Implementation of Ultra-Short Implants into Dental Practice: A Systematic Review.

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Abstract

The use of ultra-short (US) implants is a conservative, and more affordable method for rehabilitation of edentulous zones in severely atrophic jaws. US implants eliminate the necessity of augmentation procedures. With that in mind, a systematic review was established to assess the applications of US implants, and their reliability as an alternative of conventional implants.

In this systematic review, an electronic search for English literature was carried out on the 22nd of July 2022 and ended on the 27th of July 2022, in the databases of PubMed, Google scholar, Scopus, and ResearchGate, for studies in which US implants were used. A total of 151 articles were identified by keywords. Ultimately, after applying the inclusion and exclusion criteria, 28 full-text articles were included and analyzed in our systematic review. Chief question in this article was: When is the use of ultra-short implants more favourable? and how viable are they?

Twenty-eight studies comprising 1221 implants were selected for the systematic review. US implants were mainly used in atrophic alveolar ridges, to avoid bone augmentation procedures. US implants showed a survival rate of 97.1% among all authors. US implants showed a mean peri-implant bone loss of 0.38 mm over a mean period of 42 months. Placement of US implants in one- or two-stage technique had no influence on any variables.

The placement of US dental implants has presented a viable option in the rehabilitation of patients with atrophic alveolar ridge, with the aim of avoiding bone augmentation procedures. However, the long-term effectiveness of US dental implants remains to be further investigated.

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Introduction

The use of dental implants has been widely accepted in the rehabilitation of patients with partially or totally edentulous jaws to restore the phonation, function, and aesthetic appearance of the patient [1-12]. As the formation and preservation of the alveolar ridge hang on the presence of teeth, consequently, due to post-extraction bone remodelling, patients struggling from long-term edentulism naturally suffer from height and thickness bone level reduction, leading to progressive atrophy of the alveolar ridge [1,7,13,14]. Tooth loss, being a common consequence of dental trauma, periodontal disease, and of endodontic origin, result in centrifugal resorption from lingual to vestibular in the mandible, and centripetal resorption from vestibular to palatine in the maxilla [4,6,16]. In the event of insufficient residual bone parameters, poor bone quality or the close proximity of noble anatomical structures (maxillary sinus and inferior alveolar nerve) for standard dental implant placement, different strategies have been introduced to overcome such difficulties [9,16,17]. Hard tissue augmentation procedures such as guided bone regeneration (GBR), sinus floor elevation (SFE), distraction osteogenesis, and bone grafting procedures utilizing autografts, allografts, xenografts, and synthetic biomaterials are generally undertaken [5,6,18]. Moreover, inferior alveolar nerve transposition, mesiodistally tilted implants, zygomatic, and pterygoid implants have been developed [7,14]. However, patients are often reluctant to undergo such treatment tactics, as they result in multiple surgical interventions, prolonged treatment time, higher morbidity, and

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increased treatment costs [2,14,16,21,27].

Consequently, to evade such procedures, short and ultra-short (US) implants have been introduced in dental practice to simplify the rehabilitation process. A clear classification concerning the parameters of ultra-short, or extra-short dental implants remains heterogenous in the literature. In spite of that, the 11th European Consensus Conference of the European Association of Dental Implantologists stated that US implants are considered to be those of intrabony length ≤ 6.0 (6.5) mm, short implants being ≤ 8.0 mm, and standard implants measuring > 8.0 mm in length [3,5,14,15]. On the contrary, US implants have couple of drawbacks, one of them having a significantly increased crown-to-implant (C/I) ratio, resulting in a lever action; emphasizing that an increase in crown height, will significantly increase the force moment endured by the surrounding bone and the implant itself, resulting in higher stress transmitted to the peri-implant bone, that might lead to bone resorption, or in worst case, implant loss [2,6,9,10]. Anitua et al. mentioned in their study that when a force of 0.1 N is applied to a tooth with a healthy periodontal ligament, the range of mobility of the tooth is 50-200 µm, and when the same force is applied to a dental implant, the mobility is 10 µm [10]. As well as having a decreased surface are available for osseointegration, which is the intimate contact between the alveolar bone and the implant surface, which is logically less when the implant is smaller [3,7,9].

