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Dentistry

A COMPARATIVE EVALUATION OF IMPLANT STABILITY OF TAPERED VERSUS PARALLEL IMPLANTS PLACED IN FRESH EXTRACTION SOCKETS: A SYSTEMATIC REVIEW

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ABSTRACT Immediate implant placement in fresh extraction sockets has become a widely accepted clinical approach; however, achieving adequate primary stability remains a critical factor for success. This systematic review aimed to evaluate the influence of implant macrogeometry, specifically tapered versus parallel-walled implants, on primary stability in fresh extraction sockets. A comprehensive search was conducted using PubMed, Cochrane Library, and Google Scholar databases for studies published between 2005 and 2024. After screening and applying inclusion criteria, six clinical studies were included for qualitative analysis. The included studies consistently demonstrated that tapered implants achieve higher insertion torque values and improved primary mechanical engagement at placement, particularly in situations with compromised bone quality or limited apical support. However, resonance frequency analysis values, marginal bone levels, and implant survival rates were found to be comparable between tapered and parallel-walled implants over time. These findings indicate that while tapered implants provide an early biomechanical advantage, long-term outcomes are primarily influenced by biologic healing and clinical execution. Within the limitations of the included studies, both implant designs can achieve predictable outcomes when appropriate surgical and prosthetic protocols are followed. Implant selection should therefore be guided by patient-specific anatomical and biomechanical considerations rather than implant macrogeometry alone.

KEYWORDS : Immediate Implant Placement, Primary Stability, Tapered Implants, Parallel-Walled Implants, Extraction Socket, Implant Macrogeometry

1. INTRODUCTION

Immediate implant placement in fresh extraction sockets is a widely accepted approach in implant dentistry, offering advantages such as preservation of alveolar ridge contours, reduced treatment time, and fewer surgical interventions compared with delayed protocols, along with favourable soft tissue outcomes[1,2]. Successful osseointegration in extraction sockets has been demonstrated when atraumatic techniques and appropriate surgical protocols are followed[3], with improved outcomes associated with proper case selection, socket integrity, and prosthetically driven implant placement[4].

Modern implant systems show high survival rates due to advances in surface characteristics and macrodesign, with predictable outcomes even in periodontally compromised patients under adequate maintenance[5,6]. Achieving primary stability—defined as mechanical engagement between the implant and surrounding bone—is critical to minimize micromotion and ensure osseointegration[7,8]. Parameters such as insertion torque and resonance frequency analysis are commonly used to assess stability and guide loading[9].

Primary stability is influenced by bone quality, surgical technique, and implant design[10]. Tapered implants may enhance stability through lateral bone compression, particularly in low-density bone[11], whereas parallel-walled implants provide favourable load distribution in healed ridges[13,14]. Despite higher initial stability with tapered implants[15,16], long-term outcomes remain comparable[17,18], with imaging advancements further reducing dependence on implant geometry[19].

2. 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 4th Edition of the JBI Reviewer's Manual" and was registered at PROSPERO under registration code CRD42024605888.

2.1 Population, Intervention, Comparison, and Outcome

Based on the review question, the PICO was formulated. i.e., the Population Intervention Comparison Outcome format was used.

1. Population: Patients receiving dental implants in fresh extraction sockets
2. Intervention: Dental implants in fresh extraction sockets
3. Comparison: Use of tapered (conical) and straight (parallel-walled) dental implants
4. Outcome: Immediate primary implant stability

2.2 Inclusion Criteria

In vivo, human studies including randomized controlled trials and clinical trials, prospective and retrospective clinical studies, case series with more than 5 cases, studies with full text articles were included. Studies published in only English language and from 2005 to 2024 were included.

2.3. Exclusion Criteria

In vitro studies, animal studies, literature reviews, case reports,studies in which participants were given removable prosthesisand studies that provided only abstracts were excluded.

2.4. Search Strategy

Studies were chosen in accordance with the review protocol's PICOS criteria. To find studies that might be eligible, two reviewers assessed the titles and abstracts. A third reviewer was approached for any questions.

