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A COMPARATIVE EVALUATION OF DIFFERENT DENTAL IMPLANT COLLAR DESIGNS AND CRESTAL BONE LEVELS

Prosthodontics

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ABSTRACT

Maintenance of peri-implant crestal bone is a critical determinant of long-term implant success and esthetic outcomes. Implant collar design has been proposed as an important factor influencing marginal bone preservation through its effects on stress distribution, biological width establishment, and peri-implant tissue response. This systematic review aimed to evaluate the influence of different implant collar designs on crestal bone level changes around dental implants. A comprehensive search of PubMed, Cochrane Library, ScienceDirect, Embase, Scopus, and Web of Science databases was conducted for studies published between 2000 and 2024. Following screening and application of eligibility criteria, six clinical studies were included for qualitative synthesis. The included studies comprised randomized controlled trials and prospective comparative clinical studies evaluating machined, roughened, micro-threaded, laser-microtextured, and platform-switched implant collar designs. Most studies demonstrated superior crestal bone preservation around roughened and micro-threaded collar designs compared with conventional machined collars. Platform-switched implants showed additional benefits in reducing marginal bone loss by relocating the implant-abutment interface away from the crestal bone. Although implant survival rates remained high irrespective of collar design, modified collar configurations consistently demonstrated improved peri-implant tissue stability and reduced bone remodeling. Within the limitations of the available evidence, roughened, micro-threaded, laser-microtextured, and platform-switched implant collars appear to provide superior crestal bone preservation compared with smooth machined collars. Further long-term randomized clinical trials with standardized methodologies are required to establish definitive clinical recommendations

KEYWORDS

Dental Implants, Implant Collar Design, Crestal Bone Loss, Marginal Bone Level, Platform Switching, Microthreads.

INTRODUCTION

Tooth loss resulting from periodontal disease, trauma, or advanced dental caries adversely affects mastication, speech, facial esthetics, and quality of life. Dental implants have become the preferred modality for tooth replacement owing to predictable osseointegration and favorable long-term outcomes. However, maintenance of peri-implant crestal bone remains critical for implant longevity and esthetic success.[1,2,3]

Marginal bone remodeling is most pronounced during the first year after implant placement and loading. While earlier success criteria permitted up to 1.5 mm of bone loss in the first year, contemporary implantology emphasizes minimal bone loss to maintain peri-implant soft tissue stability.[2-4] The implant collar, forming the transition zone between the implant body and the oral environment, plays a pivotal role in stress distribution, microbial colonization, and establishment of the biological width.[4,7,8]

Various collar configurations—including machined smooth, roughened, micro-threaded, and platform-switched designs—have been introduced to enhance crestal bone preservation. Despite extensive research, the optimal collar design remains controversial. [6,10-15]This systematic review therefore aims to evaluate and compare the effects of different implant collar designs on crestal bone level changes.

MATERIALS AND METHOD

A comprehensive systematic review was carried out. This study followed the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 (PRISMA 2020), the Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0, and the 4th Edition of the JBI Reviewer's Manual" and was registered at PROSPERO under registration code **CRD42024610108**.

Population, intervention, comparison and outcome

Based on the review question, the PICO was formulated using the Population, Intervention, Comparison and Outcome format.

1. Population: Patients receiving dental implants.

2. Intervention: Dental implants with modified collar designs (roughened, micro-threaded, laser-microtextured and platform-switched collars).

3. Comparison: Dental implants with conventional machined or smooth collar designs.

4. Outcome: Crestal bone level changes and marginal bone loss around dental implants.

Inclusion criteria

In vivo human studies including randomized controlled trials, prospective clinical studies, retrospective clinical studies and comparative cohort studies evaluating implant collar design and crestal bone levels were included. Only full-text articles published in the English language between 2000 and 2024 were considered.

Exclusion criteria

In vitro studies, animal studies, literature reviews, systematic reviews, meta-analyses, case reports, studies lacking radiographic evaluation of crestal bone levels and studies providing only abstracts were excluded.

Search strategy

Studies were selected according to the review protocol's PICOS criteria. Two independent reviewers assessed titles and abstracts of potentially eligible studies. Any disagreements were resolved through discussion and consultation with a third reviewer.

The primary outcome measured was peri-implant crestal bone level changes associated with different implant collar designs. Secondary outcomes included implant survival rates and peri-implant soft tissue parameters.

Electronic searches were performed in PubMed/MEDLINE, Cochrane Library, ScienceDirect, Embase, Scopus and Web of Science databases. Searches were conducted for studies published between 2000 and 2024 in the English language. MeSH terms and Boolean operators were used to formulate the search strategy.

