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Loosening and fracture of original vs. non-original abutment screws in implantology: Systematic review

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1 ABSTRACT

Introduction: Comparing original and non-original abutment screws is essential for optimizing dental implant procedures. Understanding the biomechanical behavior of these components helps clinicians make informed decisions, ensuring implant stability and durability. Complications such as screw loosening and fracture can lead to implant failure, emphasizing the need to identify any differences between original and non-original screws to diminish risks. Additionally, assessing the performance of non-original screws provides valuable insights into their suitability as alternatives, considering factors like cost and availability. Overall, this comparison enhances patient outcomes and improves the reliability of dental implant treatments. The aim of the review is to study the biomechanical behavior and specifically to compare the fracture resistance and loosening incidence between original and non-original abutment screws.

Materials and Methods: This review used a systematic approach following PRISMA guidelines, examining studies indexed in major databases such as Medline-PubMed, Web of Science, and Scopus. The focus was on comparing original and non-original abutment screws regarding their biomechanical behavior, specifically their fracture resistance and torque loss.

Results: Ten studies met the inclusion criteria; 5 studies on screw loosening, 4 studies on screw fracture and 1 study of both loosening and fracture. Original abutments showed better performance in terms of lower torque loss (20.33%) in respect to non-original abutments (38,87%). Original abutments showed better fracture resistance compared to non-original abutments. Variations in manufacturing standards and compatibility were noted as significant influences on performance.

Conclusion: Original abutment screws exhibit better biomechanical stability than non-original ones. This suggests a higher reliability of original components in maintaining the structural integrity and functionality of dental implants. Ensuring compatibility and adhering to manufacturing standards are critical for optimizing implant success.

2 RESUMEN

Introducción: La comparación de tornillos de pilares originales y no originales es esencial para optimizar los procedimientos de implantes dentales. Comprender el comportamiento biomecánico de estos componentes ayuda a los clínicos a tomar decisiones informadas, garantizando la estabilidad y durabilidad del implante. Complicaciones como el aflojamiento y la fractura de los tornillos pueden provocar el fracaso del implante, lo que subraya la necesidad de identificar cualquier diferencia entre los tornillos originales y los no originales para disminuir los riesgos. Además, la evaluación del rendimiento de los tornillos no originales proporciona información valiosa sobre su idoneidad como alternativas, teniendo en cuenta factores como el coste y la disponibilidad. En general, esta comparación mejora los resultados de los pacientes y aumenta la fiabilidad de los tratamientos con implantes dentales. El objetivo de la revisión es estudiar el comportamiento biomecánico y, en concreto, comparar la resistencia a la fractura y la incidencia de aflojamiento entre tornillos de pilares originales y no originales.

Materiales y métodos: Esta revisión utilizó un enfoque sistemático siguiendo las directrices PRISMA, examinando los estudios indexados en las principales bases de datos como Medline-PubMed, Web of Science y Scopus. La atención se centró en la comparación de los tornillos de pilar originales y no originales en cuanto a su comportamiento biomecánico, concretamente su resistencia a la fractura y la pérdida de torque.

Resultados: Diez estudios cumplieron los criterios de inclusión; 5 estudios sobre aflojamiento de tornillos, 4 estudios sobre fractura de tornillos y 1 estudio tanto de aflojamiento como de fractura. Los pilares originales mostraron un mejor rendimiento en términos de menor pérdida de torque (20,33%) con respecto a los pilares no originales (38,87%). Los pilares originales mostraron una mejor resistencia a la fractura en comparación con los pilares no originales. Las variaciones en las normas de

fabricación y la compatibilidad se observaron como influencias significativas en el rendimiento.

Conclusiones: Los tornillos de pilares originales muestran una mejor estabilidad biomecánica que los no originales. Esto sugiere una mayor fiabilidad de los componentes originales a la hora de mantener la integridad estructural y la funcionalidad de los implantes dentales. Garantizar la compatibilidad y respetar las normas de fabricación es fundamental para optimizar el éxito de los implantes.

3 KEYWORDS

I. Loosening
II. Fracture
III. Original screw
IV. Non-original screw
V. Dental abutment

4 INTRODUCTION

4.1 Background and significance

Replacing missing teeth with dental implants has rapidly become a major treatment for tooth loss (1–8). Advances in our understanding of tissue healing, combined with continuous technical improvements, have broadened the applicability of dental implants to different treatment modalities and ensured consistently successful and predictable long-term outcomes. Despite these advances, complications associated with dental implants, often occurring years later, have significant consequences for patients, requiring considerable time, cost, and effort for effective treatment (1).

Even though teeth replacement has a long history, the endoosseous implants where not found until recently (9). In 1960´s Brånemark discovered the ability of titanium to form a tight contact with bone, this phenomenon was later introduced as osseointegration (10). Brånemark presented a set of criteria to follow which are still used today in Implantology (9). In 1960´s Professor Schroeder studied the integration of different implant materials and soft tissue reactions. Both professors Brånemark and Schroeder are considered the fathers of modern implant dentistry by sharing their scientific findings. The preclinical and clinical studies of Brånemark and Shroeder were mainly done on edentulous patients (10).

In 1980´s, implant treatments extended for partially edentulous patients and further studies reporting positive results encouraged the progress of implant dentistry. Currently up to 90% of the cases are partially edentulous patients (10).

The technological advances such as radiological methods, intraoral scanners and the placement of provisional structures have made treatments more efficient. Cone beam computed tomography (CBCT), intraoral scanners, digital photography, virtual planning, milling technology, provisional implants and abutments and the use of digital management systems have changed the diagnostic methods and treatment planning of dentistry (9).

Clinical protocols have advanced overtime providing better solutions for the patient as well as for the clinician. Single teeth replacements can nowadays be done on the same day of the extraction by placing the implant into the extraction socket. The

materials and methods for hard and soft tissue grafting have developed and improved (9).

The increasing demand for implant treatments has consequently caused the development of many different implant companies as well as companies offering compatible components (11).

4.2 Overview of dental implants and abutments

4.2.1 Dental implants

Most dental implants consist of two parts: the implant, it is surgically placed into patient's maxilla or mandible on which a prosthetic structure is attached (12). The dental implant is then osseointegrated with the surrounding tissue. An extension, or abutment, is placed on top of the implant. The prosthetic restoration, for example a crown or a bridge done by a dental technician, is then screwed, or cemented on to the abutment. Other types of prosthesis such as overdentures can also be attached to the abutment (13).

Implants can be placed in one or two stages. Single-stage implants require a single surgical procedure. In a single-stage surgery, a healing abutment is placed on the implant immediately after the implant is placed. The healing abutment penetrates the bone and mucous membranes, so no second surgery is required. In two-stage surgery, a cover screw is inserted first. The two-stage process therefore requires a second surgery to replace the implant's cover screw with a healing abutment. The healing abutment is used to shape the gingiva around the implant to fit the prosthetic structure (14).

The diameters and lengths of implants vary from one manufacturer to another. Implants can be bone-level or tissue-level implants. The edge of a bone-level implant remains close to the alveolar bone. A tissue level implant penetrates the mucosa, which allows the implant to be shaped around the defect with temporary structures before the final prosthetic structure is fabricated (14).

Usually, after implant placement, the implant is allowed to ossify for several months, at least 3 months for the mandible and 4 months for the maxilla, before the prosthetic structure of the implant is placed. After the healing period, the

osseointegration of the implant is assessed before loading. The implant is ossified when there is no mobility, it is asymptomatic and radiological evidence indicates direct attachment of the implant to the bone. In some cases, loading can be started soon after implantation, but the healing time required for the implant is always decided individually (15).

The improvement of dental materials, prosthetic components, clinical techniques and implant surfaces and design has led to well-established possibilities and expectations in implant supported treatments (16).

4.2.1.1 Implant materials

The most important factor for the material is its biocompatibility because implants are in direct contact with the mucosa and bone (17). The surface properties of a biomaterial affect the rate of osseointegration (18). There has been an improvement in the survival of implants mainly due to the improvement of the surface characteristics (19).

Dental implants are usually made of titanium alloys Ti6Al4V and Ti-29Nb-13Ta- 4.6Zr or pure titanium. In recent years, implants made of titanium alloys and zirconia have been studied as alternative biomaterials. Titanium alloys have better mechanical properties than commercially pure grade 4 titanium. Zirconia has other advantages over titanium or titanium alloys such as esthetics (18). However, they are stiff and have a different elastic modulus than bone (20). Surface modifications of these recently introduced biomaterials have also been found to affect the osseointegration process (18).

4.2.1.2 Osseointegration

Osseointegration is the attachment of the implant to the bone so that the bone grows tightly against the porous surface of the implant, forming a continuous joint. This phenomenon was found by Brånemark in 1960´s. Since then, it has been studied how this process can be improved and maintained. Osseointegration is crucial to the success of the implantation. If ossification fails, the implant is lost. Osseointegration is a dynamic process. Primary stability is achieved immediately in the placement of the

implant. This mechanical stability is changed overtime into a biological stability called secondary stability. The primary stability depends on the physical, chemical, and mechanical properties of the implant and the shape of its surface (18). When the bone is prepared for an implant, the drill blade becomes hot. If the drill blade gets too hot, the surrounding bone is destroyed. In this case, the implant will not ossify, leading to failure in the osseointegration (21).

Osseointegration can be improved and accelerated by treating the surface of the implant. Increasing the surface area improves stability, so the largest possible implant is chosen based on the space available in the jawbone. Threads are used to increase the implant surface area and primary stability (18). The surface can be treated by sandblasting with aluminum or titanium oxide to increase porosity. A bone constituent, hydroxyapatite, can also be added to the surface to stimulate bone growth, but it can cause resorption. Because of this, its use is not recommended. In addition, the surface can be modified by acid treatment (10,18).

Implant ossification and implant fixation can be compromised if the patient suffers from periodontal disease. If it spreads to the bone surrounding the implant, the inflammation is called peri-implantitis. In this case, the bone tissue around the implant retracts. (10)

4.2.1.3 Implant properties

There are more than 1300 implant types and 250 implant manufacturers. The prosthetic interface of an implant, where the abutment connects, can be external or internal. Most connections are hexagonal or octagonal in shape, but they can also be external spline or internal Morse taper. There are also implants that have a solid connection to the abutment (one-piece) (14).

External connection offers advantages such as antirotation and orientation. However, it is susceptible to lateral forces causing micromovements at the implant-abutment interface. External forces are directly transmitted to the abutment screw and the implant restoration. Internal connection allows the abutment to extend some millimeters inside the implant increasing the surface area and distributing the stress better (22).

Implant design can be divided into micro and macrofeatures. Macrofeatures of the implant include body shape, threads, anti-rotational features, and thread design. Microfeatures include surface structure, material composition and surface coatings. Implants can be either straight or tapered and come in different lengths and widths (14). Most available implants are threaded with cylindrical or conical shape (23).

4.2.2 Abutment

The abutment acts as an intermediate part between the implant and the crown. The abutment is attached to the implant with a screw and its function is to attach the crown to the dental implant (5). The abutment is important for the stability of the implant restoration. Important factors to take into consideration when choosing an abutment are the morphological features, material, and manufacturing methods (22). Correct abutment-implant connection should not present a gap itself or due to masticatory forces (20).

4.2.2.1 Abutment materials

Metals such as titanium have long been used as an abutment material, but with the introduction of CAD/CAM technology, the use of zirconia abutments has also increased. The abutments can be transparent through the gingiva, making zirconia a better material choice than dark titanium for the aesthetically demanding anterior region, especially when the mucosa thickness is 2 mm or less (24).

When high mechanical strength is needed, chromium-cobalt (Cr-Co) alloys can be used. Their fabrication needs a milling machine, or they can be done by additive selective laser sintering techniques (25).

Poly-ether-ketone (PEK) was introduced in 1990´s. It presents an acceptable biological response and resistance to fracture. It needs more scientific evidence to be considered as an alternative material for dental abutments (20).

When comparing different abutment materials, no significant differences were found in the survival rate between titanium, gold, and ceramic abutments (16).

4.2.2.2 Prefabricated abutments and custom abutments

Dental abutments are divided into prefabricated abutments, normally manufactured by the same company as the implant, and customized abutments made with casting techniques or with CAD/CAM technologies (14).

Prefabricated titanium abutments are fabricated by the original implant manufacturer and guarantee optimal implant-abutment interface fit (26).