The clinical outcomes were measured in terms of primary implant stability in the intervention and control groups. The PRISMA for conducting the systematic review was followed. PubMed/ Medline, ScienceDirect, Cochrane databases, Google scholar were searched for the articles. Searches were conducted on all articles from 2005 upto 2024 in English language. The following MeSH terms along with Boolean operators were entered in the advanced search of the databases. A concept table was prepared based on the PICOS criteria of the review question and the search strategy was formulated according to it. (Table 1)

PICO	Population	Intervention	Comparison	Outcome
1	Edentulous maxillary and mandibular arches with fresh extraction socket	Dental implants in fresh extraction sockets	Tapered versus straight (parallel-walled) dental implants	Immediate primary stability

2.5. PubMed Search Strategy

((((((Dental implants) AND (Fresh extraction sockets)) AND (Tapered implants OR Conical implants)) AND (Parallel implants OR Straight implants OR Cylindrical implants)) AND (Primary stability)) OR (Insertion torque)) OR (Resonance frequency analysis)) OR (Implant stability quotient)

2.6. Cochrane, Science Direct and Google Scholar Search Strategy

- Dental implants
- Fresh extraction sockets
- Tapered (conical) dental implants
- Parallel (straight/cylindrical) dental implants
- Primary implant stability

The above-mentioned was the final search history for the databases accessed till December 2024.

2.7. Selection of Studies

Each study's title and abstract were examined and evaluated critically by two separate reviewers. The methods used to apply the selection criteria included integrating the search results to eliminate duplicate entries, looking at titles and abstracts to eliminate articles that were obviously irrelevant, retrieving the full texts of articles that might be relevant, grouping and binding multiple articles from the same study, looking at the full texts of the articles to determine how closely the studies complied with the eligibility criteria, and establishing connections with other studies.

2.8. Data Extraction

Data were independently gathered by two reviewers from the 6 included studies after screening the articles from all databases. Disagreements were resolved through discussion and a third reviewer was consulted whenever required. Data were recorded and analysed in respective Excel data extraction sheets. The data extracted was entered under the following headers:

1. Study ID
2. Author and year of publication
3. Study design
4. Number of patients
5. Age of patients
6. Follow-up duration
7. Number of implants
8. Implant site
9. Intervention implant group (tapered implants)
10. Comparison implant group (parallel/straight implants)
11. Outcome parameters assessed
12. Implant stability parameters (ISQ, insertion torque, RFA)
13. Marginal bone level changes
14. Follow up duration [range]
15. Clinical outcomes

3. RESULTS

3.1. Study Selection

Two independent calibrated reviewers screened all records identified through electronic and manual searches (n = 437). After removal of irrelevant studies based on title screening, 35 articles were selected for abstract review. Following abstract screening, studies not meeting the eligibility criteria, including case reports, reviews, small case series, and studies with inappropriate populations or comparisons, were excluded, leaving 17 articles for full-text assessment.

Full texts were independently evaluated by both reviewers according to the predefined inclusion and exclusion criteria. Six studies fulfilled the eligibility criteria and were included in the systematic review. Any disagreements were resolved through discussion, and a third reviewer was consulted when consensus could not be reached. Authors of included studies were contacted when additional information was required. The study selection process is illustrated in the PRISMA flow diagram. (Figure 1)

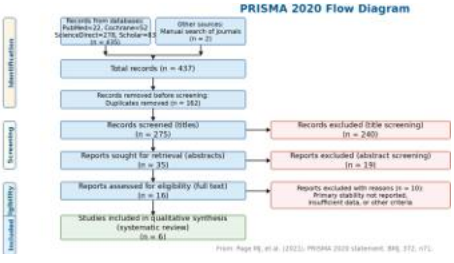

Figure 1: The Preferred Reporting Items for Systematic Reviews and Meta Analyses Flowchart

3.2. Study Characteristics

The characteristics of the included studies are reported in table 2 for study characteristics of included studies. Of the 6 finally selected studies, 4 studies were randomized controlled trials, 1 remaining 2 studies were non-randomized interventional studies, 1 of which was prospective cohort and other was pilot study. The present systematic review was based on 6 clinical studies including a total of 377 implants in around 9 centres and 134 patients of which around 50% received tapered implants as the treatment and 50% were straight/cylindrical implants.

