

The effect of implantoplasty on dental implant fracture resistance: a systematic review

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Abstract

An increase in dental implant placements in recent years has seen a growth in the reported cases of post-operative complications such as peri-implantitis. One of the available treatment modalities to overcome such complications is implantoplasty. Although this procedure is not new, the long-term effect of implantoplasty has not been addressed extensively. The aim of this systematic review was to investigate the change in fracture resistance of dental implants after implantoplasty. Three electronic databases and reference lists of included studies were searched to assess the potential effect of implantoplasty on implant fracture resistance. Titles and abstracts were screened by two reviewers in parallel. The extracted information regarding implant fracture resistance was reported based on the guidelines set by the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. A total of 56 studies were identified, of which, nine studies were included. Narrow platform implants (<3.75 mm) were more susceptible to fracture following implantoplasty compared to wider platforms (≥5 mm). Implants with internal hexagon connection may have a higher risk of fracture after implantoplasty compared to other connection designs such as external hexagon and conical connections. Other potential factors which may affect implant fracture resistance after implantoplasty include crown to implant ratio, implant material, and the amount of peri-implant bone loss. Within the limitation of in vitro studies, there is no clear evidence to demonstrate the effect of implantoplasty on implant fracture resistance. Methodological differences between the available studies did not allow for clear comparison between them. Furthermore, the limited amount of clinical reports of this resective procedure, in combination with patient and operator variability, affect the clinical assessment of this treatment modality.

Keywords: dental implant, implantoplasty, peri-implantitis, systematic review

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Introduction

Dental implants have shown to provide good functional and aesthetic outcomes for prosthetic rehabilitation of partially or fully

edentulous patients (Berglundh *et al.*, 2002). However, they are susceptible to plaque accumulation due to its non-shedding nature, which can lead to peri-implant inflammation such as peri-implant mucositis

and peri-implantitis. A systematic review of the European and American population in 2015 found that the weighted mean prevalence of peri-implant mucositis and peri-implantitis were 43% and 22% respectively (Derks & Tomasi, 2015).

Peri-implantitis can have devastating outcomes for patients as the supporting bone around the implant is affected. Various systematic reviews revealed that it was impossible to decontaminate implant surface completely through mechanical or chemical methods alone, while a combination of these methods yielded a better outcome (Louropoulou *et al.*, 2014; Stavropoulos *et al.*, 2019). These reviews also suggested that roughened implant surfaces initially introduced to increase the rate of osseointegration, have a higher tendency to accumulate and retain plaque which may negatively impact the management of peri-implant infection.

A multitude of non-surgical and surgical treatment protocols have been suggested to treat peri-implantitis around osseointegrated dental implants. A Cochrane review including nine randomized controlled trials showed insufficient evidence to support or refute the effectiveness of any specific treatment protocol for peri-implantitis (Esposito *et al.*, 2012). There was also no consensus on surface decontamination methods for dental implants to obtain a predictable long-term result (Heitz-Mayfield & Mombelli, 2014).

Surface decontamination is important to decrease the bacterial load around the dental implant and achieve a biocompatible surface for direct apposition of alveolar bone. Non-surgical debridement with or without antimicrobials has been shown to have limited efficacy when it is employed for peri-implantitis due to insufficient decontamination of the implant surface (Figuro *et al.*, 2014). In this context, various methods to decontaminate the implant surface have been introduced such as mechanical, chemical debridement and laser therapy. Non-surgical debridement has been suggested as the pre-treatment phase of peri-implantitis management while surgical

access should be considered when peri-implantitis persists (Heitz-Mayfield & Mombelli, 2014). Surgical therapy can be carried out through either a regenerative or resective approach depending on the defect morphology and the objective of the surgical intervention.