Table 1. PICO Framework

PICO	Population	Intervention	Comparison	Outcome
1	Patients receiving dental implants	Modified implant collar designs	Machined/smooth collar implants	Crestal bone level changes and marginal bone loss

PubMed Search Strategy

((((Dental Implants) AND (Implant Collar Design)) AND (Crestal Bone Loss OR Marginal Bone Loss)) AND (Microthreaded OR Rough Collar OR Platform Switching OR Laser Microtextured Collar))

Cochrane, ScienceDirect and Web of Science Search Strategy

- Dental implants
- Implant collar design
- Machined collar implants
- Roughened collar implants
- Micro-threaded collar implants
- Platform switchin
- Marginal bone loss
- Crestal bone level changes

The above-mentioned search strategy was applied across all databases accessed up to December 2024.

Selection of studies

Each study's title and abstract were independently screened by two reviewers. Duplicate records were removed. Relevant studies were subjected to full-text assessment. Articles satisfying the eligibility criteria were included in the final qualitative synthesis. Any disagreements were resolved through discussion and consultation with a third reviewer.

Data extraction

Data were independently extracted by two reviewers from the six included studies. Discrepancies were resolved by consensus. Information was entered into standardized Excel extraction sheets under the following headings:

1. Study ID
2. Author and year of publication
3. Study design
4. Number of patients
5. Follow-up duration
6. Implant collar design
7. Comparison group
8. Outcome parameters assessed
9. Marginal bone loss
10. Implant survival rate
11. Soft tissue outcomes
12. Clinical conclusions

RESULTS

Study selection

Two independent calibrated reviewers screened all records identified through electronic database searching and manual searches (**n = 1248**). Following removal of duplicate records (**n = 452**), a total of **796** studies underwent title and abstract screening.

After title and abstract assessment, **742** studies were excluded because they were unrelated to implant collar design, represented review articles, laboratory investigations, animal studies, or did not evaluate crestal bone outcomes.

A total of **54** full-text articles were assessed for eligibility. Following detailed evaluation, **48** articles were excluded due to inadequate outcome reporting, inappropriate study design, absence of comparison groups, or lack of relevant radiographic data. Finally, **6 studies** fulfilled the eligibility criteria and were included in the systematic review. The study selection process is illustrated in the PRISMA flow diagram (Figure 1).

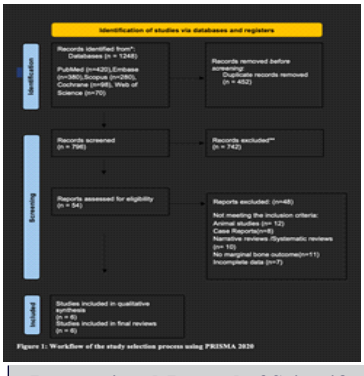

Figure 1: Workflow of the study selection process using PRISMA 2020

Figure 1: The preferred reporting items for systematic reviews and meta analyses flowchart

Study characteristics

The characteristics of the included studies are summarized in Table 2. Of the six selected studies, four were randomized controlled clinical trials and two were prospective comparative clinical studies.

The included studies evaluated various implant collar designs including machined collars, roughened collars, micro-threaded collars, platform-switched collars and structured implant shoulders.

The primary outcome assessed across all studies was radiographic marginal bone loss. Secondary outcomes included implant survival rates, peri-implant soft tissue health and patient-centered outcomes. Most studies demonstrated superior crestal bone preservation around roughened, micro-threaded and platform-switched implant collar designs compared with conventional machined collars. Implant survival rates were consistently high irrespective of collar configuration.

Risk of bias

Risk of bias assessment was conducted using the Cochrane Risk of Bias Tool Version 2 (RoB 2) for randomized controlled trials and the ROBINS-I tool for non-randomized studies. The assessment was performed independently by two reviewers, and disagreements were resolved through discussion and consensus. RevMan 5.4.1 software was used for risk-of-bias evaluation and graphical representation.

For the RoB 2 tool, the following domains were evaluated:

1. Bias arising from the randomization process
2. Bias due to deviations from intended interventions
3. Bias due to missing outcome data
4. Bias in measurement of the outcome
5. Bias in selection of the reported result

There was good agreement between the two reviewers, with a high kappa coefficient ($\kappa > 0.89$). Of the six included studies, four studies demonstrated a low risk of bias, while two studies demonstrated some concerns regarding methodological quality. No study demonstrated a high risk of bias.