When dental implants were initially announced, it was believed that longer implants are more favourable over shorter implants, as they deliver lower C/I ratio, optimal primary stability, and greater implant surface is available for osseointegration, which are factors that are considered as a key to success, but more recently, this theory has been questioned [1,3,5]. With the aim of measuring the biomechanics of US implants, *in silico* finite element three-dimensional analysis were used to study stress dissipation on US implants and their surrounding structures [23,24,25]. Capatti et al. findings that compared conventional 10 mm with US 4 mm implants have shown that effect of crown heightening was similar for both conventional and US implants on peri-implant bone stress, and on the outer and inner portion of the abutment in oblique load of 100 N in the posterior maxillary region[23]. Moreover, Sumra et al. concluded in their study on 5 mm US implants, that increasing the implant diameter reduced peri-implant stresses, strains, and micromovements[25]. All things considered, *in silico* analysis are digital simulations, and do not completely mimic the environment of the oral cavity [27]. Moreover, it does not exclude human factors, such as the surgical technique of the surgeon, and the compliance of adequate oral hygiene throughout the treatment from the patient. Therefore, further *In vivo* studies are needed to evaluate the viability and reliability of ultra-short dental implants.

That said, the goal of our systematic review was to assess the applications of US dental implants over the last century, evaluating their reliability and viability, when compared to conventional implants.

Materials and methods

The concept of the following review is based on PRISMA (Preferred Reporting Items for Systematic review and Meta-analysis). A detailed Protocol according to the PICO system was designed to answer the following question: When is the use of ultra-short implants more favourable? and how viable are they? (P) Patient/Problem: atrophic alveolar ridge. (I) intervention: Use of ultra-short implants. (C) Control: Conventional implants. (O) Outcome: successful rehabilitation of the edentulous zone.

Selection criteria

Publications that met the following criteria were included:

1.Full-text articles in English language, not older than 10 years.

2. Articles containing relative information about the topic of research.

Publications that had no relative data to the topic of study and literature reviews were dropped out.

İnformation sources

Electronic search of English literature was carried out in July 2022, in the databases of PubMed, Google scholar, Scopus, and ResearchGate. The search started on the 22nd of July 2022 and ended on the 27th of July 2022.

Search and selection of studies

The following combination of these keywords was used in the search: ultra-short OR extra-short OR short AND dental implants. As a result, 151 articles from PubMed, Google scholar, Scopus, and ResearchGate were analyzed. The articles were selected and filtered in several stages. Initially, the articles were evaluated by titles, then they were additionally assessed by reading through the abstracts and full text articles. All duplicates were dropped out.

Data collection process

Data was extracted from the studies in accordance with the interest of the current review.

Inclusion and exclusion criteria

The literature search was limited to publications published in the English language, including randomized and non-randomized controlled clinical trials, clinical studies, retrospective studies, prospective studies, three-dimensional finite element analysis (3DFEA), and case reports.

The inclusion criteria were:

1. Human subjects.
2. Subjects must be ≥ 18 years of age.
3. Both genders.
4. The usage of ultra-short implants.
5. *In silico* studies.

The exclusion criteria were:

1. Current active periodontal disease.
2. intravenous bisphosphonate use or continuous oral bisphosphonate use for more than 5 years.
3. dental condition considered contraindicated for implant placement.
4. immune-suppressive conditions or the use of immune-suppressive medications.
5. recent organ transplant or artificial joint replacement.
6. Pregnant patients.

Outcome variables:

The following outcome variables were defined:

1) Circumstances favoring the use of ultra-short implants.
2) Peri-implant (marginal) bone loss.
3) Implant survival rate.
4) Influence of crown-to-implant ratio.
5) Surgical approach.
6) Biomechanics of ultra-short implants.

Data extraction

All headlines were screened to dropout irrelevant results. Onwards, abstracts were screened to analyze the number of 1221 implants placed and the main characteristics of the study. The publications that remained after the abstract screening were analyzed according to inclusion/exclusion criteria. At last, 28 articles were included in the present review.