Implantoplasty is used as an adjunct to resective procedures to smoothen and remove contaminated implant surface in order to reduce or eliminate bacterial colonization on the implant surface (Stavropoulos *et al.*, 2019). This procedure aims to achieve a relatively smooth implant surface and reduce the screw shape topography of the implant to facilitate ongoing implant maintenance. This has been successfully implemented by numerous clinicians and researchers to manage peri-implantitis with good clinical and radiographic outcomes in areas with limited potential for bone regeneration due to the anatomy of the defect (Matarasso *et al.*, 2014; Monje *et al.*, 2021; Schwarz *et al.*, 2013). Instrumentation of the implant surface will inevitably result in a narrower implant, which will likely decrease the maximum force it can withstand before fracturing. Therefore, the aim of this systematic review was to investigate the impact of implantoplasty on fracture resistance of dental implants.

Materials and Methods

This systematic review was conducted based on the guidelines given by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher *et al.*, 2009), and Cochrane Collaboration (Higgins, 2021). This review aimed to address a focused question “Will implantoplasty on dental implants affect its fracture resistance?” using the PICO (participant/problem, intervention, comparison/control, and outcome) method (Miller & Forrest, 2001).

- P:** Dental implants
- I:** Implantoplasty
- C:** Pristine implants
- O:** Fracture resistance

Type of Studies

The following inclusion criteria were applied during literature search on studies without restriction in publication year: (a) In vitro studies; (b) reported the fracture resistance of dental implants before and after implantoplasty; (c) published in an English peer-reviewed journal; (d) available in full-text.

Search Strategies

The following electronic databases were searched for ongoing and unpublished studies up to July 31, 2021: MEDLINE, Scopus and EMBASE (Table 1). The following search format was performed using Boolean operators: (implantoplasty OR implant surface modification) AND (fracture resistance OR fracture OR breakage). The bibliographies of all eligible articles were analysed for additional studies. Two calibrated reviewers (R.G and A.T.S) carried out the search for title, abstract, and full-text using the eligibility criteria in parallel. Opengrey.eu was used to search for grey literature. In case of uncertainty, the final decision was made by a third author (W.D). The reasons for excluding inapplicable studies were reported. The selected studies were imported into a reference managing program (EndNote 20; Clarivate Analytics, Philadelphia, PA, USA).

Data Collection

A data extraction form was designed and carried out by two reviewers (R.G and A.T.S) with the following aspects:

1. Study details: title, authors' names, contact address, study location, language and year of publication, published or unpublished data, source of funding
2. Dental implants: brand, diameter, length, material, instrumentation sequence, abutment-implant interface, number of implants in test and control groups, type of loading
3. Outcomes: fracture resistance of implants, location of implant fracture

Assessment of Quality and Risk of Bias

The In Vitro Critical Appraisal Tool (IV-CAT) was used to assess the risk of bias and study quality of the studies included in this review to ensure the validity of the assessment (de Vries, 2018).

Results

Characteristics of the trial settings and investigators

A total of 56 studies were identified from the initial electronic literature search (Figure 1). No additional studies were found through screening of the reference lists of these studies. Out of these 56 studies, only 15 were eligible for full-text evaluation after review of the abstracts and key words.

After full-text evaluation, six studies were excluded because they failed to meet the inclusion criteria. The remaining nine studies were further analysed in depth and included in this review.

Table 1. Electronic search strategy employed to identify relevant studies

Databases	Keywords
Published studies MEDLINE(PubMed), Scopus, Embase via Ovid	<i>(implantoplasty OR implant surface modification) AND (fracture resistance OR fracture OR breakage)</i>
Unpublished studies MetaRegister of controlled trials OpenGrey (www.opengrey.eu) (July 28, 2021)	<i>(implantoplasty OR implant surface modification) AND (fracture resistance OR fracture OR breakage)</i>