The primary outcomes across the studies were Resonance frequency measurements (implant stability quotient (ISQ)) and torque values, bone augmentation, healing events, implant stability and patient-centred outcomes and secondary outcomes were visible plaque index (VPI), the peri-implant inflammation (PI), the probing depth index (PDI), and the gingival bleeding index (GBI), and Wound healing. Majority of the study results showed that all cylindrical and tapered implants were clinically stable at all observation periods. No statistically significant differences were noted. All of the studies concluded that tapered or standard cylindrical implants yielded clinically equivalent short-term outcomes after immediate implant placement into the extraction socket

Table 2 – Description of Selected Studies

Study id 1	Lang NP et al
Title	Immediate implant placement with transmucosal healing in areas of aesthetic priority- A multicenter randomized-controlled clinical trial I. Surgical outcomes
Intervention	tapered implants
Comparison	cylindrical implants
Methodology	In this randomized-controlled clinical trial, outcomes wereevaluated over a 3-year observation period. This report deals with the need for boneaugmentation, healing events, implant stability and patient-centered outcomes up to 3 months only. Nine centers contributed a total of 208 immediate implant placements. All surgical and post-surgical procedures and the evaluation parameters were discussed with representatives of all centers during a calibration meeting.
Outcome parameter assessed	bone augmentation, healing events, implant stability and patient-centered outcomes, Wound healing was evaluated after 1, 2, 6 and 12 weeks post-operatively.
Results	All cylindrical and tapered implants were clinically stable at all observation periods. No statistically significant differences were noted
Conclusion	This RCT has demonstrated that tapered or standard cylindrical implants yielded clinically equivalent short-term outcomes after immediate implant placement into the extraction socket

Study id 2	West JD et al
Title	Identification for stability changes of immediately placed dental implants
Intervention	tapered, self-tapping implants
Comparison	single stage, rough surface, standard implant
Methodology	This prospective cohort study was carried out in 3 implant patient populations. Immediate implant placement was carried out after the extraction.
Outcome parameter assessed	Resonance frequency analysis, ISQ
Results	Initial immediate implant stability was similar in both groups,
Conclusion	immediate placement protocols are viable options and provide biologic stability similar to tapered implants

Study id 3	Torroella-Saura et al
Title	Effect of implant design in immediate loading. A randomized, controlled, split-mouth, prospective clinical trial
Intervention	tapered implants (test group)
Comparison	cylindrical implants (control group)
Methodology	total of 20 tapered implants (test group) and 20 cylindrical implants (control group) were placed. All implants were loaded immediately with provisional fixed prostheses during the healing period before the final restoration. The implants were evaluated at the implant placement by analyzing the insertion torque values (ITVs) and the resonance frequency analysis (RFA) and after the healing period of three months, the success of those implants and the marginal bone loss were evaluated.

Outcome parameter assessed	insertion torque values (ITVs) and the resonance frequency analysis (RFA), success of those implants and the marginal bone loss
Results	Two cylindrical implants were mobile within the same patient and no tapered implants failed, resulting in implant survival rates of 90% and 100%, no statistically significant differences in RFA values
Conclusion	The tapered implant achieved greater primary stability values measured with ITVs and less marginal bone loss than the cylindrical implants.

Study id 4	Simmons DE et al
Title	Comparative evaluation of the stability of two different dental implant designs and surgical protocols—a pilot study
Intervention	Group A received 10 tapered implants (OSPTX) (Astra Tech OsseoSpeed TX™) using the soft bone surgical protocol (TXSoft). Group B received 10 tapered implants (OSPTX) (AstraTech OsseoSpeedTX™) using the standard surgical protocol (TXStd).
Comparison	Group C received 10 parallel wall implants (OSP) (AstraTech OsseoSpeed™) using the standard surgical protocol (OStd).
Methodology	Resonance frequency measurements (implant stability quotient (ISQ)) and torque values were recorded to determine initial implant stability. All implants were uncovered 6 weeks after placement and restored with a functionally loaded resin provisional screw-retained crown. Resonance frequency measurements were recorded at the time of implant placement, at 6 weeks and 6 and 12 months. Twelve months after implant placement, the stability of the implants was recorded and the final restorations were placed using custom CAD/CAM fabricated abutments and cement-retained PFM DSIGN porcelain crowns. After implant restoration, bone levels were measured at 6 and 12 months with standardized radiographs.
Outcome parameter assessed	Resonance frequency measurements (implant stability quotient (ISQ)) and torque values were recorded, bone levels were measured
Results	Implant survival rate at 1 year was 93.3%, with 2/30 implants failing to integrate prior to functional loading at 6 weeks. No statistically significant difference was found between ISQ measurements between the three groups at all time intervals measured
Conclusion	Survival and stability of OSPTX and OSP implants is comparable. Osteotomy preparation by either standard or soft bone surgical protocol presented no significant effect on implant survival and stability for the specific implant designs.