Data items

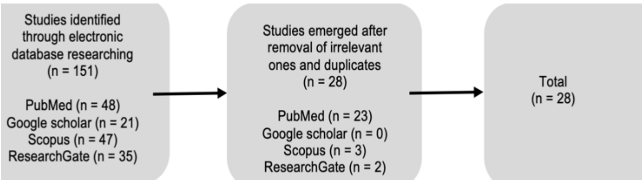
Data from the articles were extracted and filled in table 1, with the following information: Table 1: Author, year, and study type; Aim of the study; Implant used; Peri-implant bone loss; Implant survival rate; Crown-to-Implant ratio; and Surgical approach [1-22,26]. Data from 3DFEA could not be fitted in a table form due to heterogeneity of the outcome variables by the authors [23-25,27,28].

Statistical analysis: A meta-analysis of the data could not be performed, due to the heterogeneity of the data of the manuscripts included.

Risk of bias: Risk of Bias was not conducted.

Results

A total of 151 articles were identified by keywords and resumes. All duplicates were excluded. A total of 83 articles were identified as potentially relevant, by checking the titles and abstracts. Afterwards, full-text of 47 articles were analyzed, in compliance with the inclusion criteria, Articles that didn't meet the inclusion criteria were excluded, Ultimately, after applying the inclusion and exclusion criteria, 28 full-text articles were included and analyzed in our systematic review. The process of sampling and analyzing the studies is presented in the block schematic diagram (Graphic 1).



Graphic 1. Research selection process.

Regarding the 28 included articles, 8 were clinical studies, 6 were case reports, 6 were retrospective studies, 5 were three-dimensional finite element analysis, 2 randomized controlled clinical trials (RCCT), and 1 prospective study. In the selected literature, a total number of 1221 implants were inserted. All results of the *in vivo* studies were yielded by the authors through radiographic examination [1-22,26], and the results of the *in silico* studies were rendered digitally [23-25,27].

Circumstances favoring the use ultra-short implants

US implants were mainly used in posterior masticatory region with severe atrophy of the alveolar ridge, where the residual bone loss was insufficient for conventional implant placement, with the aim of evading bone augmentation procedures, or due to contraindications of bone augmentation procedures [1-3,5-14,16-21,26]. Different authors used US dental implants in combination with SFE procedures; Nizam et al. compared the placement of US implants alone, or in conjunction with osteotome SFE, US implants showed better results with placed alone, when compared US implants with osteotome SFE, showing slightly better survival rate 96.3% to 90%, and lower PBL (0.27mm to 0.32mm) on an 18-month follow-up, although results were not statistically significant [4]. Moreover, Lombardo et al. [22] utilized US implants with a modified osteotome SFE, at a 36-month follow-up, results were similar to the findings of Nizam et al. [4] at 0.39 mm PBL, and a 95.65% survival rate. On the contrary, Shah et al. [1] comparing US implants with conventional implants in conjunction with vertical bone augmentation using alloplastic bone graft showed that US implants showed slightly lower PBL (0.6 mm), when compared to the conventional implants group (0.86 mm) at a12-month follow-up. Furthermore, US implants in combination with GBR procedures were used in extremely atrophic mandibulae, both showing 100% implant survival rate at a 7-year follow-up [11], and a 3-year follow-up [15]. Additionally, Ewers et al. [19] evaluated the outcomes of inserting US implants in the incisal foramen, with two other US implants in the premolar region in an “all-on-three” prosthesis for the rehabilitation of edentulous maxillae, over a mean follow-up period of 8.3 months (maximum of 22 months), all implants were osseointegrated showing 100% survival rate and patient satisfaction.

Peri-implant (marginal) bone loss

Peri-implant marginal bone loss, being a crucial aspect for long-term implant success and stability of osseointegration [26], was analyzed. Since some authors had a longer follow-up period than others, therefore, in order to analyze the mean PBL truthfully, two groups were assigned, short-term follow-up < 42 months[1-5,8-10,14-19,22,26], and long-term follow-up > 42 months[6,7,11-13,20-21]. Short term follow-up group showed a mean PBL of 0.38 mm (range, 0.27 to 0.95 mm), and a mean of 0.45 mm (range, 0.3 to 1.1 mm) for the long-term follow-up group. Hernandez-Marcos et al. [2] concluded that US implants which were restored at the platform level experienced more PBL at 0.38 mm when compared to the implants restored at gingival level 0.07 mm after a 1-year follow-up. Anitua et al. [10] concluded in their study the type of antagonist significantly affected PBL, reporting that 9 US implants with a natural dentition as the antagonist had a mean PBL of 0.73 mm, while 17 ultra-short implants with a fixed partial denture as the antagonist had a mean PBL of 1.28 mm. Moreover, patients with history of periodontal disease showed greater PBL, when compared to healthy patients [13,17]. Remarkably, it has been noted by multiple authors that 6 mm implants resulted in more PBL when compared to 4-5 mm implants, although the results were not statistically significant[12,13,16,17,22].