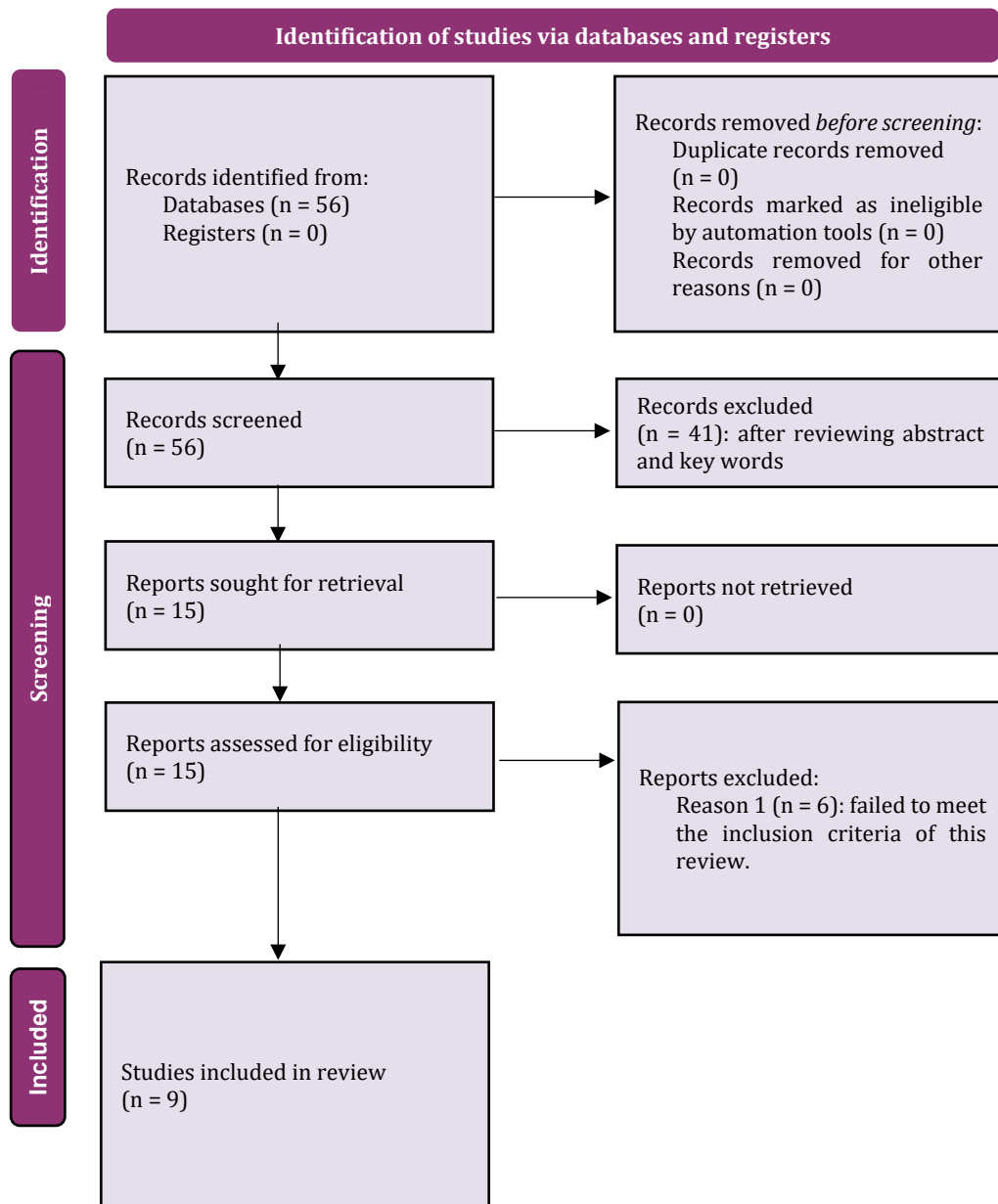


Figure 1. Flowchart of study selection

Risk of bias in included studies

Using the In Vitro Critical Appraisal Tool (IV-CAT), the included studies were assigned a low risk of bias and were recommended to be included in the review. All studies reported on primary in vitro research and utilised a framework for post-conduct appraisal.

Incomplete outcome data and selective reporting

Eight out of the nine studies obtained and reported all of the outcome data. One study which compared the fracture resistance of narrow and wide platform implants did not carry out the fracture resistance test on the 4.7mm wide platform implants in the control group (Chan *et al.*, 2013). This was because the wide implants in the test group fractured at the abutment screw and not at the implant body.

Effects of interventions

This review included nine studies with a total of 420 dental implants. The abutment connection design of these 420 dental implants consisted of 154 external connections, 230 internal connections, and 36 conical Morse taper connections. 86.7% of the total implants were bone level fixtures made of titanium while the remaining 13.3% were tissue level fixtures made of titanium and zirconia. 57.7% of the titanium implants included in this review were made of grade IV titanium while the other 42.3% were made of grade V titanium. Meta-analysis and quantitative analysis were not possible due to the limited number of included studies and heterogeneity of the extracted data.