With custom abutments the correction of the angle and depth of the implant, as well as the contour of the gingival margin is possible. This is why their use is on the increase. In the past customized abutments were done by gold casting, but due to the high cost of gold, CAD/CAM systems have taken over (26). CAD/CAM technology allows the fabrication of abutments in various materials (25).

4.2.2.3 Ti-base

Titanium-base abutments were introduced to create a strong connection between the implant and the ceramic abutment or crown and to overcome the esthetic problems of titanium abutments. A CAD/CAM ceramic crown structure is cemented extraorally onto the Ti-base extension (27).

The Ti-base hybrid abutments consists of a prefabricated titanium base abutment on which a custom ceramic abutment is made and then cemented onto the ceramic crown structure (17).

Ti-base abutments are inexpensive, versatile, and suitable for use in the posterior region. Titanium abutments are often unesthetic due to their color and ceramics present a low fracture strength which is why titanium bases were introduced. Ti-bases are commonly used instead of zirconia abutments because zirconia abutments were found to wear the implant interface more than titanium (27).

4.2.3 Crown

When choosing the crown, there are different factors to take into consideration, such as interocclusal space, position of the implant, maintenance, esthetics, recovery, cost, and occlusion. There are different ways to connect the crown

to the implant, the most common being screw and cement retained. Both have advantages and disadvantages, but the survival rates are similar (16).

There are different materials of crowns. Metal-ceramic and ceramic crowns are the most used in implant supported fixed restorations. The esthetics and peri-implant health are affected by the choice of material. Ceramic crowns are esthetic and biocompatible but in comparison to metal-ceramic crowns they have poorer marginal adaptation (2). Metal ceramic-crowns can cause peri-implant problems and the color of the metal can transparent through the gingiva causing esthetic problems (2,24). Metal-ceramic crowns are still considered the best option for implant supported fixed restorations however they are slowly being replaced by ceramic restorations due to their improved properties (2).

There are two main types of implant supported restorations, screw and cement retained (28). Screw retained crown may be connected to the abutment (one-piece) or separate from it (two-piece). Screw retained crowns present more technical problems in comparison to cement retained and they require an adequate position of the implant (16). However they can be easily repaired because they can be easily removed (28). Cement retained crowns present more biologic problems (16) but they present a much lower cost of fabrication because of its easy fabrication (28,29).

Implant supported restorations can also be done by using optical scans and computer aided design/computer aided manufacturing (CAD-CAM) techniques (30).

4.3 Complications

These days, implant treatments are highly predictable reaching up to 99% of success rate (4,10). Despite this, there are complications related to them (1,4). Up to 40% of patients with implant supported restoration will suffer from a complication in the first five years (1).

Complications related to implants are often divided into biological and technical problems (1,4,29). The most common biological complication is the peri-implant mucositis (10,16). Other biologically related complications include; soft tissue inflammation and radiographic signs of loss of osseointegration (4). Metal-ceramic

restorations can affect the periodontal tissues or cause allergic reactions to the mucosa (2).

Mechanical or technical problems include; loss of retention and fracture of porcelain, framework, or screw (4,16,19). The most common problem is the screw loosening (29). The screw loosening can lead to worse complications such as screw fracture, marginal gap, peri-implantitis, microbial leakage and crown loosening, which will eventually cause patient discomfort (31). Ceramic chipping or fracture is a common problem but with the development of zirconia it is less significant (2).

Implants are often maintained but also placed by general dentists. This is why dental study curriculums are adjusted, so that graduating dentists would have more knowledge to maintain implants and detect complications in checkups (1).

Mechanical and technical problems are a big concern in implant dentistry as they can potentially elevate the repair or remake rates, consequently affecting patients time, finances, and quality of life (19).

4.4 Causes and consequences of abutment screw loosening and fracture

The implant supported prosthetic structure is fixed by a retention screw which acts as a spring maintaining friction between them (32). In most of the cases, implant complications do not occur without a cause. Factors leading to abutment screw loosening and fracture are many (1). The most common factors affecting screw loosening are the implant abutment connection, diameter, length, material of the prosthetic abutment, screw and implant supported restoration (29).

The screw is initially tightened to a specific torque value recommended by the implant manufacturer to generate a tension force called the preload. Preload is important for the stability of the implant-abutment connection (22). The friction between the components will resist the movement due to occlusal forces (6). The occlusal forces wear the screw threads causing a decrease in preload and leading to direct contact between the screw and the implant (33). If the preload is too low, it will cause the screw to loosen faster. On the other hand, an excessive preload will cause excessive tension between the components and lead to fracture of the screw (22).

Implant-abutment connection is the weakest point of the implant restoration (29,31). The first implants presented an external hexagon connection but due to its limitations, internal hexagon and later conical connection were developed (29). A study concluded that internal connection presented less torque loss and rotational freedom, but external connection presented a better marginal fit (34).

Angled abutments are used to correct the position of the implant. They are more susceptible to lateral forces which increases the risk of screw loosening (22).

The contact length of the screw may affect the loosening torque (33). The torque values of the screws given by the manufacturer should be respected to avoid the retightening and loosening of the screws. If the value exceeds the materials yield limit, capacity to withstand stress, it can cause permanent deformation such as loosening or fracture of the screw (22).

Titanium presents lower plastic deformation compared to gold, which makes titanium screws more stable long term (31). The advantages of surface treatment of abutments are unclear. Porcelain has a higher elastic modulus than titanium which causes stress during masticatory forces on the implant and the screw. This causes decrease in preload and torque loss and elevating the risk of screw loosening and fracture (22).

Different materials require different manufacturing techniques causing discrepancies in the manufacturing precision and fit. Customized zirconia abutments present more instability compared to prefabricated titanium abutments (22).

The implant position determines the position of the prosthetic restoration. The implant should be placed so that the axial forces of mastication are directed along the long axis of the implant (8). The fit of the prothesis is an important factor for the success of the implant. A poorly fitting prosthesis can cause screw loosening (31). Implant-supported restorations experience lateral forces during mastication which create an uneven stress distribution lowering the stability. The correct biomechanics of the prosthetic restorations are important. The use of cantilevers for example, increase the risk of screw loosening (22).

Parafunctional habits are considered a risk factor to suffer from mechanical complications such as screw loosening and fracture (22).

Some brands have introduced treated surfaces to decrease the loss of preload and in this way reduce the loosening (8), however it is questionable whether it improves the stability (22).

The most common complications of screw loosening include fracture of the screw, gingival inflammation, and implant failure (35). Microbial leakage due to unfitting components will lead to periimplantitis, bone loss and eventually failure of the implant (36).

4.5 Importance of comparing original and non-original screws

There are multiple brands of implants on the market. Every implant brand has its own original components (36). High costs, increased demand and competition has caused compatible products to enter the market and into use. Compatible prosthetic parts can be branded or generic (no name) (6). Some clinicians opt for compatible components due to cost of the components, availability, or unfamiliarity of a specific brand (1,37). The increase in the use of compatible components makes it imperative to study the influence on the success of implant treatments (36).

The use of compatible or non-original components poses challenges due to limited research; most studies predominantly use original components in university clinics under strict protocols (6). Complications arising from implants placed elsewhere become problematic to clinicians lacking information about the implant brand (1).

Micro and macroscopical distinctions exist between original and non-original abutments and their screws (36). Non-original screws present visible differences relative to their original counterparts (1,37) due to patent constraints and manufacturing differences (37,38).

Their chemical composition and physical characteristics affect the union in the junction potentially leading to adverse effects (6). Non fitting components can leave a gap between the components causing microbial leakage which can eventually lead to a failure of the implant treatment. The internal accuracy of non-original components was found to be compromised when combined with original implants (36). A requisite of implant treatment success and complication avoidance is the achievement of passive fit among different components (32). The mechanical fatigue behavior was decreased when using non original components often leading to screw fracture (36).

The biggest difference when comparing original and non-original screws was found in the area where the internal surface of the implant connects with the external surface of the abutment. Non original components exhibit higher risk of failure in short term, whereas the long-term success is more favorable with original components (36).

Non-original components exhibit variations in the design of connecting surfaces, shape, dimensions, and material leading to rotational misfit. These differences may lead to unexpected complications. This is why it is important to do more clinical studies assessing the failure and complication rates of non-original components (38).

5 JUSTIFICATION & HYPOTHESIS

JUSTIFICATION

The loosening of the implant abutment screw is one of the most common problems occurring with the implant supported restorations, but there is a lack of studies and literature reviews about the factors associated with it.

Nowadays, there are many companies on the market for implants and abutments, and they promise their compatibility with other brands but there is no scientific evidence of their interchangeability (33). Even though abutment screw loosening is not dangerous or harmful, if it occurs repeatedly, it can affect negatively on the patient satisfaction about the treatment (29).

There are interesting studies about the difference between original and non-original abutment screws. For example, those that assess screw loosening by comparing different non-original abutments with an original one (33). Other studies evaluate rotational misfit of original and non-original implant abutment connections (38). These studies found higher rotational misfit, higher incidence of screw loosening and difference in component design of non-original screws. This may cause negative effects on the clinical behavior of the implant structure. The accuracy in compatibility of original versus non-original screws was evaluated in some studies but they didn't evaluate loosening and fracture (39).

There are literature reviews about the mechanism associated with the loosening of the abutment screws, but they don't compare the difference between original and non-original screws, as well as their objective is to study only the loosening of the screws (22,29,31).

In this review, we will focus on comparing the original and non-original screws and in addition to loosening we will evaluate the fracture.

This justifies doing a systematic review which evaluates the biomechanical behavior of implant abutment screws comparing the original screws with non-original screws to understand the potential differences and risks of using non-original components. There are few literature reviews related to this topic, so it is important to investigate it.

Abutment screw fracture or loosening can be associated with the sustainable development goal number 3 “good health and well-being”. Dental implants improve the health by restoring the function of the patient. Even though abutment screw loosening is not a dangerous complication, it prevents the patient from performing basic functions like mastication. Abutment screw fracture affects people's access to quality healthcare and by studying the factors leading to it, we can prevent it. It can have an impact on a person’s oral health and well-being. If a screw fractures, it can cause discomfort and additional dental treatment. It can affect the longevity and success of the dental implant treatment. It may require additional procedures such as implant removal or replacement surgery, which can have a negative impact on a person’s health. The abutment screw loosening can affect the osseointegration of the implant, which may cause failure of the treatment. Implant and its superstructure can restore an aesthetic defect by restoring a dental piece that can affect positively the patient's mental health. By addressing dental issues like abutment screw fractures, we can improve oral health and help achieve the sustainable development goal 3.

HYPOTHESIS

The hypothesis of our study is that non-original abutment screws have a higher incidence of fracture and loosening in comparison to original screws when evaluating the biomechanical behavior of the implants in in-vitro studies.

6 OBJECTIVES

General objective

1. Compare the biomechanical behavior of original versus non-original abutment screws.

Specific objectives

1. In vitro evaluation and comparison of the loosening incidence of original screws with respect to the non-original abutment screws.
2. In vitro evaluation and comparison of the fracture resistance of original abutment screws with respect to the non-original abutment screws.

7 MATERIALS AND METHODS

This systematic review was carried out following the statement of the PRISMA Guide (Preferred Reporting Items for Systematic reviews and Meta-Analyses) (40).

7.1 Identification of PICO question

The Medline-PubMed database (United States National Library of Medicine), Web of Science and Scopus were used to search for indexed articles on in-vitro articles about the fracture and loosening of original versus non-original implant screws to answer the following question: Do original abutments, in comparison with non-original, present a lower incidence of fracture and loosening?

This study question was set according to the PICO structured question. The question format was established as follows:

- P (population): Abutment screws placed in vitro
- I (intervention): Non-original abutments
- C (comparison): Original abutments
- O (outcome): Biomechanical behavior
    - O1: Loosening (torque loss)
    - O2: Fracture (resistance)

7.2 Eligibility criteria

Inclusion criteria:

- **Type of study**: In-vitro studies; Publications in English; Published until January of 2024
- **Type of patient:** In-vitro studies
- **Type of intervention**: Measuring the loosening and fracture
- **Type of outcome variables**: Studies that provide data about the fracture and/or loosening of screws as main variable.

The exclusion criteria were:

- **Type of study**: Reviews, clinical case studies, letters or comments to the editor, expert reports
- **Type of intervention**: Articles that do not compare original vs non-original.

No restrictions were imposed based on the year of publication.