Implant survival rate

All authors had a statistically high Implant survival rate with the usage of US implants in their studies, with a mean value of 97.1% throughout all studies [1-23,26]. Amato et al. [3] concluded in their study that no difference was observed between implants inserted in healed bone, in fresh extraction sockets, or with SFE. Lombardo et al. [13] results concluded that patients with a history of periodontal disease had a slightly lower survival rate of 92.16%, when compared to healthy patients at 97.41%, although the results were not statistically significant.

Influence of Crown-to-Implant ratio

In the studies included in the systematic review analysis of the influence of C/I ratio was analyzed by the following authors[7,9,10,20,21].

Certain Authors agreed that the C/I ratio did not have any statistically significant influence on PBL, or implant survival rate[7,9,20]. On the contrary, Mangano et al. reported that prosthetic complications were more frequent when the C/I was ratio ≥ 2 (12.5%) than when the C/I ratio was < 2 (6%), but this difference was not statistically significant, and after calculating a repeated-measures linear regression model, an estimate of 0.023mm increase in 1-year PBL for every 0.1 increase in C/I ratio, but at 5 years, the association decreased to 0.019mm[21].

Furthermore, Anitua et al. reported that use of a cantilever bridge for pontic support was found to have a negative influence on PBL during the first-year post-loading, showing a mean PBL value of 0.74 mm in the 12 implants where cantilevers were used versus 0.31 mm in the other 116 implants which were not rehabilitated using cantilevers[10].

Surgical approach

In the studies included in the systematic review, both one-stage[1-3,5,8,9,11,16,17], and two-stage[4,6,7,10,12,13-15,18-22,26] techniques were used. Analysis of the surgical approach used by the authors have shown no statistically significant difference between the one- or two-stage surgical techniques[1-22,26]. Menini et al. study, which compared the outcomes of US implants inserted with one-stage versus two-stage technique, have concluded no statistically significant difference between the two surgical techniques, showing a mean PBL of 0.45 mm for one-stage, and 0.46 mm for two-stage over a 12-month follow-up. Moreover, stating an implant stability quotient of 81.39 for one-stage, and 81.1 for two-stage over a 12-month follow-up, which is not statistically significant[14].

Biomechanics of ultra-short implants

3DFEA was used to analyze the biomechanics of US implants. Regarding peri-implant bone, authors came to conclusion that US implants under axial load had a high concentration of stress on the cortical bone region, and oblique loads resulted in expressive rise of stress peak on the cortical bone region, adding that the increase in implant length led to significantly higher stress levels around the neck of the implant[9,23-25,27]. Regarding abutment biomechanics, under axial load, peak values on the outer portion of the abutment were low, but on the inner portion, the peaks were almost 3 times higher, that increases with the increase of crown height [23-25,27]. de Souza Rendohl et al. concluded that 20-degree angled abutments under oblique loading generated von Mises stress in cortical bone exceeding the yield stress by 100%, resulting in permanent deformation of the implant, creating a micro-gap between the abutment and implant [27].

Discussion

In the pioneering era of oral implantology, the rationale for using implant-supported restorations had to be based on the hypothesis of considering the implant as a tooth root. In other words, clinicians practiced the insertion of the longest implant possible in any given site, to increase the surface available for osseointegration and maintain a C/I ratio that mimics the natural tooth-root ratio[5,13,21].

Whenever anatomical limitations are present, the use of US implants has been suggested as an alternative method for rehabilitation where anatomical limitations are present [2,13,18]. and over the last decades, it has become widespread, and a practical option in the treatment of edentulism [1,13,21]. Authors had different opinions about a specific length the defines an “ultra-short” implant, some specified US implants as implants with ≤ 6.0 mm in length, and others ≤ 6.5 mm in length, therefore a ≤ 6.5 mm implant mark was selected for this review[3,5,16,20].