Outcome

Two studies in this review investigated the effect of abutment connection design on the fracture resistance of dental implants (Camps-Font *et al.*, 2020; Gehrke *et al.*, 2016). The 2016 study by Gehrke *et al.* found

that the conical Morse taper connection design provided the highest fracture resistance in 11mm long, 4.0mm regular diameter implants regardless of implantoplasty status. Implantoplasty in conical Morse taper connection implants reduced the fracture resistance by approximately 20% whilst external hexagon and internal hexagon implants experienced a more drastic decrease in fracture resistance after implantoplasty at approximately 37% and 40% respectively. Camps-Font *et al.* (2020) found conflicting results, whereby external hexagon connection implants had the highest fracture resistance in comparison to internal hexagon and conical Morse taper connection implants independent of implantoplasty in 3.5mm narrow platform, 10mm long implants. Regardless of the abutment connection design, there was a similar reduction of fracture resistance of approximately 29% after implantoplasty for each of the designs.

Two out of the four studies with narrow diameter implants showed a statistically significant decrease in fracture resistance following implantoplasty (Bertl *et al.*, 2020; Camps-Font *et al.*, 2020). The exceptions, (Leitao-Almeida *et al.*, 2020; Leitão-Almeida *et al.*, 2021) both included groups with the greatest amount of exposed implant threads, 7.5mm, albeit with 15mm long implants. Bertl *et al.* (2020) carried out an extensive study involving 112 dental implants of different materials, levels and diameters. The results indicated that implantoplasty reduced the fracture resistance of 3.3mm narrow platform tissue level titanium implants the most. Likewise, the other study which investigated the effects of platform diameter on fracture resistance concluded that 3.75mm diameter implants were more prone to fracture after implantoplasty compared to 4.7mm diameter implants (Chan *et al.*, 2013). An acknowledged limitation of this study was that the 4.7mm diameter implants in the control group were not tested for fracture resistance. The rationale given was that the test implants

fractured at the abutment screw, which did not influence the implant body. Out of the six studies which involved regular diameter implants, three studies (Chan *et al.*, 2013; Costa-Berenguer *et al.*, 2018; Sivoilella *et al.*, 2021) concluded that implantoplasty did not affect the fracture resistance while the other three (Bertl *et al.*, 2020; Gehrke *et al.*, 2016; Jorio *et al.*, 2021) found a significant decrease in fracture resistance after implantoplasty.

Most of the articles used tungsten carbide burs with or without additional silicone polishing burs or Arkansas stones (Bertl *et al.*, 2020; Camps-Font *et al.*, 2020; Chan *et al.*, 2013; Costa-Berenguer *et al.*, 2018; Gehrke *et al.*, 2016; Jorio *et al.*, 2021; Leitao-Almeida *et al.*, 2020; Leitão-Almeida *et al.*, 2021; Sivoilella *et al.*, 2021). Two of the included studies performed the implantoplasty with diamond burs of various grits followed by polishers (Chan *et al.*, 2013; Jorio *et al.*, 2021). Bertl *et al.* (2020) and Gehrke *et al.* (2016) were the only studies which carried out computer-controlled implantoplasty to standardise the complete removal of implant threads for all of the tested implants.

Sivoilella *et al.* (2021) investigated the difference between tungsten carbide burs with Arkansas stones and diamond sonic tips with Arkansas stone on fracture resistance. They found that the implants treated with diamond sonic tips were more conservative in terms of structure loss but did not have a significantly higher fracture resistance compared to the tungsten carbide burs group. Another study, which investigated the effect of different implantoplasty protocol on fracture resistance of implants, found that diamond burs and silicon carbide stone did not result in a statistically significant change in fracture resistance of implants (Jorio *et al.*, 2021).

The study by Leitao-Almeida *et al.* (2021) suggested that a greater degree of bone loss is associated with a decrease in fracture resistance. The implants in the test group which underwent implantoplasty did not

have a statistically significant difference in fracture resistance compared to the pristine implants in the control group.