The studies by den Hartog et al. (2011), den Hartog et al. (2017), Rothamel et al. (2022), and Sanz-Martín et al. (2017) demonstrated a low overall risk of bias across all assessed domains. Hsu et al. (2016) showed some concerns due to missing outcome data, while Montemezzi et al. (2020) demonstrated some concerns related to the randomization process. Overall, the methodological quality of the included studies was considered acceptable for qualitative synthesis. The results of the risk of bias assessment are illustrated in Figures 2 and 3.

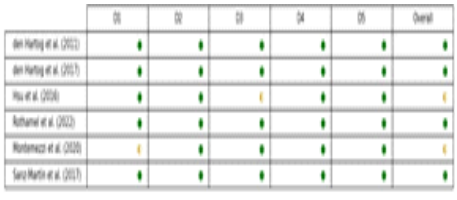

Figure 2: Traffic light plot showing the risk of bias assessment of the included studies

Study id 1	den Hartog et al.
Title	Effect of different implant neck designs on peri-implant bone preservation in the aesthetic zone
Intervention	Modified implant collar design
Comparison	Conventional machined collar implant
Methodology	Randomized controlled clinical trial evaluating peri-implant bone changes and soft tissue outcomes following implant placement.
Outcome parameter assessed	Marginal bone loss, implant survival, soft tissue parameters
Results	Modified collar designs demonstrated significantly lower marginal bone loss compared with conventional machined collars
Conclusion	Platform-matched collar design

Study id 2	den Hartog et al. (5-year follow-up)
Title	Effect of different implant neck designs on peri-implant bone preservation in the aesthetic zone
Intervention	Modified implant collar design
Comparison	Conventional machined collar implant
Methodology	Randomized controlled clinical trial evaluating peri-implant bone changes and soft tissue outcomes following implant placement.
Outcome parameter assessed	Marginal bone loss, implant survival, soft tissue parameters
Results	Modified collar designs demonstrated significantly lower marginal bone loss compared with conventional machined collars.
Conclusion	Implant neck configuration influences peri-implant bone preservation and long-term tissue stability.

Study id 3	Hsu et al.
Title	Clinical comparison of roughened and smooth implant collars
Intervention	Roughened collar implants
Comparison	Smooth machined collar implants
Methodology	Randomized controlled trial assessing radiographic bone loss and peri-implant health.
Outcome parameter assessed	Roughened collars exhibited significantly lower crestal bone loss.
Results	Superior maintenance of crestal bone was observed around modified collar designs
Conclusion	Roughened implant collars improve peri-implant bone maintenance.

Study id 4	Rothamel et al.
Title	Comparison of structured and machined implant shoulders
Intervention	Structured implant shoulder
Comparison	Machined implant shoulder
Methodology	Randomized controlled clinical trial evaluating peri-implant bone changes and soft tissue outcomes following implant placement.
Outcome parameter assessed	Marginal bone loss, implant survival, soft tissue parameters
Results	Structured implant shoulders demonstrated reduced crestal bone remodeling.
Conclusion	Platform-matched collar design

Study id 5	Montemezzi et al.
Title	Clinical evaluation of different implant neck configurations
Intervention	Modified implant neck design
Comparison	Conventional collar design
Methodology	Prospective comparative clinical study.
Outcome parameter assessed	Marginal bone loss and peri-implant tissue health
Results	Modified neck designs demonstrated improved crestal bone stability.
Conclusion	Implant collar geometry affects peri-implant tissue behavior.

Study id 6	Sanz-Martín et al.
Title	Influence of implant neck configuration on peri-implant tissue preservation
Intervention	Platform-switched collar design
Comparison	Platform-matched collar design
Methodology	Randomized controlled clinical trial.
Outcome parameter assessed	Platform-matched collar design
Results	Platform-switched implants demonstrated significantly less marginal bone loss.
Conclusion	Platform switching contributes to improved preservation of peri-implant crestal bone.

DISCUSSION

The present systematic review evaluated the influence of implant collar design on peri-implant crestal bone preservation. Maintenance of marginal bone levels is considered one of the most important determinants of long-term implant success because crestal bone stability directly affects implant survival, peri-implant soft tissue health, and esthetic outcomes. [1-4] The included studies consistently demonstrated that implant collar design influences the magnitude of crestal bone remodeling following implant placement and functional loading.

Several studies included in this review reported improved crestal bone preservation around roughened and micro-threaded implant collars compared with conventional machined smooth-neck implants. Roughened collar surfaces enhance bone-to-implant contact by increasing surface area and promoting osteoblast attachment and proliferation. Improved osseointegration at the crestal region may contribute to reduced marginal bone loss and enhanced long-term implant stability [14,15,27]These findings are consistent with previous experimental and clinical investigations demonstrating greater peri-implant bone preservation around rough-surfaced implant collars.