In this review, the usage of US implants has proven to be a reliable alternative technique in the rehabilitation of atrophic jaws, showing a mean rate of success of 97.1% among all the authors[1-22,26]. Shah et al.’s study compared 6-mm implants group versus conventional 10-mm implants with vertical bone augmentation group, analyzing 25 implants in each group, the 6-mm implants group showed lower survival rate at 4 implants failing out of 25, where only 1 implant failed in the conventional implant group, although the conventional implant group had a higher PBL of 0.86 mm, when compared to the US implant group at 0.6 mm, however, these results were statistically insignificant over a one year follow up[1]. Furthermore, the usage of US in an “all-on-short” prosthesis in the rehabilitation of edentulous jaws, have shown great success, reporting patient satisfaction, and the restoration of the patient’s masticatory function[8,19]. Ewers et al. investigated the insertion of US implants in the incisal foramen in an “all-on-three” prosthesis, as it provides the thickest and highest bone structure in the atrophic maxilla, which is suitable for implant placement, reported a 100% success rate over 9 patients reported[19].

C/I ratio, being the relationship between the length of the crown and the implant. C/I ratio could be defined anatomically, taking the implant shoulder as the borderline between the crown and the implant, or clinically, taking the bone level as the borderline separating the crown and the implant [7,9,10,21]. It should be always taken into consideration, that the usage of short or US implants will always have an unfavorable C/I ratio, meaning that a higher crown height will act as a lever, creating a moment of lateral forces, transmitting stress to the peri-implant bone [7,20,26]. The 5th consensus conference of the European Academy of osseointegration (EAO) concluded that a C/I ratio of 2:1 is acceptable and is not associated with biological complications in single or splinted crowns [10,14]. Malchiodi et al. stated in his study that critical thresholds for the C/I ratio stands at 3.1 and 3.4, for the anatomical and clinical C/I ratio respectively, as exceeding these numbers could result in excessive bone loss or implant failure[21,28]. Moreover, it has been reported increasing the implant diameter reduces the stress transmitted to the peri-implant bone, which could prevent microfractures formation in the peri-implant bone, that could cause bone resorption[10,14,25,27]. Malchiodi et al. and Anitua et al. reported no statistically significant influence of parameters, such as sex, smoking habits, diabetes, prosthetic variables, biomechanical, or implant design on PBL during first year post-loading or after[7,9], although higher failure percentage was reported for implants placed in the posterior maxilla, due to the low bone density and high masticatory function in this area[7,9,20].

Menini et al. stated that the possibility to apply a one-stage technique when using ultra-short implants brings several advantages, including less morbidity, more patient's comfort, reduced chairside time, and reduced costs while providing a favourable clinical outcome [14]. de Souza Rendohl et al. concluded in his 3DFEA that the use of angled abutments in US implants is unwise, as they produced stress exceeding the yield strength of grade V titanium under oblique load of 150 N[27].

Thus, the results of the present review remain reliable, further studies are needed with longer follow-up periods to evaluate the consistency of US implants, so they can be approved as a substitute of conventional implants.

Limitations

During our systematic review, various research results could not be obtained. Firstly, not all authors enlisted the C/I ratio in their studies. Secondly, not all authors enlisted PML in their studies. Finally, only one paper was found regarding the insertion of US implants in the anterior area, therefore, further studies should be conducted on this topic.

Conclusions

The results of the present review suggest that the placement of ultra-short implants is a viable option in the rehabilitation of patients with atrophic alveolar ridge. In fact, US implants showed similar results to conventional implants, with similar survival rate, and peri-implant bone loss, and in some cases, lower peri-implant bone loss, but the results are not statistically significant. Hence, the long-term effectiveness of ultra-short dental implants remains to be further investigated.

Acknowledgments

The authors report no conflicts of interest related to this study.

Declaration of Interest

The authors report no conflict of interest.