Another study led by the same author, the year before, manipulated the crown to implant ratio by adjusting the height of the abutment (Leitao-Almeida *et al.*, 2020). It was found that implantoplasty on an implant with a crown to implant ratio of 2.5:1 led to a decrease in fracture resistance in comparison with pristine implants (Table 6). Costa Berenguer *et al.*, (2018) carried out a study on 4.1mm diameter implants with the external hexagonal connection. The results indicated that implantoplasty did not significantly affect the fracture resistance in the tested implants.

A summary of the findings is presented in Table 2.

Discussion

Implant fracture is one of the most frustrating mechanical complications that can occur with dental implants. The effect of implantoplasty on fracture resistance of dental implants showed conflicting results which may be attributed to the different implants used in these studies. This review only included *in vitro* studies as it is impractical to perform implant fracture resistance tests on human subjects. To the author's knowledge, there are no *in vivo* studies available at present. In a clinical setting, implantoplasty is a lot more challenging for the operator due to the limited access *intra-orally* and blood affecting visibility. The results of these studies may not truly reflect on the fracture resistance of dental implants after implantoplasty in the oral cavity. More studies, designed to evaluate the short and long-term effects of implantoplasty in patients are needed.

Table 2. Comparison between studies

Author (year)	Brand	Number of implants	Diameter x length	Exposed length	Type of test	Abutment connection	IP protocol	Results
Gehrke et al., 2016	Implacil De Bortoli, São Paulo, Brazil	60	4.0mm x 11mm (60)	5mm (60)	Static (60)	External hexagon (20) Internal hexagon (20) Conical Morse taper (20)	Conical carbide cutter burs in mechanical lathe machine (model BV-20, Ferrari, South Africa)	IP reduced FR. Conical Morse taper abutment connection had the highest FR
Camps-Font et al., 2020	Biomimetic Ocean, Avinent Implant System, Santpedor, Spain	48	3.5mm x 10mm (48)	5mm (48)	Static (48)	External hexagon (16) Internal hexagon (16) Conical Morse taper (16)	Tungsten carbide bur, two silicon carbide (SiC) polishers	IP reduced FR in narrow implants. External hexagon connection had the highest FR
Bertl et al., 2020	Institut Straumann AG, Basel, Switzerland	112	3.3mm x 10mm (66) 4.1mm x 10mm (66)	3mm (112)	Dynamic, then static (112)	Internal hexagon (112)	Computer-controlled instrumentation	IP reduced FR in all implants tested, but more so in narrow titanium tissue level implants.
Chan et al., 2013	TRI-Vent Implants, TRI Dental Implants, Baar, Switzerland	32	3.75mm x 10mm (16) 4.7mm x 10mm (16)	5mm (32)	Static (32)	Internal hexagon (32)	30- and 15- µm diamond burs, Arkansas burs and fine silicone polishers	IP reduced FR in narrower 3.75mm platform implants.
Sivolella et al., 2021	Zimmer Biomet, Palm Beach Gardens, Florida, USA	18	4.0mm x 13mm (18)	6mm (18)	Static (18)	External hexagon (18)	Two tungsten carbide bur (decreasing tothing) (9) Diamond sonic tips (9)	IP did not affect FR. IP protocol did not significantly affect FR