7.3 Information sources and data search strategy

An automatized electronic and manual searches were carried out in the three databases mentioned above (PubMed, Scopus and Web of Science) with the following keywords: "Dental Implant-Abutment Design", "Dental Abutments", “implant abutment”, “implant-abutment complex”, “titanium base”, non-original, “non-original screw”, replica, compatible, original screw, “fixing screw”, “original abutment”, “abutment screw”, “implant screw”, “stock abutment”, “screw fracture”, “screw loosening”, “abutment screw fracture”, “abutment screw loosening”, “implant screw fracture”, “implant screw loosening”, “mechanical behavior”, “mechanical resistance”, fatigue, reverse torque. Keywords were combined with the Boolean operators AND, OR and NOT, as well as controlled terms ("MeSH" for Pubmed) to obtain the best and broadest search results.

The search in PubMed was the following: ("Dental Implant-Abutment Design"[MeSH Terms] OR "Dental Abutments"[MeSH Terms] OR "implant abutment"[All Fields] OR "implant-abutment complex"[All Fields] OR "titanium base"[All Fields]) AND ("non-original"[All Fields] OR "non-original screw"[All Fields] OR ("replica"[All Fields] OR "replicas"[All Fields]) OR ("compatability"[All Fields] OR "compatibilities"[All Fields] OR "compatibility"[All Fields] OR "compatible"[All Fields] OR "compatibles"[All Fields])) AND ((("creativity"[MeSH Terms] OR "creativity"[All Fields] OR "originality"[All Fields] OR "original"[All Fields] OR "originalities"[All Fields] OR "originally"[All Fields] OR "originals"[All Fields] OR "originator"[All Fields] OR "originator s"[All Fields] OR "originators"[All Fields]) AND ("bone screws"[MeSH Terms] OR ("bone"[All Fields] AND "screws"[All Fields]) OR "bone screws"[All Fields] OR "screw"[All Fields] OR "screw s"[All Fields] OR "screwed"[All Fields] OR "screwing"[All Fields] OR "screws"[All Fields])) OR "fixing screw"[All Fields] OR "original abutment"[All Fields] OR "abutment screw"[All Fields] OR "implant screw"[All Fields] OR "stock abutment"[All Fields]) AND ("screw fracture"[All Fields] OR "screw loosening"[All Fields] OR "abutment screw fracture"[All

Fields] OR "abutment screw loosening"[All Fields] OR "implant screw fracture"[All Fields] OR "implant screw loosening"[All Fields] OR "mechanical behavior"[All Fields] OR "mechanical resistance"[All Fields] OR ("fatiguability"[All Fields] OR "fatiguable"[All Fields] OR "fatigue"[MeSH Terms] OR "fatigue"[All Fields] OR "fatigued"[All Fields] OR "fatigues"[All Fields] OR "fatiguing"[All Fields] OR "fatigueability"[All Fields]) OR (("reversal"[All Fields] OR "reversals"[All Fields] OR "reverse"[All Fields] OR "reversed"[All Fields] OR "reversely"[All Fields] OR "reverses"[All Fields] OR "reversibilities"[All Fields] OR "reversibility"[All Fields] OR "reversible"[All Fields] OR "reversing"[All Fields] OR "reversion"[All Fields] OR "reversions"[All Fields]) AND ("torque"[MeSH Terms] OR "torque"[All Fields] OR "torques"[All Fields] OR "torqued"[All Fields] OR "torqueing"[All Fields] OR "torquing"[All Fields])))

The search in Scopus was the following: (ALL ("DENTAL IMPLANT-ABUTMENT DESIGN" OR "DENTAL ABUTMENTS" OR "IMPLANT ABUTMENT" OR "IMPLANT-ABUTMENT COMPLEX" OR "TITANIUM BASE") AND ALL (NON-ORIGINAL OR "NON-ORIGINAL SCREW" OR REPLICA OR COMPATIBLE) AND ALL (ORIGINAL AND SCREW OR "FIXING SCREW" OR "ORIGINAL ABUTMENT" OR "ABUTMENT SCREW" OR "IMPLANT SCREW" OR "STOCK ABUTMENT") AND ALL ("SCREW FRACTURE" OR "SCREW LOOSENING" OR "ABUTMENT SCREW FRACTURE" OR "ABUTMENT SCREW LOOSENING" OR "IMPLANT SCREW FRACTURE" OR "IMPLANT SCREW LOOSENING" OR "MECHANICAL BEHAVIOR" OR "MECHANICAL RESISTANCE" OR FATIGUE OR REVERSE AND TORQUE))

The search in Web Of Science was the following: (ALL=(("dental implant-abutment design" OR "dental abutments" OR "implant abutment" OR "implant-abutment complex" OR "titanium base") AND (non-original OR "non-original screw" OR replica OR compatible) AND (original AND screw OR "fixing screw" OR "original abutment" OR "abutment screw"OR "implant screw" OR "stock abutment") AND ("screw fracture" OR "screw loosening" OR "abutment screw fracture" OR "abutment screw loosening"OR "implant screw fracture" OR "implant screw loosening" OR "mechanical behavior" OR "mechanical resistance" OR fatigue OR reverse AND torque) AND "dental implants")) AND ALL=(("Dental Implant-Abutment Design" OR "Dental Abutments" OR “implant abutment” OR “implant-abutment complex” OR “titanium

base") AND (non-original OR "non-original screw" OR replica OR compatible) AND (original screw OR "fixing screw" OR "original abutment" OR "abutment screw" OR "implant screw" OR "stock abutment") AND ("screw fracture" OR "screw loosening" OR "abutment screw fracture" OR "abutment screw loosening" OR "implant screw fracture" OR "implant screw loosening" OR "mechanical behavior" OR "mechanical resistance" OR fatigue OR reverse torque))

Table 1 in the Annexes section shows the summary of the searches of each of the databases consulted.

In order to identify any eligible studies that the initial search might have missed, the search was completed with a review of the references provided in the bibliography of each of the studies. In addition, a hand search was conducted for scientific articles.

Finally, a cross-search of potentially interesting articles for analysis was performed. Duplicate studies were eliminated from the review.

7.4 Study selection process

A three-stage selection process was carried out. The selection of studies was carried out by two reviewers (DL, ZC).

In the first stage, articles were filtered by titles in order to eliminate irrelevant publications.

In the second stage, the abstracts were screened and selected according to the type of study, type of intervention, number of samples, and outcome variables.

In the third stage, articles were filtered by reading the full text and proceeded to data extraction using a data collection form previously developed to confirm the eligibility of the studies.

7.5 Data extraction

The following information was extracted from the studies and arranged in tables: authors with year of publication, type of study (in-vitro), implant connection type, implant length and diameter, implant brand, original abutment brand, non-original abutment brand, number of original abutments, number of non-original abutments,

total of abutments, number of cyclic loads, loading force (N), insertion torque (Ncm), mean preloading reverse torque value (RTV), mean postloading RTV, torque loss, fracture resistance.

Specific variables

- **Screw fracture**: The fracture resistance was evaluated comparing original and non-original abutment screws.
- **Screw loosening**: After cyclic loading, removal torque values were measured with a digital torque gauge. The torque loss, from the initial torque to the removal torque value was evaluated.

The way these variables (loosening and/or fracture) were measured in each of the studies is described in Table 2 in annexes.

7.6 Quality assessment

The risk of bias assessment was evaluated by two reviewers (DL, ZC) in order to analyze the methodological quality of the included articles.

A quality assessment of full-text articles was performed according to modified ARRIVE and CONSORT criteria tool for in vitro studies (the evaluation was based on predefined grading system). Categories used to assess the correct conduct and structure are title, abstract, introduction, materials and methods, results, discussion, and conclusions (41,42).

7.7 Data analysis

In order to summarize and compare the outcome variables between the different studies, the means of the values of the main variables were grouped according to the study group.

To be able to compare the representative findings for torque loss a procentage was calculated to calculate an average and mean.

Conducting a meta-analysis on the loosening and fracture of abutment screws in dentistry may be challenging and was not performed due to potential

limitations in the number, heterogeneity, and quality of existing studies, as well as issues related to publication bias and the diversity of abutment and implant systems.

8 RESULTS

8.1 Selection of the studies. Flow chart

A total of 67 articles were obtained from the initial search process: Medline - PubMed (n=12), SCOPUS (n=51) and the Web of Science (n=4). In addition, 2 studies were obtained through manual search (reference list and primary sources). From these publications, 18 were identified as potentially eligible articles by screening by titles and abstracts. Full-text articles were subsequently obtained and thoroughly evaluated. As a result, 10 articles met the inclusion criteria and were included in the present systematic review (Fig. 1).

Information regarding the excluded articles (and the reasons for their exclusion) is presented in Table 3.

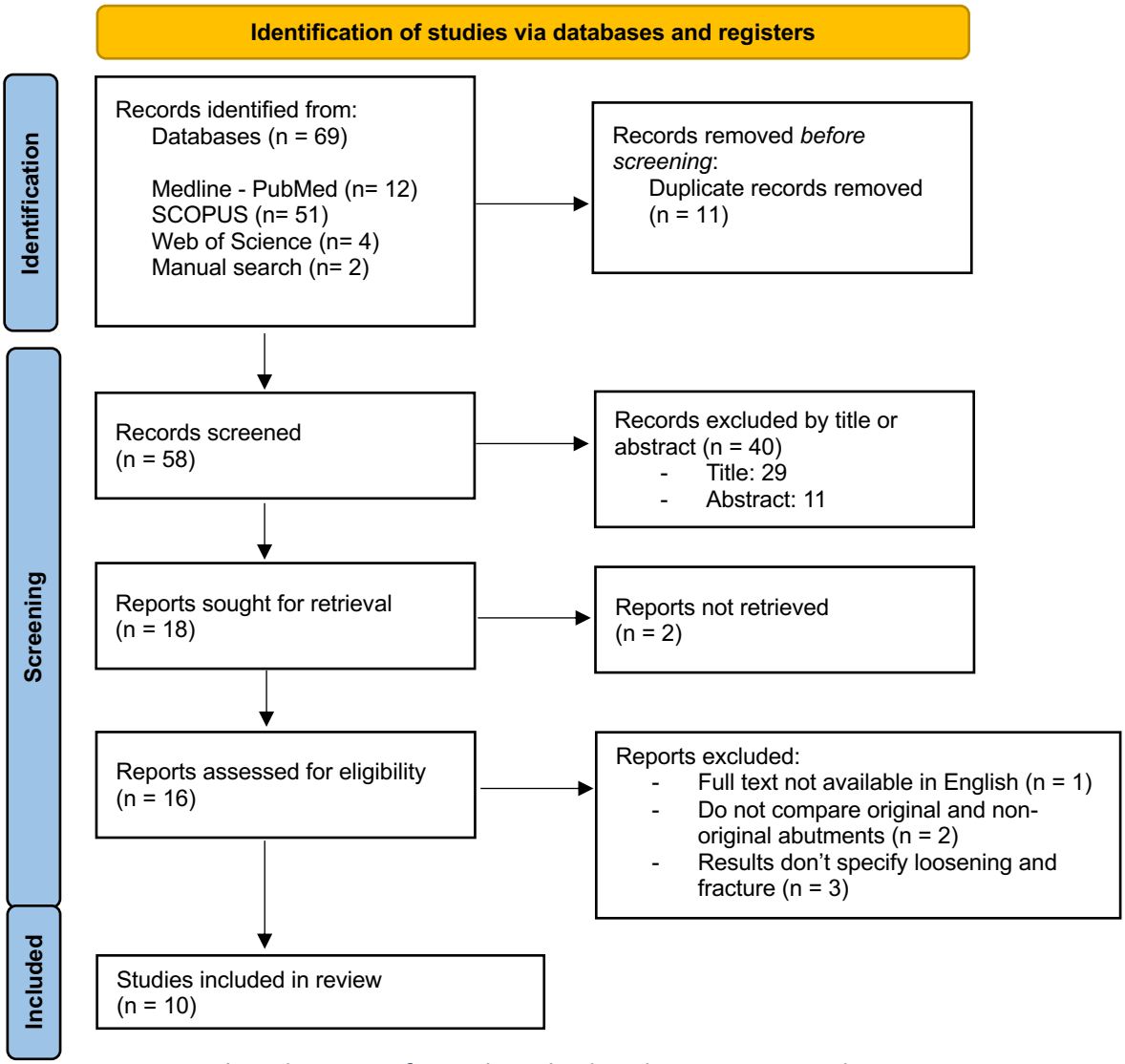

Figure 1: Flow diagram of search and title selection process during systematic review.