Abbreviations

US - ultra-short
GBR - guided bone regeneration
SFE - sinus floor elevation
C/I - Crown-to-Implant
PBL - Peri-implant bone loss
RCCT - randomized controlled clinical trial
SPS - sintered porous-surfaced
3DFEA- three-dimensional finite element analysis

Author, year, and study type	Aim of the study	Implant used	Peri-implant bone loss	Implant survival rate	Crown-to-Implant ratio	Surgical approach
Shah et al.[1] 2018 RCCT	Placement of US implants as an alternative to conventional implant with bone augmentation procedures	25 6-mm implants (MIS seven)	1-year average - 0.6 ± 0.16 mm	84%	-	One-stage
Hernandez-Marcos et al.[2] 2018 Retrospective Study	Marginal bone loss around implants inserted at gingival level when compared at platform level	5 - 4.5-mm, 13 - 5.5-mm, 15 - 6.5-mm implants	1-year average - 0.07 ± 0.25 at gingival level, 0.38 ± 0.52 at platform level	-	-	One-stage

Amato et al.[3] 2020 Clinical study	Evaluate marginal bone loss and survival rate after immediate loading	62 5-mm and 6-mm implants (T3, Zimmer Biomet)	average follow-up period of 38 ± 10 months, (0.35 ± 0.24 mm; range: 0.0 to 0.8 mm)	98.4%	-	One-stage
Nizam et al.[4] 2020 Prospective Study	outcomes of ultra-short implants either alone or in conjunction with osteotome sinus floor elevation and	29 ultra-short implants + osteotome sinus floor elevation (mean length 5.33 ± 0.734), and 27 ultra-short implant group (mean length 5.31 ± 0.79)	18 months mean - ultra-short implant + osteotome sinus floor elevation group (0.32 ± 0.36), ultra-short implant group (0.27 ± 0.31)	90% ultra-short implant + osteotome sinus floor elevation group, and 96.3% ultra-short implant group	ultra-short implant + osteotome sinus floor elevation group (2.75 ± 0.77), ultra-short implant group (2.84 ± 0.82)	Two-stage
Ramos et al.[5] 2020 Case reports	evaluated marginal bone stability in individualized ultra-short implants for masticatory function in the posterior mandible	13 4-mm implants (Straumann implants)	1 year mean 0.256-mm	-	-	One-stage
Luciano et al.[6] 2019 Case report	Rehabilitation of tooth 16, patient with history of periodontal disease.	5-mm SPS implant	11 years follow-up	100%	3.1 at baseline, 3.3 after 11 years	Two-stage
Malchiodi et al.[7] 2019 Clinical study	relationship between crestal bone levels and C/I ratio of US implants after functional loading	27 - TTx WINSIX, BioSAFin, Ancona, Italy implants. 39 - K WINSIX, BioSAFin, implants. Both 6-mm in length	Mean follow-up - 48 month 0.3 ± 0.3 mm.	96.9%	2.6 at baseline, 2.8 after 11 years	Two-stage
Falisi et al.[8] 2018 Case report	Rehabilitate edentulous mandibula with occlusal guided implant cross-arch prosthesis supported by US implants (all-on-short)	6 – 4-mm implants (Twinkon4, TEKKA)	1 year follow up 0-mm	100%	-	One-stage
Anitua et al.[9] 2015 Retrospective study	influence of C/I ratio on marginal bone loss and on the survival rates	5 – 5.5-mm, 27 6.5-mm implants	3 years follow up 0.45-mm	100%	2.45	One and two stage
Anitua et al.[10] 2014 Clinical study	effect of crown height space, C/I ratio, and offset placement of a prosthesis on implant survival, crestal bone loss, and prosthetic complications	14 5.5-mm, 38 6.5-mm implants	23.18 months follow up 0.94-mm	-	2.44	Two-stage
Carosi et al.[11] 2020 Case report	Evaluate the use of ultra-short and short implants in combination with Guided Bone Regeneration (GBR) to rehabilitate a case of severe mandibular reabsorption	4-mm implant (Straumann Standard Plus), 6-mm implant (Straumann Standard Plus)	7 years follow up	100%	-	One stage
Lombardo et al.[12] 2020 Retrospective study	evaluate implant survival, marginal bone loss, and peri-implant complications	91 5-mm, 115 6-mm implants (Bicon Dental Implants)	5 years follow up. 0.64 for 5-mm, and 0.68 for 6-mm implants	95.6% for 5-mm, 95.65% for 6-mm implants	2.01 ± 0.48 (range 1.09–3.03) for 6-mm, 2.57 ± 0.59 (range 1.80–3.81) for 5-mm implants	Two-stage