Jorio et al., 2021	TRI-Vent Implants, TRI Dental Implants, Baar, Switzerland	50	4.1mm x 11mm (50)	6mm (50)	Cyclic, then static (40) Cyclic only (10)	Internal hexagon (50)	Diamond burs (106-, 40-, 4µm), Arkansas stone (10) SiC bur, Arkansas stone, silicone polishers (10) Diamond burs (30- and 15µm), Arkansas stone and silicone polishers (10) Control (no implantoplasty) (20)	IP and cyclic loading decreased FR. IP protocol did not affect FR
Leitao-Almeida et al., 2021	Ocean E.C., Avinent Implant System S.L., Santpedor, Spain	32	3.5mm x 15mm (32)	3mm (16) 7.5mm (16)	Static (32)	External hexagon (32)	Tungsten carbide bur, two SiC polishers (32)	IP did not affect FR in narrow diameter dental implants. Increase in exposed implant surfaces led to decreased FR
Costa-Berenguer et al., 2018	Titamax Smart Cortical, Neodent, Curitiba, Brazil	20	4.1mm x 13mm (20)	6mm (20)	Static (20)	External hexagon (20)	Tungsten carbide bur, two SiC polishers (20)	IP did not affect FR in standard diameter dental implants
Leitao-Almeida et al., 2020	Ocean E.C., Avinent Implant System S.L., Santpedor, Spain	48	3.5mm x 15mm (48)	7,5mm (48) Crown to implant ratio: 2:1 (16) 2.5:1 (16) 3:1 (16)	Static (48)	External hexagon (48)	Tungsten carbide bur, two SiC polishers	IP reduced FR in implants with CIR of 2.5:1. Mean total value of all implants showed no significant difference in FR after IP

IP = implantoplasty; FR = fracture resistance; SD = standard deviation; N = newton; CIR = crown-implant ratio; n/a = not available; SiC = silicon carbide

However, these *in vitro* studies still provided us with valuable insights into the effect of implantoplasty on the mechanical integrity of implants.

This review adopted the classification of implant diameter as proposed by Al-Johany *et al.* (2017), which described narrow platform diameter as ≥ 3.0 mm to < 3.75 mm; regular diameter as ≥ 3.75 mm to < 5 mm; and wide diameter as ≥ 5 mm. A recent systematic review that looked at dental implant fracture reported that implants of narrower diameter have a higher incidence of fracture (Goiato *et al.*, 2019). Similarly, narrower implants in this systematic review were found to be at a higher risk of fracture after implantoplasty, especially in the presence of significant bone loss around the implant. Narrow diameter implants have a smaller contact area between the implant surface and the alveolar bone, which may increase stress concentration in the implant body (Qian *et al.*, 2009). Implantoplasty on narrow diameter implants will likely compromise its structural integrity by further reducing the implant diameter.

There is insufficient evidence to state whether external hexagon or conical Morse taper connection is more fracture resistant (Camps-Font *et al.*, 2020; Gehrke *et al.*, 2016). However, there is some indication that internal hexagon connection may be the weakest abutment connection design. Interestingly, the other studies which used implants with external hexagon connection showed that implantoplasty did not affect fracture resistance (Costa-Berenguer *et al.*, 2018; Leitao-Almeida *et al.*, 2020; Leitão-Almeida *et al.*, 2021; Sivoletta *et al.*, 2021). Internal hexagon connection implants, on the other hand, showed a decrease in fracture resistance after implantoplasty in two studies. One study showed a reduction in narrow implants only (Chan *et al.*, 2013), and the other study acknowledged a reduction in regular diameter implants (Jorio *et al.*, 2021). A possible explanation could be that implantoplasty further reduces the thickness of the thin lateral fixture wall at the neck of the implant where the fixture connects to the internal connection abutment, which compromises the integrity

of the implant body. This suggests that external hexagon connection implants that have undergone implantoplasty may be less likely to fracture compared to other connection designs.

Implantoplasty instrumentation protocol may not have a significant effect on the fracture resistance but diamond sonic tips seem to be more conservative in nature, albeit more time consuming (Sivoletta *et al.*, 2021). Two of the studies utilised computer-controlled instrumentation (Bertl *et al.*, 2020; Gehrke *et al.*, 2016). This ensured that the implantoplasty done on each implant was standardised with identical pressure and surface roughness. However, as implantoplasty has to be performed by a trained operator in a clinical setting, the other studies in this review may have higher clinical relevance because it allows for variability amongst clinicians. Bertl (2020), as well as Jorio (2021) carried out cyclic loading on the implants prior to static loading until failure to better simulate masticatory forces. Both studies found that implantoplasty resulted in a decrease in fracture resistance. Cyclic loading on implants can increase the stress at the interface between implant and bone, which affect the mechanical properties of the implant (Chen *et al.*, 2010).