Table 3: Articles excluded (and reason for exclusion) from this systematic review.

Author. Year	Publication	Reason for exclusion
Shen Q. 2022 (43)	West China Journal of Stomatology	Full text not available in English
Ožiūnas R. 2023 (44)	Journal of Advanced Prosthodontics	Do not compare original and non-original abutments
Mattheos N. 2017 (45)	Clinical Oral Implants Research	Do not specify results of loosening and/or fracture
Karl M. 2018 (46)	International Journal of Oral and Maxillofacial Implants	Do not specify results of loosening and/or fracture
Karl M. 2016 (47)	International Journal of Oral and Maxillofacial Implants	Do not specify results of loosening and/or fracture
Barreiros P. 2020 (48)	Dentistry Journal	Do not compare original and non-original abutments

8.2 Analysis of the characteristics of the studies revised

From the 10 articles reviewed five study the loosening of the abutment screw (7,37,49–51), four studied the fracture of the abutment screws (38,52–54) and one both loosening and fracture of the abutment screw (3).

Nine studies were using original and non-original abutments connecting them to implants with internal connection (7,33,37,38,49,51–54), only one study was testing the original and non-original abutments on external connection implants (50).

All of the studies were in-vitro studies. A total of 405 samples were studied: 149 original abutments and 226 non-original abutments (Table 4).

Table 4: Number of abutments studied

	N° of original abutments	N° of non-original	Total N° of abutments
Silva et al. (2021)	10	20	30
Pournasiri et al. (2022)	10	20	30
Ožiūnas et al. (2022)	8	24	32
Gigandet et al. (2014)	34	24	58
Cashman et al. (2011)	20	20	40
Alonso-Pérez et al. (2018)	21	42	63
Alonso-Pérez et al. (2022)	16	32	48
Alonso-Pérez et al. (2021)	16	32	48
Kim et al. (2012)	7	21	28
Park et al. (2017)	7	21	28
Total N°	149	226	405

The studies also consider the dimensions of implants, including length and diameter configurations. The implant dimensions vary from 10-13mm in length and 3.5-4.8mm in diameter. The lengths and diameters of each study are specified in Table 5.

The studies evaluate various implant and abutment brands. Brands such as Straumann, Nobel, Astra Tech, Zimmer Biomet, Mis and Dentsply are tested across different studies. The implants and their original and nonoriginal parts used in the various studies are specified in Table 6.

Table 5: General characteristics of the studies reviewed

Author (year)	Type of study	Implant connection type	implant length x diameter (mm)	N° of original abutments	N° of non-original	Total N° of abutments	Number of cycles	Loading force (N)
Silva et al. (2021) (52)	In-vitro	internal		10	20	30		
Pournasiri et al. (2022) (37)	In-vitro	internal	12 x 4.8	10	20	30	500,000	75
Ožiūnas et al. (2022) (49)	In-vitro	internal-conical	11 x 3.5	8	24	32	1,200,000	50
Gigandet et al. (2014) (38)	In-vitro	internal		34	24	58		
Cashman et al. (2011) (50)	In-vitro	external	12x4.1	20	20	40	5x10^6 = 5,000,000	10-200
Alonso-Pérez et al. (2018) (7)	In-vitro	internal	12x4.8	21	42	63	2x10^6 = 2,000,000	
Alonso-Pérez et al. (2022) (53)	In-vitro	internal hexagon	13x3.5	16	32	48		
Alonso-Pérez et al. (2021) (55)	In-vitro	internal hexagon		16	32	48		
Kim et al. (2012) (33)	In-vitro	internal	10 x 4.1	7	21	28	1,000,000	150
Park et al. (2017) (51)	In-vitro	internal	10 x 4.1	7	21	28	500,000	25

Table 6: General characteristics of the studies reviewed

Author (year)	Implant brand	OA brand	NOA brand
Silva et al. (2021) (52)	Mis	Mis	1. Iconekt 2. Exaktus
Pournasiri et al. (2022) (37)	Straumann, ITI	Straumann, ITI	1. Cowell Medi 2. Euroteknika,
Ožiūnas et al. (2022) (49)	Dentsply Sirona	Dentsply Sirona	1. Arum®, Doowonid Co. 2. Implant Protesis Dental 2004 S.L. 3. Terrats Medical S.L
Gigandet et al. (2014) (38)	Straumann Nobel Astra Tech	Straumann Nobel Astra Tech	1. Nobel 2. Astra Tech
Cashman et al. (2011) (50)	Straumann	Straumann	Titan Implant Inc.
Alonso-Pérez et al. (2018) (7)	Straumann	Straumann	1. LC 2. Proclinic
Alonso-Pérez et al. (2022) (53)	Zimmer Biomet	Hex-Lock contour abutment, Zimmer Biomet	1. Medical Implant System 2. Implant Direct
Alonso-Pérez et al. (2021) (55)	Zimmer Biomet	Zimmer Biomet	1. Implant Direct 2. MIS
Kim et al. (2012) (33)	Straumann	Straumann	1. Restore RDS COC abutment, Lifecore Biomedical Inc 2. Neoplant solid abutment, Neobiotech 3. AVANA solid abutment, Osstem Co
Park et al. (2017) (51)	Straumann	Straumann	1. Southern Implants 2. Implant Direct 3. Blue Sky Bio

8.3 Assessment of methodological quality and risk of bias

As there are no established sets of criteria/guidelines for assessing the quality or risk of bias for in vitro studies, we assessed the quality of all selected full-text articles using the modified ARRIVE combined with CONSORT (consolidated reporting of trials) guidelines for in vitro experiments (Table 7), based on the previous studies (41). The evaluation was based on a predefined grading system of the checklist for in vitro studies.

Table 7: Quality assessment of in-vitro studies (modified from the ARRIVE and CONSORT guidelines)

	Silva et al. (2021)	Pournasiri et al. (2022)	Ožiūnas et al. (2022)	Gigand et al. (2014)	Cashman et al. (2011)	Alonso-Pérez et al. (2018)	Alonso-Pérez et al. (2022)	Alonso-Pérez et al. (2021)	Kim et al. (2012)	Park et al. (2017)
1. Title	1	1	1	1	1	1	1	1	1	1
2. Abstract either a structured summary of background, research objectives, key experiment methods, principal findings, and conclusion of the study or self-contained (should contain enough information to enable a good understanding of the rationale for the approach)	3	3	3	3	3	3	3	3	3	3
3. Introduction: background, experimental approach, and explanation of rationale/hypothesis	3	3	3	3	3	3	3	3	2	2
4. Introduction: preprimary and secondary objectives for the experiments (specific primary/secondary objectives)	2	2	2	2	2	2	2	2	2	2
5. Methods: study design explained number of experimental and control groups, steps to reduce bias (demonstrating the consistency of the experiment (done more than once), sufficient detail for replication, blinding in evaluation, etc.)	2	2	2	2	3	2	2	2	2	2
6. Methods: precise details of experimental procedure (i.e., how,	3	3	3	2	3	3	3	3	3	3

when, where, and why)										
7. Methods: How sample size was determined (details of control and experimental group) and sample size calculation.	3	3	3	3	3	3	3	3	3	2
8. Methods: Details of statistical methods and analysis (statistical methods used to compare groups)	3	3	3	3	3	3	3	2	3	3
9. Results: explanation for any excluded data, results of each analysis with a measure of precision as standard deviation or standard error or confidence interval	3	2	3	3	3	3	3	3	3	3
10. Discussion: interpretation/scientific implication, limitations, and generalizability/translation	2	2	2	1	3	2	2	2	1	1
11. Statement of potential conflicts and funding disclosure	1	1	0	0	1	1	1	0	1	1
12. Publication in a peer-review journal	1	1	1	0	1	0	1	1	1	1

8.4 Synthesis of results

8.4.1 Abutment screw loosening

Six studies out of 10 presented results for screw loosening comparing original and non-original abutments (7,33,37,49–51). When comparing the insertion torque and post-loading RTV of original abutment screws the mean torque loss was 20.33%, ranging from 2.85% (51) to 44.93% (49).

Regarding the non-original abutments, the mean rate of loosening was 38.9%, ranging from 6.9% (51) to 72.5% (49).

The smallest rate for torque loss corresponds to the study which administered the smallest amount of cyclic loads (500,000) with the lowest force (25N) (51). On the other hand the highest rate of torque loss corresponds to the study which had the lowest preload value and administered high number of cycles (1,200,000) with a higher force (50N) (49). Ožiūnas et al. (49) also compared the screw loosening with original and non-original titanium-bases instead of normal abutments.

One study (50) did not present screw loosening after cyclic loading, instead the post-loading RTV increased after cyclic loading in both original and non-original abutments. This may be due to the fact that the implant connection type was external connection.

In general original abutments exhibit lower torque loss compared to non-original abutments, indicating potentially better stability and performance.

Descriptive results on screw loosening are demonstrated in Table 8.

Table 8: Descriptive results of the screw loosening comparing original and non-original screws

	Insertion torque (Ncm)	Preloading RTV (Ncm)		Postloading RTV (Ncm)		Torque loss	
Original abutments		**Mean**	**SD**	**Mean**	**SD**	**Ncm**	**%**
Pournasiri et al. (2022)	35	30.7	2.26	23	4.63	12.0	34.29
Ožiūnas et al. (2022)	15	11.5	0.86	8.26	1.24	6.74	44.93
Cashman et al. (2011)	35	33.75	1.86	42.65	6.70	+	+
Alonso-Pérez et al. (2018)	35	33.4	1.5	30.4	1.8	4.6	13.14
Kim et al. (2012)	35	-	-	32.74	2.74	2.26	6.46
Park et al. (2017)	35	-	-	34.0	1.1	1.0	2.85
TOTAL average							**20.33**
TOTAL median							**13,14**
Min torque loss							**2,85**
Max torque loss							**44,93**
Non-original abutments		**Mean**	**SD**	**Mean**	**SD**	**Ncm**	**%**
Pournasiri et al. (2022)	35	29.2	3.61	21.6	3.89	13.4	38.29
		29.1	2.6	21.0	4.78	14	40
Ožiūnas et al. (2022)	15	13.16	0.64	8.53	0.87	6.47	43.08
		11.48	0.84	6.22	1.41	8.78	58.50
		10.95	1.0	4.12	1.26	10.88	72.50
Cashman et al. (2011)	35	35.56	3.55	36.25	2.63	+	+
Alonso-Pérez et al. (2018)	35	31.6	1.1	26.4	3.2	8.6	24.6
		24.5	2.9	23.8	2.9	11.2	32.1
Kim et al. (2012)	35	-	-	22.79	5.46	12.21	34.89
		-	-	12.00	0	23	65.71
		-	-	18.67	3.21	16.33	46.65
Park et al. (2017)	32	-	-	25.0	1.5	7	21.9
	30	-	-	23.9	2.1	6.1	20.2
	30	-	-	27.9	1.3	2.1	6.9
TOTAL average							**38,87**
TOTAL median							**38,29**
Min torque loss							**6,9**
Max torque loss							**72,50**

8.4.2 Abutment screw fracture

Five studies out of then presented results for screw fracture comparing original and non-original screws (3,38,52–54).

In the comparative analysis of fracture resistance between original and non-original abutment screws, the majority of studies (four out of five) demonstrated superior outcomes in the original abutment group (Table 9).

However, one study reported unexpected findings favoring the non-original abutment group, potentially attributed to the utilization of stiffer materials in the abutments, specifically grade V titanium.

The descriptive results on screw fracture comparing original and non-original screws are presented in Table 9.

Table 9: Descriptive results on screw fracture comparing original and non-original

Author (year)	Better fracture resistance
Silva et al. (2021) (52)	Original
Gigandet et al. (2014) (38)	Non-original
Alonso-Pérez et al. (2022) (53)	Original
Alonso-Pérez et al. (2021) (55)	Original
Kim et al. (2012) (33)	Original

9 DISCUSSION

The present systematic review provides evidence-based information on loosening and fracture of abutment screws comparing original and non-original abutments. The aim of this review was to compare the biomechanical behavior of original versus non-original abutment screws; and specifically, to evaluate the loosening (torque loss) and fracture resistance of original and non-original screws.