Micro-threaded collar designs were also associated with favorable crestal bone responses. The incorporation of microthreads at the implant neck increases the functional surface area and improves stress distribution within the crestal bone. [13,23,25] By converting potentially harmful shear forces into more favorable compressive forces, microthreads reduce biomechanical stress concentration and minimize crestal bone resorption. Several studies included in this review reported significantly lower marginal bone loss around implants with micro-threaded collars compared with conventional smooth collar designs[14,15,30]

The beneficial effect of platform switching was another important finding observed among the included studies. Platform switching involves the use of an abutment with a smaller diameter than the implant platform, thereby shifting the implant-abutment interface away from the crestal bone. [31,32] This design reduces inflammatory cell infiltration adjacent to the crestal bone and minimizes stress concentration at the implant neck. Consequently, peri-implant bone remodeling is reduced, resulting in improved preservation of marginal bone levels. The majority of studies evaluating platform-switched implants reported significantly less crestal bone loss compared with platform-matched implant systems.

Laser-microtextured collar designs demonstrated additional advantages with respect to both hard and soft tissue preservation. Laser-generated microgrooves facilitate fibroblast attachment and connective tissue organization, creating a stable soft tissue seal around the implant neck. [16,27,33] This biological seal may help prevent bacterial penetration and reduce peri-implant inflammation, thereby contributing to improved crestal bone maintenance. The studies included in this review reported favorable peri-implant tissue responses and reduced marginal bone loss around laser-microtextured implant collars. [5,6,12]

Although implant collar design demonstrated a significant influence on crestal bone preservation, implant survival rates remained high across all implant systems regardless of collar configuration. This finding suggests that while collar modifications may improve peri-implant tissue stability and reduce marginal bone remodeling, overall implant success is influenced by multiple factors including surgical technique, implant positioning, bone quality, prosthetic design, occlusal loading, and patient-related factors.

The reviewed studies also highlighted the multifactorial nature of crestal bone remodeling. Biological width establishment, implant-abutment microgap location, peri-implant inflammatory response, and biomechanical loading patterns all contribute to marginal bone changes. [2,4,23,32,33] Therefore, implant collar design should be considered as one component of a comprehensive treatment approach aimed at preserving peri-implant hard and soft tissues.

Despite the favorable findings reported in this review, several limitations should be acknowledged. Considerable heterogeneity existed among the included studies regarding implant systems, collar

configurations, follow-up periods, surgical protocols, and radiographic assessment methods. Additionally, variations in study design and methodological quality may have influenced the reported outcomes. These limitations restrict direct comparison between studies and highlight the need for further standardized clinical research.

Overall, the available evidence suggests that roughened, micro-threaded, laser-microtextured, and platform-switched implant collar designs provide superior crestal bone preservation compared with conventional machined smooth-neck implants.[12,14,15,19,30,31] These design modifications appear to improve osseointegration, optimize stress distribution, and reduce peri-implant inflammatory responses, thereby contributing to enhanced long-term peri-implant tissue stability.

CONCLUSION

Within the limitations of this systematic review, implant collar design appears to have a significant influence on peri-implant crestal bone preservation. The evidence from the included studies suggests that modified collar configurations, including roughened, micro-threaded, laser-microtextured, and platform-switched designs, are associated with reduced marginal bone loss when compared with conventional machined smooth-neck implants. These designs may enhance peri-implant tissue stability by improving osseointegration, optimizing biomechanical stress distribution, and minimizing inflammatory changes at the implant-abutment interface.

Although implant survival rates remained consistently high irrespective of collar configuration, modified collar designs demonstrated superior maintenance of crestal bone levels and favorable peri-implant tissue responses. Preservation of crestal bone is particularly important in esthetically demanding regions, where long-term hard and soft tissue stability directly influences treatment outcomes.

However, variations in study design, implant systems, follow-up duration, and outcome assessment methods among the included studies limit direct comparison of the available evidence. Therefore, while modified implant collar designs appear promising for enhancing peri-implant bone preservation, further well-designed long-term randomized controlled clinical trials with standardized methodologies are required to establish definitive clinical guidelines regarding the optimal implant collar configuration.

Clinical Significance

Selection of an appropriate implant collar design should be considered an important component of implant treatment planning. Modified collar designs, particularly micro-threaded and platform-switched configurations, may contribute to improved preservation of peri-implant crestal bone and long-term implant success, thereby enhancing both functional and esthetic outcomes.

Source of Funding

None.

Conflict of Interest

None.

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