Most implant fractures were also found to occur at the platform, which indicates that mechanical stress may be concentrated in this zone, especially when the amount of bone loss increases. Narrow implants irrespective of platform connection included in this review demonstrated a tendency to fracture at the platform level. However, the risk of implant body and prosthetic screw fracture increased after implantoplasty (Camps-Font *et al.*, 2020; Leitao-Almeida *et al.*, 2020; Leitão-Almeida *et al.*, 2021). Similar findings were reported for regular diameter implants, which showed weakening of the implant body following implantoplasty (Costa-Berenguer *et al.*, 2018). Gehrke *et al.* (2016) on the other hand found that in regular diameter dental implants with external and internal hexagonal connections, fracture is similarly more likely to occur at the platform level, but

with less risk of damage to the abutment and implant body after implantoplasty. The study by Bertl *et al.* (2020) focusing on 112 Straumann implants indicated that 110 of the implants of various diameter (3.3mm and 4.1mm), material (grade IV titanium and titanium-zirconia) and level (bone and tissue) fractured at the implant body irrespective of implantoplasty status. The remaining two were bone level regular diameter titanium implants without implantoplasty which fractured at the neck. This study was the only one in this review which compared implants with different levels and materials. They stated that grade IV titanium tissue level implants were more likely to fracture compared to titanium-zirconia alloy bone level implants.

One study documented a difference in fracture resistance due to the degree of simulated bone loss around the implant (Leitão-Almeida *et al.*, 2021). This sparse evidence suggests that the fracture resistance of dental implants decrease as the amount of bone loss around the implant increases (Leitão-Almeida *et al.*, 2021). This study is similar to earlier work done by the same authors (Leitao-Almeida *et al.*, 2020). In this earlier study, a crown to implant ratio of 2.5:1 was significantly less resistant to fracture after implantoplasty compared to ratios of 2:1 and 3:1 (Leitao-Almeida *et al.*, 2020). A study which utilised finite element analyses to evaluate the effects of implantoplasty on implants of different bone levels observed that stress on the implant increased as the bone level decreased up to approximately half the length of the implant (Tribst *et al.*, 2017). With further bone loss past this point, the stress on the implant decreased with decreasing implant bone levels, and the micro strain exerted on the bone tissue drastically increased. This study also suggested that implantoplasty resulted in an increase in stress concentration on the implant, which implied that the critical stress point will be achieved earlier, contributing to implant fracture.

The majority of the included studies employed a fatigue testing protocol according to the ISO 14801:2007 guidelines, as revised in 2016 (Bertl *et al.*, 2020; Camps-

Font *et al.*, 2020; Costa-Berenguer *et al.*, 2018; Jorio *et al.*, 2021; Leitao-Almeida *et al.*, 2020; Leitão-Almeida *et al.*, 2021; Sivoilella *et al.*, 2021). It is important to note that this guideline specifically states that while it simulates the functional loading of the dental implant body and associated prosthetic component under worst case conditions, it is not applicable for predicting the *in vivo* performance of an implant.

There are many other factors at play in these studies which can affect the results and add to the observed heterogeneity amongst the studies. It is difficult to make a complete extrapolation of these findings in a real clinical scenario as patients differ in the degree of edentulism, being either fully or partially edentulous. For partially edentulous patients, edentulism location, prosthodontic rehabilitation and force distribution differ significantly between patients which will clearly affect the fracture resistance of dental implants (Stavropoulos *et al.*, 2019). More studies in this area are needed to further understand the various factors associated with a change in fracture resistance after implantoplasty.

Conclusion

This systematic review showed that the true impact of implantoplasty on fracture resistance of dental implants is not clear due to multiple potential confounding factors such as the extent of bone loss, implant diameter and connection design. However, within the limitations of this review, the results revealed that narrow platform implants with internal hexagon connection may be more susceptible to fracture. To overcome this limitation of narrow diameter implants, the use of titanium-zirconia alloy and bone level implants should be considered to increase the structural strength of the implants. A small number of clinical cases with implantoplasty, patient and operator variability, and ethical implications of fracture resistance evaluations will affect potential clinical assessment of this treatment modality. Clinicians are advised to take these into consideration during treatment planning,

especially for patients with increased risk of peri-implantitis.

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