9.1 Screw loosening

The findings from the systematic review regarding abutment screw loosening reveal several important insights. Firstly, the comparison between original and non-original abutments across six studies indicates that original abutments generally exhibit lower rates of screw loosening. The mean torque loss for non-original abutments was notably higher 38,89% in comparison to original abutments 20,33% respectively. These results suggest that original abutments may offer better biomechanical behavior and stability in terms of screw retention.

The effectiveness of using compatible components depends on the adherence to manufacturer standards and machining tolerance. It is anticipated that compatible components have a better fit with original components. However, findings from the study of Pournasiri et al. indicate that there is not a significant difference in reverse torque values among the three original and non-original components. These findings imply that non-original components demonstrate satisfactory compatibility with original abutments, and the combination of implant components from the mentioned systems does not result in screw loosening. However, these results could be affected by the small sample size in the study (37). In contrast, previous research by Kim et al. and Cashman et al. suggest that original components demonstrate greater stability and resistance to screw loosening when compared to other compatible systems (3,50).

Oziunas et al. evaluated screw loosening after cyclic loading with original titanium bases or with non-original components. The study concludes in that it is evident that the brand of the titanium base significantly impacts screw loosening after fatigue testing. Specific factors contributing to these differences could be varying machine tolerance, material properties and surface irregularities of the components made by different

manufacturers. In agreement with our hypothesis original components are recommended to ensure long-term stability of the implant restoration complex (49).

Alonso-Perez et al. (2018) evaluated the removal torque values of original and non-original abutment screws after cyclic loading. Screw loosening was less prevalent when using original abutments, which showed a lesser reduction in torque of the abutment-implant screw following cyclic loading compared to non-original components. These findings suggest that the original configuration offers the most favorable outcomes for the long-term success of implant restorations (7).

Similarly in the study of Park et al. removal torque values were evaluated after cyclic loading comparing the loosening of interchangeable abutments. The original abutment reported a significantly higher reverse torque value compared to the copy abutments, indicating differences in the physical and chemical properties. Although there is no conclusive evidence in this study, the results suggest that there may be risks associated with the use of interchangeable abutments. Therefore, to reduce the risk of abutment screw loosening, it is recommended to use abutments manufactured by the same implant company (51).

Regarding reverse torque values, in this systematic review we observed a significant torque loss after cyclic loading, consistent with findings by Yilmaz et al (56). However, Tsuge et al. (57) and Cashman et al. (50) reported post-loading values being significantly higher than initial preload, while Khraisat et al. (58) found no significant difference between pre-loading and post-loading reverse torque values. Discrepancies in results could be attributed to variations in abutment screw type, material, and tightening torque.

While pre-loading and post-loading reverse torque values differed among samples in each study group, the differences were not significant. This could be due to variations in the finishing process of screws leading to different embedment relaxation and preload. Additionally, surface roughness of implant components can affect preload.

Ghanbarzadeh et al. demonstrated that one-piece abutments exhibit higher reverse torque values and resistance to screw loosening compared to two-piece abutments, potentially explaining the variance in results between different studies (59). Implant-abutment fit plays a significant role in screw loosening. Some studies have measured vertical misfit between implants and abutments instead of torque loss to

assess compatibility. In disagreement with the current study, Zanardi et al. found that alternative abutments were compatible with other studied systems (60).

9.2 Screw fracture

Most studies favored original abutments in terms of fracture resistance. However, one study (38) unexpectedly found better results with non-original abutments, possibly due to the use of stiffer materials in the abutments (grade V titanium). This highlights the complexity of factors influencing screw fracture and underscores the importance of considering material properties in future studies.

Piermatti et al.'s work highlights the importance of screw material strength in preload. It is suggested to tighten the screw to 75% to 80% of the material's yield strength to prevent permanent deformation. However, while stronger screws theoretically allow for higher preload, beyond a certain tightening threshold, the friction between the implant and screw threads can become excessive (61).

Silva et al. conducted a comparison of the fracture sites of original and replica screws, yielding notably divergent results. This outcome is unexpected considering the similarities in material composition and morphologies between the brands. Further research is necessary to investigate whether specific properties in the alloy or screw morphology contribute to these findings. Despite observing lower maximum torque values in the replica screws, statistical analysis revealed no significant differences in fracture torque between the original and replica screws (52).

Gigandet et al. evaluated the maximal force needed up to fracture and obtained clearly lower value in the non-original abutment connections than in the original connection, with some non-original abutments showing higher misfit that could lead to fractures (38).

The results obtained by Alonso-Perez et al. suggest that resistance to cyclic loading decreases significantly when non-original abutment components are used, presenting a major risk of failure in a short period of time. In the case of non-originals abutment-implant system under cyclic loading, the stress tends to concentrate at the screw of abutments, which could lead to microfractures (53).

Kim et al. measured the removal torque values after cyclic loading and reported no mechanical failures in the original group, however the non-original group presented screw fractures and implant fractures supporting the hypothesis of our study (3).

Rizvi et al. analyzed 40 studies focusing on different types of implant-abutment connections, particularly the use of original and non-original abutments. Their findings revealed that original abutments exhibited superior precision of fit, resistance to microleakage, prevention of rotational misfit and micromotion, and greater fatigue strength when compared to non-original abutments (39).

In a prospective 10-year clinical study by Fischer et al. mechanical complications of original prosthetic components in 132 implants were studied. No fractures of abutments or abutment screws were observed (62).

9.3 Limitations of the study

The primary limitation of the current systematic review lies in the inclusion of only in vitro studies, which often lack comprehensive methodological details. In vitro studies are often chosen in research settings to provide controlled and standardized conditions for investigating specific variables or phenomena without the complexity and variability inherent in clinical environments. Inconsistent and multi-directional loads in the oral cavity make it challenging to predict clinical outcomes only based on in vitro studies.

To enhance in vitro studies investigating the loosening and fracture of implant crown screws, several improvements can be implemented to better mimic clinical conditions. Firstly, efforts should be made to replicate oral biomechanics more accurately within the laboratory setting. This may involve developing custom loading apparatus that can simulate the complex and dynamic forces experienced in the oral cavity, such as occlusal forces and parafunctional habits.

Additionally, using more realistic surrogate materials to mimic the mechanical properties of surrounding dental tissues, such as bone and soft tissue, can provide a more realistic testing environment.

Furthermore, incorporating cyclic loading protocols that simulate long-term function can better replicate the fatigue processes that contribute to screw loosening and fracture over time.

Finally, standardizing testing methodologies and reporting parameters across studies can facilitate comparisons between different research findings and improve the overall reliability and reproducibility of in vitro investigations in this field.

The variability in torque loss rates among the studies underscores the influence of experimental factors such as cyclic load magnitude and duration, as well as preload values. For instance, the study with the lowest torque loss rate utilized a smaller number of cycles and lower force, while the study with the highest torque loss rate employed a higher number of cycles and force. This variability highlights the importance of standardizing experimental conditions in future research to enable more accurate comparisons. Establishing standardized protocols for experimental procedures and reporting guidelines for research publications can improve the consistency and reproducibility of research findings. Adhering to standardized protocols facilitates comparisons across studies and enhances the reliability of meta-analyses and systematic reviews.

Moreover, the observation that one study did not report screw loosening after cyclic loading, but instead showed an increase in post-loading reverse torque values, suggests potential limitations in the experimental setup or differences in implant connection types. Differences in experimental setup or implant connection types for example variations in implant-abutment interface design, material, and surface treatment of implants, tightening protocol, loading protocol, and experimental conditions can significantly influence results regarding post-loading reverse torque values and screw loosening in studies. This finding emphasizes the need for careful consideration of experimental variables and the interpretation of results within the appropriate context.

9.4 Future research and clinical implications

The success of dental implants depends on a combination of biological and mechanical factors. Although the osseointegration is usually successful, mechanical problems like screw fractures pose notable challenges in dental implant procedures, with reported occurrences reaching as high as 44.9% (37).

Although consistency is anticipated in implants and their original parts, concerns persist about the practicality and efficacy of using compatible components rather than original abutments. The successful integration of compatible components relies on strict adherence to manufacturing standards and machining tolerances to ensure seamless compatibility with the original components (37).

Further research is required to understand the effects of cyclic loading on reverse torque value and its relationship with screw loosening, considering plastic deformation and cold welding.

Our research highlights the significant concern of screw loosening, a phenomenon which may not be fully recognized in clinical environments. Discrepancies between laboratory experiments and those observed clinically are evident, with reported incidences of screw loosening ranging from 0% to 13% despite relatively short follow-up periods (50).

To resolve these differences, it is essential to identify appropriate laboratory testing techniques and evaluate the reliability of comparing pre and postfatigue retentive torque value measurements, considering potential alterations during fatigue loading.

Additionally, our study lacked clarity on the primary factors contributing to screw and crown loosening between original and non-original components.

Future research should also involve analyzing the chemical composition of screw materials or evaluations of screw design and comparison, ideally with larger sample sizes to detect statistically significant differences in fracture torque.

These actions are critical for advancing our understanding of dental implant mechanics and improving clinical outcomes in implant dentistry.

More studies are required to determine the threshold of cyclic loading affecting reverse torque value and leading to screw loosening.

Researchers can enhance practicality by establishing clear experimental protocols, using various loading conditions to simulate clinical scenarios, incorporating realistic loading scenarios, monitoring reverse torque value changes over time, assessing plastic deformation and cold welding, considering material properties and surface treatments, and validating findings with clinical data.

By following these guidelines, researchers can conduct more practical and clinically relevant studies to enhance our understanding of implant behavior under dynamic loading conditions.

10 CONCLUSION

General conclusion

1. Biomechanical behavior of abutment screws varies between original and non-original screws, with notable differences observed in fracture resistance and torque loss.

Specific conclusions

1. Original screws present less torque loss compared to non-original screws.
2. Original screws present better fracture resistance compared to non-original screws.

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12 ANNEXES

Table 1: Summary of the searches for each of the databases consulted

Database	Search	Number of articles	Date
PubMed	("Dental Implant-Abutment Design"[MeSH Terms] OR "Dental Abutments"[MeSH Terms] OR "implant abutment"[All Fields] OR "implant-abutment complex"[All Fields] OR "titanium base"[All Fields]) AND ("non-original"[All Fields] OR "non-original screw"[All Fields] OR ("replica"[All Fields] OR "replicas"[All Fields]) OR ("compatability"[All Fields] OR "compatibilities"[All Fields] OR "compatibility"[All Fields] OR "compatible"[All Fields] OR "compatibles"[All Fields])) AND ((("creativity"[MeSH Terms] OR "creativity"[All Fields] OR "originality"[All Fields] OR "original"[All Fields] OR "originalities"[All Fields] OR "originally"[All Fields] OR "originals"[All Fields] OR "originator"[All Fields] OR "originator s"[All Fields] OR "originators"[All Fields]) AND ("bone screws"[MeSH Terms] OR ("bone"[All Fields] AND "screws"[All Fields]) OR "bone screws"[All Fields] OR "screw"[All Fields] OR "screw s"[All Fields] OR "screwed"[All Fields] OR "screwing"[All Fields] OR "screws"[All Fields])) OR "fixing screw"[All Fields] OR "original abutment"[All Fields] OR "abutment screw"[All Fields] OR "implant screw"[All Fields] OR "stock abutment"[All Fields]) AND ("screw fracture"[All Fields] OR "screw loosening"[All Fields] OR "abutment screw fracture"[All Fields] OR "abutment screw loosening"[All Fields] OR "implant screw fracture"[All Fields] OR "implant screw loosening"[All Fields] OR "mechanical behavior"[All Fields] OR "mechanical resistance"[All Fields] OR ("fatiguability"[All Fields] OR "fatiguable"[All Fields] OR "fatigue"[MeSH Terms] OR "fatigue"[All Fields] OR "fatigued"[All Fields] OR "fatigues"[All Fields] OR "fatiguing"[All Fields] OR "fatigueability"[All Fields]) OR (("reversal"[All Fields] OR "reversals"[All Fields] OR "reverse"[All Fields] OR "reversed"[All Fields] OR "reversely"[All Fields] OR "reverses"[All Fields] OR "reversibilities"[All Fields] OR "reversibility"[All Fields] OR "reversible"[All Fields] OR "reversing"[All Fields] OR "reversion"[All Fields] OR "reversions"[All Fields]) AND ("torque"[MeSH Terms] OR "torque"[All Fields] OR "torques"[All Fields] OR "torqued"[All Fields] OR "torqueing"[All Fields] OR "torquing"[All Fields]))	12	1.2.2024
Scopus	(ALL ("DENTAL IMPLANT-ABUTMENT DESIGN" OR "DENTAL ABUTMENTS" OR "IMPLANT ABUTMENT" OR "IMPLANT-ABUTMENT COMPLEX" OR "TITANIUM BASE") AND ALL (NON-ORIGINAL OR "NON-ORIGINAL SCREW" OR REPLICA OR COMPATIBLE) AND ALL (ORIGINAL AND SCREW OR "FIXING SCREW" OR "ORIGINAL ABUTMENT" OR "ABUTMENT SCREW" OR "IMPLANT SCREW" OR "STOCK ABUTMENT") AND ALL ("SCREW FRACTURE" OR "SCREW LOOSENING" OR "ABUTMENT SCREW FRACTURE" OR "ABUTMENT SCREW LOOSENING" OR "IMPLANT SCREW FRACTURE" OR	51	1.2.2024

