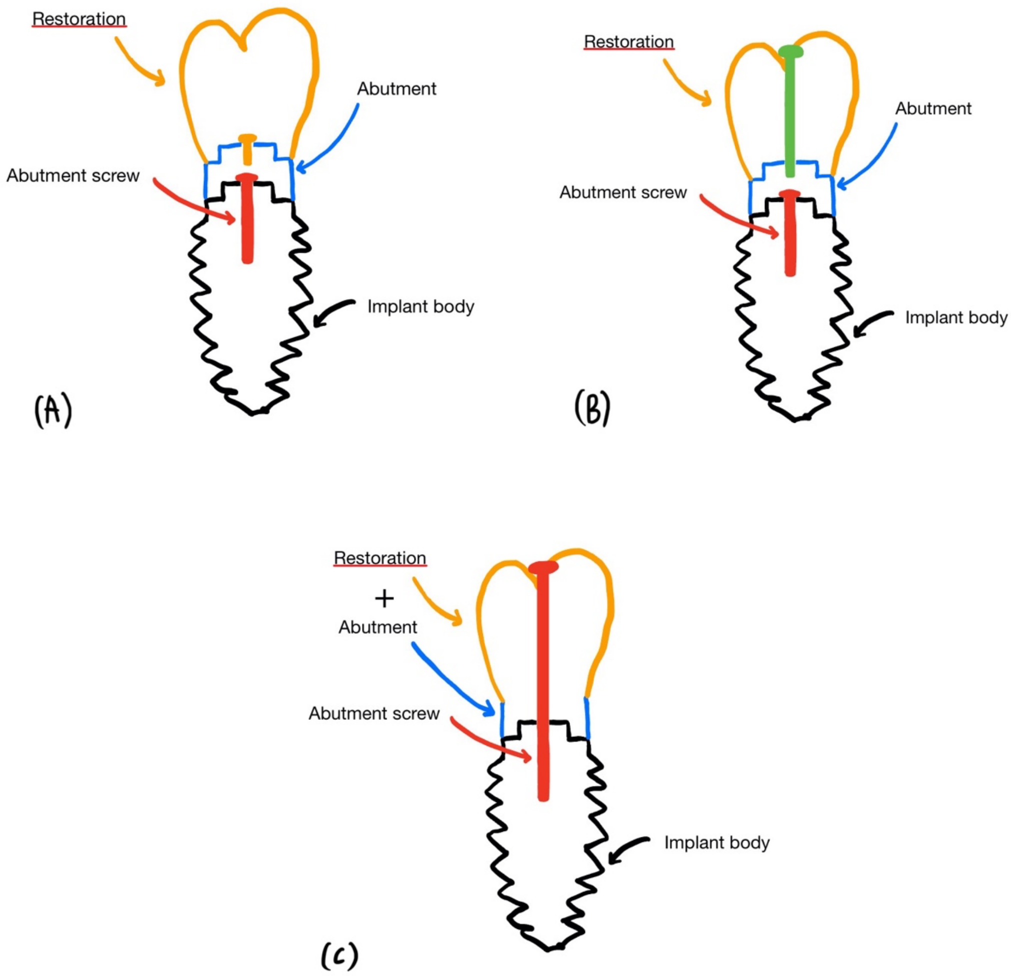


Figure 2, 3 and 4: Crown abutment designs; (A) Cemented 2-piece abutment (3 parts); (B) Screwed 2-piece abutment (3 parts); (C) 1-piece abutment (2 parts)

The goal of making the restoration and abutment into two separate parts is to mitigate the forces applied on the implant body and reduce the likelihood that, in the event of a fracture occurring, the screw breaking is the one in the implant body rather the one that fixes the restoration to the abutment. Having the last one break rather than the first makes for an easier repair and replacement of the screw (52).

When looking at 1-piece abutment, since the restoration and the abutment are one, there is one long screw that fixes the complex to the implant body. That screw is exposed to a lot of forces and because of its bigger length, it is more prone to breaking. If it does break, it is a possibility that remanents of the screw get stuck in the implant and therefore force the practitioner to replace the entire implant (42,52).

However, it is important to mention that one study conducted in 2020 found that a one-piece zirconia abutment was more fracture resistant than a titanium abutment (38). Although this is contradictory to our previous findings regarding titanium versus zirconia abutments.

5.1.8. Mechanical stress

Occlusal overloading causes both bone micro-damage and peri-implantitis. 15-56% of implants are affected by peri-implantitis, which is the continuous loss of bone surrounding an implant. The micro-damages on the bone caused by occlusal overloading or incorrect contact points will lead to implant micro-motion and consequently screw-loosening and potential fracture of the implant. Additionally, micro-fractures along the bone-implant interface could lead to a fracture of either the implant body or the prosthetic crown (5).

Furthermore, mechanical stress on the prosthetic crown might cause screw loosening which inevitably leads to implant connection fracture. This happens when the external occlusal forces applied on the implant connection surpass the internal force (preload) that the screw applies on the inside of the implant body. This goes to show the importance of proper planning and implant placement in reducing those potentially harmful forces on the implant connection (11).