Lombardo et al.[13] 2022 Retrospective study	evaluate implant survival, marginal bone loss and peri-implant complications placed in periodontally healthy patients and patients with a history of periodontal disease	91 5-mm, 115 6-mm implants (Bicon Dental Implants	5 years follow up. 0.64 for 5-mm, and 0.68 for 6-mm implants	95.6% for 5-mm, 95.65% for 6-mm implants	2.01 ± 0.48 (range 1.09–3.03) for 6mm, 2.57 ± 0.59 (range 1.80–3.81) for 5-mm implants	Two-stage
Menini et al.[14] 2022 Clinical study	Evaluate the clinical outcomes of US implants inserted with one-stage versus two-stage technique	38 5.5- or 6.5-mm implants	1 year follow up 0.46-mm in two-stage group, and 0.45-mm in one-stage group	100%	-	One and two-stage
Fabris et al.[15] 2018 Case report	Rehabilitation of the posterior mandible with 4-mm implants with GBR	4 4-mm implants (Standard Plus RN, Straumann)	3 years follow up	100%	-	Two-stage
Estévez-Pérez et al.[16] 2020 Clinical study	evaluate the influence of implant length on marginal bone loss	16 4-mm, 16 6-mm implants (Straumann Standard Plus)	Mean follow up 36.4 months. 4-mm 0.43 mm, 6-mm 0.53 mm	100%	-	One-stage
Lombardo et al.[17] 2020 Retrospective study	evaluate implant survival, marginal bone loss and peri-implant complications in patients with and without a history of periodontal disease	114 6-mm, and 76 5-mm	Mean follow up 36 months. 0.32 mm for 5-mm implants, 0.36 mm for 6-mm implants	97.37% for 5-mm and 6-mm implants	1.92	One-stage
Magdy et al.[18] 2021 RCCT	Evaluate if US implants could provide a viable therapeutic alternative to osteotome mediated sinus floor elevation in combination with conventional-length dental implants	42 5.5mm implants	1 year follow up. 0.815mm	-	-	Two-stage
Ewers et al.[19] 2018 Case reports	Outcomes of inserting US implants in the incisal foramen in an “all-on-three” prosthesis	18 4-mm, 4 4.5-mm, 5 5-mm implants (Bicon Integra CP)	Mean follow up 8.3 months	100%	-	Two-stage
Malchiodi et al.[20] 2020 Clinical study	Evaluate the influence of crown–implant ratio on implant success rate of US dental implants	50 5-mm SPS implants (Endopore Dental System, Innova Corporation)	Mean follow up 9.5 years. 1.01 mm	94%	At prosthetic loading 2.87, at latest follow up 3.34	Two-stage
Mangano et al.[21] 2016 Clinical study	evaluate the influence of C/I ratio on the survival, PBL, and complications of US locking-taper implants	68 6.5-mm locking-taper implants (Leone Implant System, Florence, Italy)	5 years mean 0.41 mm	97%	1.72	Two-stage
Lombardo et al.[22] 2020 Clincal study	evaluate the outcomes of short and US locking-taper implants, placed in combination with a modified osteotome sinus floor elevation procedure	21 5-mm, and 23 6-mm locking taper (Bicon Dental Implants, Boston, MA, USA	3 years mean, 0.36 mm for 5-mm, and 0.42 mm for 6-mm implants	95.65%	2.27 for 5-mm, and 1.92 for 6-mm implants	Two-stage
Lombardo et al.[26] 2020 Retrospective study	Evaluate the survival and PBL of short and US implants placed in the posterior mandible	48 5-mm, and 82 6-mm implants	3 years mean, 0.38 mm for 5-mm, and 0.34 mm for 6-mm implants	95.83% 5-mm, and 97.56% for 6-mm implants	2.71 for 5-mm, and 1.99 for 6-mm implants	Two-stage

Table 1. Synthesis of results.

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