	"IMPLANT SCREW LOOSENING" OR "MECHANICAL BEHAVIOR" OR "MECHANICAL RESISTANCE" OR FATIGUE OR REVERSE AND TORQUE))		
Web Of Science	(ALL=(("dental implant-abutment design" OR "dental abutments" OR "implant abutment" OR "implant-abutment complex" OR "titanium base") AND (non-original OR "non-original screw" OR replica OR compatible) AND (original AND screw OR "fixing screw" OR "original abutment" OR "abutment screw"OR "implant screw" OR "stock abutment") AND ("screw fracture" OR "screw loosening" OR "abutment screw fracture" OR "abutment screw loosening"OR "implant screw fracture" OR "implant screw loosening" OR "mechanical behavior" OR "mechanical resistance" OR fatigue OR reverse AND torque) AND "dental implants")) AND ALL=(("Dental Implant-Abutment Design" OR "Dental Abutments" OR “implant abutment” OR “implant-abutment complex” OR “titanium base”) AND (non-original OR “non-original screw” OR replica OR compatible) AND (original screw OR “fixing screw” OR “original abutment” OR “abutment screw” OR “implant screw” OR “stock abutment”) AND (“screw fracture” OR “screw loosening” OR “abutment screw fracture” OR “abutment screw loosening” OR “implant screw fracture” OR “implant screw loosening” OR “mechanical behavior” OR “mechanical resistance” OR fatigue OR reverse torque))	4	1.2.2024

Table 2: The method of measurement of the principal variable in each article

Authors and year	Variable	Way of measurement
Silva et al. (2021) (52)	Fracture	Fracture torque (Ncm) *the screws to be tested were subjected to a torsional force with a torque wrench until fracture occurred
Pournasiri et al. (2022) (37)	Loosening	1) pre-loading reverse torque value (RTV) 2) post-loading RTV *the reverse torque value was evaluated prior to and after cyclic loading (1.200.000 cycles)
Ožiūnas et al. (2022) (49)	Loosening	1) initial RTV 2) postload RTV *the reverse torque value was evaluated prior to and after cyclic loading (500.000 cycles)
Gigandet et al. (2014) (38)	Fracture	Maximal force needed up to fracture (N)
Cashman et al. (2011) (50)	Loosening	1) Baseline RTV 2) Post-fatigue RTV
Alonso-Pérez et al. (2018) (7)	Loosening	1) RTV after 10min 2) RTV after dynamic loading
Alonso-Pérez et al. (2022) (53)	Fracture	Fatigue limit (N) *Maximum load/cycles to failure
Alonso-Pérez et al. (2021) (55)	Fracture	Fatigue limit (N) *Maximum load/cycles to failure
Kim et al. (2012) (33)	1) Loosening 2) Fracture	1) Loosening RTV *after 1 million loads 2) Fracture Cycles to fracture (150 N)
Park et al. (2017) (51)	Loosening	RTV (Ncm) *after ½ million cycles

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	front page
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	20
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	23
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	25
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	26
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	26-28
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	28
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	28-29
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	28-29
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	28-29
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	29
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	28-29
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	29-30
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	29-30
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	29-30
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	29-30
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	29-30
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	29-30
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	29-30

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	29-30
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	32
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	33
Study characteristics	17	Cite each included study and present its characteristics.	33
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	37-38
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	40,41
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	38-41
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	43-46
	23b	Discuss any limitations of the evidence included in the review.	47-49
	23c	Discuss any limitations of the review processes used.	47- 49
	23d	Discuss implications of the results for practice, policy, and future research.	47- 49
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	26	Declare any competing interests of review authors.	
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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Title of the article:

Loosening and fracture of original vs non-original abutment screws in Implantology: Systematic review

Running title:

Loosening and fracture of original vs non-original abutment screws in Implantology

Authors:

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Abstract:

Background: Comparing original and non-original abutment screws is essential for optimizing dental implant procedures. Understanding the biomechanical behavior of these components helps clinicians make informed decisions, ensuring implant stability and durability. Complications such as screw loosening and fracture can lead to implant failure, emphasizing the need to identify any differences between original and non-original screws to diminish risks. Additionally, assessing the performance of non-original screws provides valuable insights into their suitability as alternatives, considering factors like cost and availability. Overall, this comparison enhances patient outcomes and improves the reliability of dental implant treatments. The aim of the review is to study the biomechanical behavior and specifically to compare the fracture resistance and loosening incidence between original and non-original abutment screws.

Material and Methods: This review used a systematic approach following PRISMA guidelines, examining studies indexed in major databases such as Medline-PubMed, Web of Science, and Scopus. The focus was on comparing original and non-original abutment screws regarding their biomechanical behavior, specifically their fracture resistance and torque loss.

Results: Ten studies met the inclusion criteria; 5 studies on screw loosening, 4 studies on screw fracture and 1 study of both loosening and fracture. Original abutments showed better performance in terms of lower torque loss (20.33%) in respect to non-original abutments (38,87%). Original abutments showed better fracture resistance compared to non-original abutments. Variations in manufacturing standards and compatibility were noted as significant influences on performance.

Conclusions: Original abutment screws exhibit better biomechanical stability than non-original ones when studying loosening and fracture. This suggests a higher reliability of original components in maintaining the structural integrity and functionality of dental implants. Ensuring compatibility and adhering to manufacturing standards are critical for optimizing implant success.

Key Words: Loosening, fracture, original screw, non-original screw, dental abutment

Introduction:

In recent years, dental implants have revolutionized the field of dentistry, providing effective solutions for tooth loss with high success rates (1–8). However, despite significant advancements, complications associated with dental implants can arise, causing inconvenience, expense, and discomfort for patients (1,5). Understanding the causes and consequences of these complications is essential for improving treatment outcomes and patient satisfaction.

Implant complications can be broadly categorized into biological and technical problems (1,5,9). Biological complications include peri-implant mucositis, soft tissue inflammation, and radiographic signs of osseointegration loss (5,10). On the other hand, technical problems involve issues such as screw loosening and fracture, framework or porcelain fracture, and marginal gap formation (5,9–11).

One of the primary concerns in implant dentistry is abutment screw loosening and fracture, which can compromise the stability and longevity of the implant restoration. Several factors contribute to screw loosening, including implant-abutment connection design, diameter and length of the screw, material of the abutment and screw, implant position, and occlusal forces (9). Excessive or insufficient preload, as well as parafunctional habits, can also play a role in screw loosening (12,13).

Differentiating between original and non-original components is crucial in implant dentistry, as compatibility issues and variations in design and material composition can affect treatment outcomes (2). While original components are often associated with higher success rates and long-term stability, non-original components may present higher risks of failure, particularly in the short term. The internal accuracy and mechanical fatigue behavior of non-original components are often compromised, leading to rotational misfit and increased risk of complications such as screw fracture (14).

This review aims to address the biomechanical behavior of original versus non-original abutment screws, specifically differences in torque loss and fracture resistance.

Material and Methods:

This systematic review adhered to the PRISMA guidelines to ensure a thorough and unbiased analysis of existing literature (15).

PICO question:

This study question was set according to the PICO structured question. The question format was established as follows: P (population): Abutment screws placed in vitro, I (intervention): Non-original abutments, C (comparison): Original abutments and O (outcome): Biomechanical behavior; O1: Loosening (torque loss), O2: Fracture (resistance).

Eligibility criteria:

The inclusion criteria were: Type of study: In-vitro studies; Publications in English; Published until January of 2024. Type of patient: In-vitro studies. Type of intervention: Measuring the loosening and fracture. Type of outcome variables: Studies that provide data about the fracture and/or loosening of screws as main variable.

Regarding the exclusion criteria: Type of study: Reviews, clinical case studies, letters or comments to the editor, expert reports. Type of intervention: Articles that do not compare original vs non-original abutments.

Information sources and data search:

An automatized electronic and manual search, was carried out in three databases: PubMed, Scopus and Web of Science. Keywords were combined with the Boolean operators AND, OR and NOT, as well as controlled terms ("MeSH" for Pubmed) to obtain the best and broadest search results.

In order to identify any eligible studies that the initial search might have missed, the search was completed with a review of the references provided in the bibliography of each of the studies. In addition, a hand search was conducted for scientific articles.

Finally, a cross-search of potentially interesting articles for analysis was performed. Duplicate studies were eliminated from the review.

Search strategy:

A three-stage selection process was carried out. The selection of studies was carried out by two reviewers (ZC, DL).

In the first stage, articles were filtered by titles to eliminate irrelevant publications.

In the second stage, the abstracts were screened and selected according to the type of study, type of intervention, number of samples, and outcome variables.

In the third stage, articles were filtered by reading the full text and proceeded to data extraction using a data collection form previously developed to confirm the eligibility of the studies.

Extraction data:

The following information was extracted from the studies and arranged in tables: authors with year of publication, type of study (in-vitro), implant connection type, implant length and diameter, implant brand, original abutment brand, non-original abutment brand, number of original abutments, number of non-original abutments, total of abutments, number of cyclic loads, loading force (N), insertion torque (Ncm), mean preloading reverse torque value (RTV), mean post loading RTV, torque loss, fracture resistance.

Quality and risk of bias assessment:

The risk of bias assessment was evaluated by two reviewers (ZC, DL) to analyze the methodological quality of the included articles.

A quality assessment of full-text articles was performed according to modified ARRIVE and CONSORT criteria tool for in vitro studies (the evaluation was based on predefined grading system). Categories used to assess the correct conduct and structure are title, abstract, introduction, materials and methods, results, discussion, and conclusions (16,17).

Data synthesis:

To summarize and compare the outcome variables between the different studies, the means of the values of the main variables were grouped according to the study group.

Conducting a meta-analysis was not possible due to potential limitations in the number, heterogeneity, and quality of existing studies, as well as issues related to publication bias and the diversity of abutment and implant systems.

Results:

Study selection

A total of 69 articles were obtained from the initial search process: Medline-PubMed (n=12), SCOPUS (n=51) and Web of Science (n=4). In addition, 2 articles were obtained through manual searching (reference list). Of these articles, 18 were identified as potentially eligible articles through screening by title and abstract. The full-text articles were subsequently obtained and thoroughly evaluated. As a result, ten studies met the inclusion criteria and were included in the study.

Study characteristics

From the 10 articles reviewed five study the loosening of the abutment screw (7,18–21), four studied

the fracture of the abutment screws (14,22–24) and one both loosening and fracture of the abutment screw (4).

Nine studies were using original and non-original abutments connecting them to implants with internal connection (7,13,14,18,20–24), only one study was testing the original and non-original abutments on external connection implants (19).

All of the studies were in-vitro studies. A total of 405 samples were studied: 149 original abutments and 226 non-original abutments.

Risk of bias

As there are no established sets of criteria or guidelines for assessing the quality or risk of bias for in vitro studies, we assessed the quality of all selected full-text articles using the modified ARRIVE combined with CONSORT (consolidated reporting of trials) guidelines for in vitro experiments (Table 1), based on the previous studies (16). The evaluation was based on a predefined grading system of the checklist for in vitro studies.

Synthesis of results

Abutment screw loosening:

Six studies out of 10 presented results for screw loosening comparing original and non-original abutments (7,13,18–21). When comparing the insertion torque and post-loading RTV of original abutment screws the mean torque loss was 20.33%, ranging from 2.85% (18) to 44.93% (20).