5.1.9. Ceramic implants

For the past 30 years, titanium implants have been the norm. However, recently total zirconia implants have been introduced in the market to replace the traditional titanium implants. This is because zirconia provides fast clinical stability of the implant in the bone and is very biocompatible and well tolerated by the bone. However, it was shown that it presented with major mechanical failures that lead to common fractures of the implant body in the bone. For now, zirconia implants haven't been on the market for long enough to showcase the real benefits and advantages in using them and possibly replacing titanium implants. More extended studies and reviews need to be conducted on the subject to establish a clear benefit to using zirconia implants (5).

5.2. Recommendations

5.2.1. Nightguard

As a general recommendation post implant surgery, it is recommended to fabricate a hard acrylic maxillary nightguard to reduce occlusal loads and undesirable occlusal contacts on the implant that might possibly harm the connection or the implant itself. This nightguard should be worn for the entire implant's lifespan, especially if the patient presents bruxism as it becomes mandatory (5).

5.2.2. Same manufacturer

It is strongly recommended that all the implant components are manufactured by the same company to avoid implant fractures due to poorly adapted connections. Whenever possible, it is strongly suggested to avoid using aftermarket or "copycat" components as those are not subject to the same regulations and standards as the official components and therefore present a bigger risk of complications (5).

5.2.3. Final prosthetic screws

Most commonly, laboratory screws are made of stainless steel. However, it is recommended to avoid using such screws and try using final prosthetic screws made of gold or titanium alloys whenever possible to screw temporary or final restorations as laboratory screws have a greater incidence of loosening and fractures (5).

In regards to the material that the screw is made of, it was seen that the titanium screw was the most resistant to fractures over all, then came the gold screw and finally the stainless steel screws that are the least resistant (45).

5.2.4. Tightening of the screw

As mentioned before, screw loosening is often the initial stage of a screw fracture, which happens as the outside forces surpass the internal force maintaining the screw in place. To reduce the risk of screw loosening, it is recommended that the screw be retightened 10 minutes after the initial procedure. The optimal torque value when tightening the screw should be around 75% of the torque necessary to break the screw (11).

It was seen that with a higher torque value, there was less screw loosening happening as more internal force was applied by the screw on the inside of the implant body connection (51).

However, it is important to make sure not to tighten the screw too much to the point of causing breakage when fixating the abutment. This is usually when we can observe vertical implant fractures, most commonly found on narrow implant platforms (11). An example of such fracture can be seen below in Figure 5 and 6, where it is shown a fracture of the part of the implant body that surrounds the abutment screw (Figure 5 and 6).

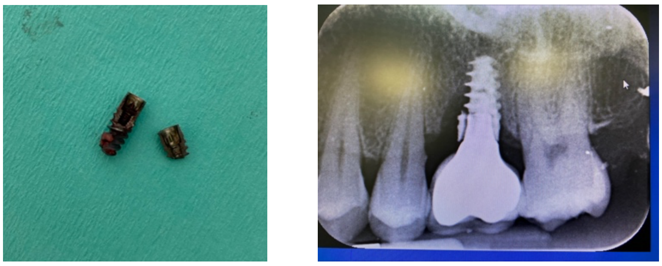


Figure 5 and 6: Pictures of implants fractured at the connection (Annex 1)

That is why it is recommended to tighten the screw according to manufacturer's instructions, using a torque measuring device to achieve the best results possible (5,51).

5.2.5. Custom abutments

Custom abutments are abutments that can be milled, cast or waxed and are made specifically for the patient's clinical situation. They allow us to correct for angulation problems and raise the abutment-crown interface which reduces the risk of fractures by reducing the transversal forces applied on the implant body in the bone. When using those abutments, it is also important to control the emergence profile by providing a proper concave design that is usually reproduced from the provisional in order to give it the best chances of clinical success (5).

6. CONCLUSIONS

At the level of the implant connection, what most often causes the fracture of a component of the connection are the occlusal or outside forces acting on the internal force that the abutment screw applies on the implant body. When the first force exceeds the second, there begins to be a loosening of the screw which ultimately results in the fracture of either the screw, the abutment or even the implant body. When choosing the components of the implant connection it is important to consider those forces and elect the material or connection type that would be the most resistant to those outside forces or the one that offers a greater amount of those inside forces that the screw applies on the implant body.

In conclusion and to answer our PICO question, to favour a more fracture resistant implant connection, it is favourable to use a cemented, titanium and two-piece abutment with a lower crown height. In regards to the other criteria, we cannot be definitive on which option is better. The studies have found that using an external connection is more resistant but the literature disagrees, showing that an internal connection provides better stability. Neither stock nor cast / milled abutments were favoured when looking at fracture resistance. Finally, more research needs to be done on engaging versus non-engaging connections as only one source was found to support that engaging connections provided more resistance against fractures.

7. SUSTAINABILITY

It is important to consider the economic impact of implant connection fractures. When an implant fractures, there is a need to replace either just the screw, just the abutment or in some cases the entire implant. This is why it is important to avoid as much as possible implant fractures, to both save money and time to the dentist and patient.

Replacing this implant will also cause an environmental effect as both the production of this new implant as well as the disposal of the old will create a contamination of the environment.

Finally, it also puts the patient at risk as a fractured implant can mean a possible infection for the patient and will most certainly mean additional surgery.

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9. ANNEXES

Annex 1: Email authorization for Figure 5 and 6

Would you possibly have any pictures or radiographs of implant connection fractures that I may use in my thesis?
I would like to use the images that you send to me to illustrate my thesis.
Do I have your approval?

Thank you,

Of course, you can use the images that I send you on your final grade work.

Best regards,