Regarding the non-original abutments, the mean rate of loosening was 38.9%, ranging from 6.9% (18) to 72.5% (20).

The smallest rate for torque loss corresponds to the study which administered the smallest number of cyclic loads (500,000) with the lowest force (25N) (18). On the other hand, the highest rate of torque loss corresponds to the study which had the lowest preload value and administered high number of cycles (1,200,000) with a higher force (50N) (20). Ožiūnas et al. (20), also compared the screw loosening with original and non original titanium-bases instead of normal abutments.

One study (19) did not present screw loosening after cyclic loading, instead the post-loading RTV increased after cyclic loading in both original and non-original abutments. This may be due to the fact that the implant connection type was external connection.

In general, original abutments exhibit lower torque loss compared to non-original abutments, indicating potentially better stability and performance (Table 2).

Table 2: Descriptive results of the screw loosening comparing original and non-original screws

	Insertion torque (Ncm)	Preloading RTV (Ncm)		Postloading RTV (Ncm)		Torque loss	
Original abutments		**Mean**	**SD**	**Mean**	**SD**	**Ncm**	**%**
Pournasiri et al. (2022)	35	30.7	2.26	23	4.63	12.0	34.29
Ožiūnas et al. (2022)	15	11.5	0.86	8.26	1.24	6.74	44.93
Cashman et al. (2011)	35	33.75	1.86	42.65	6.70	+	+
Alonso-Pérez et al. (2018)	35	33.4	1.5	30.4	1.8	4.6	13.14
Kim et al. (2012)	35	-	-	32.74	2.74	2.26	6.46
Park et al. (2017)	35	-	-	34.0	1.1	1.0	2.85
TOTAL average							**20.33**
TOTAL median							**13,14**
Min torque loss							**2,85**
Max torque loss							**44,93**
Non-original abutments		**Mean**	**SD**	**Mean**	**SD**	**Ncm**	**%**
Pournasiri et al. (2022)	35	29.2	3.61	21.6	3.89	13.4	38.29
		29.1	2.6	21.0	4.78	14	40
Ožiūnas et al. (2022)	15	13.16	0.64	8.53	0.87	6.47	43.08
		11.48	0.84	6.22	1.41	8.78	58.50
		10.95	1.0	4.12	1.26	10.88	72.50
Cashman et al. (2011)	35	35.56	3.55	36.25	2.63	+	+
Alonso-Pérez et al. (2018)	35	31.6	1.1	26.4	3.2	8.6	24.6
		24.5	2.9	23.8	2.9	11.2	32.1
Kim et al. (2012)	35	-	-	22.79	5.46	12.21	34.89
		-	-	12.00	0	23	65.71
		-	-	18.67	3.21	16.33	46.65
Park et al. (2017)	32	-	-	25.0	1.5	7	21.9
	30	-	-	23.9	2.1	6.1	20.2
	30	-	-	27.9	1.3	2.1	6.9
TOTAL average							**38,87**
TOTAL median							**38,29**
Min torque loss							**6,9**
Max torque loss							**72,50**

Abutment screw fracture:

Five studies out of then presented results for screw fracture comparing original and non-original screws (4,14,22–24).

In the comparative analysis of fracture resistance between original and non-original abutment screws, the majority of studies (four out of five) demonstrated superior outcomes in the original abutment group (Table 3).

However, one study reported unexpected findings favoring the non-original abutment group, potentially attributed to the utilization of stiffer materials in the abutments, specifically grade V titanium.

Table 3: Descriptive results on screw fracture comparing original and non-original abutment screws

Author (year)	**Better fracture resistance**
Silva et al. (2021) (22)	Original
Gigandet et al. (2014) (23)	Non-original
Alonso-Pérez et al. (2022) (14)	Original
Alonso-Pérez et al. (2021) (25)	Original
Kim et al. (2012) (13)	Original

Table 1: Quality assessment of in-vitro studies (modified from the ARRIVE and CONSORT guidelines)

	Silva et al. (2021)	Pournasiri et al. (2022)	Ožiūnas et al. (2022)	Gigandet et al. (2014)	Cashman et al. (2011)	Alonso-Pérez et al. (2018)	Alonso-Pérez et al. (2022)	Alonso-Pérez et al. (2021)	Kim et al. (2012)	Park et al. (2017)
1. Title	1	1	1	1	1	1	1	1	1	1
2. Abstract either a structured summary of background, research objectives, key experiment methods, principal findings, and conclusion of the study or self-contained (should contain enough information to enable a good understanding of the rationale for the approach)	3	3	3	3	3	3	3	3	3	3
3. Introduction: background, experimental approach, and explanation of rationale/hypothesis	3	3	3	3	3	3	3	3	2	2
4. Introduction: preprimary and secondary objectives for the experiments (specific primary/secondary objectives)	2	2	2	2	2	2	2	2	2	2
5. Methods: study design explained number of experimental and control groups, steps to reduce bias (demonstrating the consistency of the experiment (done more than once), sufficient detail for replication, blinding in evaluation, etc.)	2	2	2	2	3	2	2	2	2	2
6. Methods: precise details of experimental procedure (i.e., how, when, where, and why)	3	3	3	2	3	3	3	3	3	3
7. Methods: How sample size was determined (details of control and experimental group) and sample size calculation.	3	3	3	3	3	3	3	3	3	2
8. Methods: Details of statistical methods and analysis (statistical methods used to compare groups)	3	3	3	3	3	3	3	2	3	3
9. Results: explanation for any excluded data, results of each analysis with a measure of precision as standard deviation or standard error or confidence interval	3	2	3	3	3	3	3	3	3	3
10. Discussion: interpretation/scientific implication, limitations, and generalizability/translation	2	2	2	1	3	2	2	2	1	1
11. Statement of potential conflicts and funding disclosure	1	1	0	0	1	1	1	0	1	1
12. Publication in a peer-review journal	1	1	1	0	1	0	1	1	1	1

Discussion:

Conducting a meta-analysis was not possible due to potential limitations in the number, heterogeneity, and quality of existing studies, as well as issues related to publication bias and the diversity of abutment and implant systems. For this reason, the results presented here should be interpreted with caution and were presented descriptively in each study group.

Abutment screw loosening:

In the study by Alonso-Perez et al. (2018), it was found that original abutments generally have lower rates of screw loosening compared to non-original ones. Cashman et al. and Kim et al. suggest greater stability with original components (7). Oziunas et al. highlight the influence of machine tolerance and material properties on screw loosening. Additionally, Oziunas et al. found that the brand of the titanium base significantly impacts screw loosening after fatigue testing (20). Removal torque values of original abutment screws after cyclic loading show less screw loosening compared to non-original components, as observed by Alonso-Perez et al. (2018) (7). Variations in reverse torque values among studies could be attributed to differences in abutment screw type, material, and tightening torque, as indicated by Tsuge et al. (26) and Yilmaz et al. (27). Implant-abutment fit also plays a significant role in screw loosening, as demonstrated by Ghanbarzadeh et al. (28). Overall, Park et al. (18), Pournasiri et al. (21), and Zanardi et al. (29) suggest that original components are recommended to ensure long-term stability of the implant restoration complex.

Abutment screw fracture:

The majority of studies favored original abutments in terms of fracture resistance. However, one study unexpectedly found better results with non-original abutments, possibly due to the use of stiffer materials in the abutments (grade V titanium). This highlights the complexity of factors influencing screw fracture and underscores the importance of considering material properties in future studies (30). Piermatti et al. also suggest tightening the screw to 75% to 80% of the material's yield strength to prevent permanent deformation (30). Despite lower maximum torque values observed in replica screws, Silva et al. found no significant differences in fracture torque between original and replica screws (22). Gigandet et al. obtained a lower maximal force needed up to fracture in non-original abutment connections, potentially due to higher misfit (23). The results of

Alonso-Perez et al. (2018) suggest that resistance to cyclic loading decreases significantly with non-original abutment components, potentially leading to microfractures (7). Kim et al. reported no mechanical failures in the original group, whereas the non-original group presented screw and implant fractures (4). Rizvi et al. found that original abutments exhibited superior precision of fit, resistance to microleakage, and greater fatigue strength compared to non-original abutments (31). Additionally, Fischer et al. observed no fractures of abutments or abutment screws in a 10-year clinical study (32).

Despite limitations, the systematic review conclusively demonstrates that original abutment screws offer better biomechanical performance than non-original alternatives when studying the loosening and fracture. The resistance to torque loss and to fracture contributes to the longevity and reliability of dental implants. Clinicians are advised to prefer original components to maximize the success of implant treatments.

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Aflojamiento y fractura de tornillos de pilares originales frente a no originales en Implantología: Revisión sistemática

Título corto: Aflojamiento y fractura de tornillos pilares originales vs no originales en Implantología

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Resumen:
Antecedentes: La comparación de tornillos de pilares originales y no originales es esencial para optimizar los procedimientos de implantes dentales. Comprender el comportamiento biomecánico de estos componentes ayuda a los clínicos a tomar decisiones informadas, garantizando la estabilidad y durabilidad del implante. Complicaciones como el aflojamiento y la fractura de los tornillos pueden provocar el fracaso del implante, lo que subraya la necesidad de identificar cualquier diferencia entre los tornillos originales y los no originales para disminuir los riesgos. Además, la evaluación del rendimiento de los tornillos no originales proporciona información valiosa sobre su idoneidad como alternativas, teniendo en cuenta factores como el coste y la disponibilidad. En general, esta comparación mejora los resultados de los pacientes y aumenta la fiabilidad de los tratamientos con implantes dentales. El objetivo de esta revisión sistematica es estudiar el comportamiento biomecánico y, en concreto, comparar la resistencia a la fractura y la incidencia de aflojamiento entre tornillos de pilares originales y no originales.

Material y métodos: Esta revisión utilizó un enfoque sistemático siguiendo las directrices PRISMA, examinando estudios indexados en las principales bases de datos como Medline-PubMed, Web of Science y Scopus. La atención se centró en la comparación de tornillos de pilar originales y no originales en cuanto a su comportamiento biomecánico, específicamente su resistencia a la fractura y la pérdida de torque.

Resultados: Diez estudios cumplieron los criterios de inclusión; 5 estudios sobre aflojamiento de tornillos, 4 estudios sobre fractura de tornillos y 1 estudio tanto de aflojamiento como de fractura. Los pilares originales mostraron un mejor comportamiento en términos de menor pérdida de torque (20,33%) con respecto a los pilares no originales (38,87%). Los pilares originales mostraron una mejor resistencia a la fractura en comparación con los pilares no originales. Las variaciones en las normas de fabricación y la compatibilidad se observaron como influencias significativas.

Conclusiones: Los tornillos de pilares originales muestran una mejor estabilidad biomecánica que los no originales al estudiar el aflojamiento y la fractura. Esto sugiere una mayor fiabilidad de los componentes originales a la hora de mantener la integridad estructural y la funcionalidad de los implantes dentales. Garantizar la compatibilidad y cumplir las normas de fabricación es fundamental para optimizar el éxito de los implantes.

Palabras clave: Aflojamiento, fractura, tornillo original, tornillo no original, pilar dental.

Introducción:

En los últimos años, los implantes dentales han revolucionado el campo de la odontología, proporcionando soluciones eficaces para la pérdida de dientes con altas tasas de éxito (1-8). Sin embargo, a pesar de los importantes avances, pueden surgir complicaciones asociadas a los implantes dentales, que causan molestias, gastos e incomodidad a los pacientes (1,5). Comprender las causas y consecuencias de estas complicaciones es esencial para mejorar los resultados del tratamiento y la satisfacción del paciente.

Las complicaciones de los implantes pueden clasificarse a grandes rasgos en problemas biológicos y técnicos (1,5,9). Las complicaciones biológicas incluyen la mucositis periimplantaria, la inflamación de los tejidos blandos y los signos radiográficos de pérdida de osteointegración (5,10). Por otro lado, los problemas técnicos incluyen cuestiones como el aflojamiento y la fractura de tornillos, la fractura de la estructura o de la porcelana y la formación de brechas marginales (5,9-11).

Una de las principales preocupaciones en implantología es el aflojamiento y la fractura del tornillo del pilar, que puede comprometer la estabilidad y longevidad de la restauración implantológica. Hay varios factores que contribuyen al aflojamiento de los tornillos, como el diseño de la conexión implante-pilar, el diámetro y la longitud del tornillo, el material del pilar y del tornillo, la posición del implante y las fuerzas oclusales (9). Una precarga excesiva o insuficiente, así como los hábitos parafuncionales, también pueden desempeñar un papel en el aflojamiento del tornillo (12,13).

Diferenciar entre componentes originales y no originales es crucial en implantología, ya que los problemas de compatibilidad y las variaciones en el diseño y la composición del material pueden afectar a los resultados del tratamiento (2). Mientras que los componentes originales suelen asociarse a mayores tasas de éxito y estabilidad a largo plazo, los componentes no originales pueden presentar mayores riesgos de fracaso, sobre todo a corto plazo. La precisión interna y el comportamiento a la fatiga mecánica de los componentes no originales suelen verse comprometidos, lo que provoca un desajuste rotacional y un mayor riesgo de complicaciones como la fractura del tornillo (14).

Esta revisión pretende abordar el comportamiento biomecánico de los tornillos de pilares originales frente a los no originales, concretamente las diferencias en la pérdida de torque y la resistencia a la fractura.

Material y métodos:

Esta revisión sistemática se adhirió a las directrices PRISMA para garantizar un análisis exhaustivo e imparcial de la literatura existente (15).

<u>Pregunta PICO:</u>

La pregunta de este estudio se estableció de acuerdo con la pregunta estructurada PICO. El formato de la pregunta se estableció de la siguiente manera P (población): Tornillos de pilares colocados in vitro, I (intervención): Pilares no originales, C (comparación): Pilares originales y O (resultado): Comportamiento biomecánico; O1: Aflojamiento (pérdida de torque), O2: Fractura (resistencia).

<u>Los criterios de inclusión fueron</u>: Tipo de estudio: Estudios in vitro; Publicaciones en inglés; Publicado hasta enero de 2024. Tipo de paciente: Estudios in vitro. Tipo de intervención: Medición del aflojamiento y fractura. Tipo de variables de resultado: Estudios que aporten datos sobre la fractura y/o aflojamiento de tornillos como variable principal.

Respecto a los criterios de exclusión: Tipo de estudio: Revisiones, estudios de casos clínicos, cartas o comentarios al editor, informes de expertos. Tipo de intervención: Artículos que no comparen pilares originales frente a no originales.

Fuentes de información y búsqueda de datos:

Se realizó una búsqueda automatizada, electrónica y manual, en tres bases de datos: PubMed, Scopus y Web of Science. Las palabras clave se combinaron con los operadores booleanos AND, OR y NOT, así como con términos controlados ("MeSH" para Pubmed) para obtener los mejores y más amplios resultados de búsqueda.

Para identificar cualquier estudio elegible que la búsqueda inicial pudiera haber pasado por alto, la búsqueda se completó con una revisión de las referencias proporcionadas en la bibliografía de cada uno de los estudios. Además, se realizó una búsqueda manual de artículos científicos.

Por último, se realizó una búsqueda cruzada de artículos potencialmente interesantes para el análisis. Los estudios duplicados se eliminaron de la revisión.

Estrategia de búsqueda:

Se llevó a cabo un proceso de selección en tres etapas. La selección de los estudios fue realizada por dos revisores (ZC, DL).

En la primera etapa, los artículos se filtraron por títulos para eliminar las publicaciones irrelevantes.

En la segunda etapa, se filtraron los resúmenes y se seleccionaron según el tipo de estudio, el tipo de intervención, el número de muestras y las variables de resultado.

En la tercera etapa, se filtraron los artículos mediante la lectura del texto completo y se procedió a la extracción de datos

utilizando un formulario de recogida de datos previamente elaborado para confirmar la elegibilidad de los estudios.

Extracción de datos:

Se extrajo la siguiente información de los estudios y se organizó en tablas: autores con año de publicación, tipo de estudio (in vitro), tipo de conexión del implante, longitud y diámetro del implante, marca del implante, marca del pilar original, marca del pilar no original, número de pilares originales, número de pilares no originales, total de pilares, número de cargas cíclicas, fuerza de carga (N), torque de inserción (Ncm), valor medio del torque inverso (RTV) previo a la carga, RTV medio posterior a la carga, pérdida de torque, resistencia a la fractura.

Calidad y evaluación del riesgo de sesgo:

Dos revisores (ZC, DL) evaluaron el riesgo de sesgo para analizar la calidad metodológica de los artículos incluidos.

Se realizó una evaluación de la calidad de los artículos de texto completo de acuerdo con la herramienta ARRIVE modificada y los criterios CONSORT para estudios in vitro (la evaluación se basó en un sistema de clasificación predefinido). Las categorías utilizadas para evaluar la correcta realización y estructura son título, resumen, introducción, materiales y métodos, resultados, discusión y conclusiones (16,17).

Síntesis de datos:

Para resumir y comparar las variables de resultado entre los diferentes estudios, se agruparon las medias de los valores de las variables principales según el grupo de estudio.

No fue posible realizar un metanálisis debido a las posibles limitaciones en el número, la heterogeneidad y la calidad de los estudios existentes, así como a cuestiones relacionadas con el sesgo de publicación y la diversidad de sistemas de pilares e implantes.

Resultados:

Selección de estudios

Del proceso de búsqueda inicial se obtuvo un total de 69 artículos: Medline-PubMed (n=12), SCOPUS (n=51) y Web of Science (n=4). Además, se obtuvo 2 artículos mediante búsqueda manual (lista de referencias). De estos artículos, 18 se identificaron como artículos potencialmente elegibles mediante cribado por título y resumen. Posteriormente se seleccionaron los artículos a texto completo y se evaluaron exhaustivamente. Como resultado, diez estudios cumplieron los criterios de inclusión y se incluyeron en el estudio.

Características de los estudios

De los 10 artículos revisados, cinco estudiaban el aflojamiento del tornillo del pilar (7,18-21), cuatro estudiaban la fractura de los tornillos pilares (14,22-24) y uno tanto el aflojamiento como la fractura del tornillo del pilar (4).

Nueve estudios utilizaban pilares originales y no originales conectándolos a implantes con conexión interna (7,13,14,18,20-24), sólo un estudio probaba los pilares originales y no originales en implantes con conexión externa (19).

Todos los estudios eran in vitro. Se estudiaron un total de 405 muestras: 149 pilares originales y 226 pilares no originales.

Riesgo de sesgo

Dado que no existen criterios establecidos o directrices para evaluar la calidad o el riesgo de sesgo de los estudios in vitro, se evaluó la calidad de todos los artículos de texto completo seleccionados utilizando el ARRIVE modificado combinado con las directrices CONSORT (informe consolidado de ensayos) para experimentos in vitro (Tabla 1), basándose en los estudios anteriores (16). La evaluación se basó en un sistema de clasificación predefinido de la lista de comprobación para estudios in vitro.

Síntesis de los resultados

Aflojamiento del tornillo del pilar:

Seis de 10 estudios presentaron resultados de aflojamiento de tornillos comparando pilares originales y no originales (7,13,18-21). Al comparar el torque de inserción y el RTV poscarga de los tornillos de pilares originales, la pérdida media de torque fue del 20,33%, oscilando entre el 2,85% (18) y el 44,93% (20).

En cuanto a los pilares no originales, el índice medio de aflojamiento fue del 38,9%, oscilando entre el 6,9% (18) y el 72,5% (20).

El menor índice de pérdida de torque corresponde al estudio que administró el menor número de cargas cíclicas (500.000) con la menor fuerza (25N) (18). Por otra parte, la tasa más alta de pérdida de par corresponde al estudio que tenía el valor más bajo de precarga y administró un elevado número de ciclos (1.200.000) con una fuerza más alta (50N) (20). Ožiūnas et al. (20) también compararon el aflojamiento de tornillos con bases de titanio originales y no originales en lugar de en pilares normales.

En un estudio (19) no se observó aflojamiento de los tornillos después de la carga cíclica, sino que el RTV posterior a la carga aumentó después de la carga cíclica tanto en los pilares originales como en los no originales. Esto puede deberse al hecho de que el tipo de conexión del implante era de conexión externa.
En general, los pilares originales presentan una menor pérdida de torque en comparación con los pilares no originales, lo que indica una estabilidad y un rendimiento potencialmente mejores (Tabla 2).

Fractura del tornillo pilar:
Los cinco estudios presentaron resultados de fractura de tornillos comparando tornillos originales y no originales (4,14,22-24).
En el análisis comparativo de la resistencia a la fractura entre tornillos de pilares originales y no originales, la mayoría de los estudios (cuatro de cinco) demostraron resultados superiores en el grupo de pilares originales (Tabla 3).
Sin embargo, un estudio comunicó resultados inesperados favorables al grupo de pilares no originales, atribuidos potencialmente a la utilización de materiales más rígidos en los pilares, concretamente titanio de grado V.

Discusión:
No fue posible realizar un metaanálisis debido a las posibles limitaciones en el número, la heterogeneidad y la calidad de los estudios existentes, así como a cuestiones relacionadas con el sesgo de publicación y la diversidad de sistemas de pilares e implantes. Por este motivo, los resultados aquí presentados deben interpretarse con cautela y se presentaron de forma descriptiva en cada grupo de estudio.

Aflojamiento de los tornillos de los pilares:
En el estudio de Alonso-Pérez et al. (2018), se encontró que los pilares originales generalmente tienen menores tasas de aflojamiento de tornillos en comparación con los no originales. Cashman et al. y Kim et al. sugieren una mayor estabilidad con componentes originales (7). Oziunas et al. destacan la influencia de la tolerancia de la máquina y las propiedades del material en el aflojamiento de los tornillos. Además, Oziunas et al. descubrieron que la marca de la base de titanio influye significativamente en el aflojamiento del tornillo tras las pruebas de fatiga (20). Los valores de torque de extracción de los tornillos de pilares originales después de la carga cíclica muestran un menor aflojamiento del tornillo en comparación con los componentes no originales, como observaron Alonso-Pérez et al. (2018) (7). Las variaciones en los valores de torque inverso entre los estudios podrían atribuirse a las diferencias en el tipo de tornillo del pilar, el material y el torque de apriete, como indican Tsuge et al. (26) y Yilmaz et al. (27). El ajuste implante-pilar también desempeña un papel importante en el aflojamiento de los tornillos, como demostraron Ghanbarzadeh et al. (28). En general, Park et al. (18), Pournasiri et al. (21) y Zanardi et al. (29) sugieren que se recomienden componentes originales para garantizar la estabilidad a largo plazo del complejo de restauración del implante.

Fractura del tornillo del pilar:
La mayoría de los estudios favorecieron a los pilares originales en términos de resistencia a la fractura. Sin embargo, un estudio encontró inesperadamente mejores resultados con pilares no originales, posiblemente debido al uso de materiales más rígidos en los pilares (titanio de grado V). Esto pone de manifiesto la complejidad de los factores que influyen en la fractura de los tornillos y

subraya la importancia de tener en cuenta las propiedades de los materiales en futuros estudios (30). Piermatti et al. también sugieren apretar el tornillo entre el 75% y el 80% del límite elástico del material para evitar la deformación permanente (30). A pesar de los menores valores de torque máximo observados en los tornillos réplica, Silva et al. no encontraron diferencias significativas en el torque de fractura entre los tornillos originales y los réplica (22). Gigandet et al. obtuvieron una menor fuerza máxima necesaria hasta la fractura en las conexiones de pilares no originales, debido potencialmente a un mayor desajuste (23).

Los resultados de Alonso-Pérez et al. (2018) sugieren que la resistencia a la carga cíclica disminuye significativamente con los componentes de pilares no originales, lo que puede provocar microfracturas (7). Kim et al. no informaron de fallos mecánicos en el grupo original, mientras que el grupo no original presentó fracturas de tornillos e implantes (4). Rizvi et al. observaron que los pilares originales presentaban una mayor precisión de ajuste, resistencia a las filtraciones y mayor resistencia a la fatiga en comparación con los pilares no originales (31). Además, Fischer et al. no observaron fracturas de pilares ni de tornillos de pilares en un estudio clínico de 10 años (32).

A pesar de las limitaciones, la revisión sistemática demuestra de forma concluyente que los tornillos de pilar originales ofrecen un mejor rendimiento biomecánico que las alternativas no originales al estudiar el aflojamiento y la fractura. La resistencia a la pérdida de torque y a la fractura contribuye a la longevidad y fiabilidad de los implantes dentales. Se aconseja a los clínicos que escojan componentes originales para maximizar el éxito de los tratamientos con implantes.

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