Study id 5	Waechter J et al
Title	Comparison between tapered and cylindrical implants in the posterior regions of the mandible: A prospective, randomized, split-mouth clinical trial focusing on implant stability changes during early healing
Intervention	20 tapered implants
Comparison	20 cylindrical implants
Methodology	The bone type was registered during drilling via the surgeon's tactile perception, following the classification of Lekholm and Zarb. Primary stability (PS) was determined by the insertion torque (IT) and the implant stability quotient (ISQ). Secondary stability (SS) and the peri implant health was monitored for 3 months through the visible plaque index (VPI), the peri-implant inflammation (PI), the probing depth index (PDI), and the gingival bleeding index (GBI). Significant differences were investigated with t-tests for independent samples, chi-square tests or Fisher's exact test
Outcome parameter assessed	insertion torque (IT) and the implant stability quotient (ISQ), visible plaque index (VPI), the peri-implant inflammation (PI), the probing depth index (PDI), and the gingival bleeding index (GBI).
Results	Tapered and cylindrical implants showed no significant differences for any outcome variable (P>.05).
Conclusion	Tapered and cylindrical implants have similar biological behavior during the healing process. Bone site characteristics can influence insertion torque and implant stability.

Study id 6	Wei SM et al
Title	Accuracy and primary stability of tapered or straight implants placed into fresh extraction socket using dynamic navigation: a randomized controlled clinical trial
Intervention	tapered implant group (TI group)
Comparison	straight implant group (SI group).
Methodology	Patients with compromised anterior teeth in maxilla were recruited and allocated randomly into (1) tapered implant group (TI group) and (2) straight implant group (SI group). Implants were inserted into fresh sockets with dynamic navigation. Three-dimensional platform deviation, apex deviation, angular deviation, insertion torque value (ITV) and implant stability quotient (ISQ) were recorded
Outcome parameter assessed	Three-dimensional platform deviation, apex deviation, angular deviation, insertion torque value (ITV), accuracy, and implant stability quotient (ISQ) and implant stability quotient (ISQ) were recorded, sagittal root position classification
Results	The accuracy was 0.86 ± 0.26 mm, 0.76 ± 0.33 mm, and $2.49 \pm 1.54°$ for TI, and 0.89 ± 0.44 mm, 0.88 ± 0.36 mm, and $2.31 \pm 1.01°$ for SI, with no significant difference) The overall ISQ was 60.74. ISQ was 60.48 for TI and 60.96 for SI, with no significant difference.
Conclusion	High accuracy and primary stability of immediate implant placement could be achieved both in tapered and straight implants with dynamic navigation systems.

3.3. Risk of Bias

This assessment was conducted by using the recommended approach for assessing risk of bias using RoB2 tool of Cochrane for Randomized clinical trials and ROBINS-I for non-randomized interventional studies. The tool is particularly useful to those undertaking systematic reviews that include non-randomized studies using the tool RevMan 5.4.1

For RoB 2 tool, we used the following domains: -

1. Randomization process
2. Allocation concealment
3. Blinding of participants and Personnel
4. Blinding of outcome
5. Incomplete outcome data
6. Selective reporting
7. Other Bias

There was good agreement between the two reviewers, with a high kappa coefficient ($\kappa > 0.89$). Out of the 6 included studies, 3 studies demonstrated a low risk of bias, 2 studies demonstrated a moderate risk of bias, and 1 study demonstrated a high risk of bias. Demonstrated in fig 2 and 3

Figure 2 : Traffic Light Plot for Risk of Bias+/Green Color: Low

Risk of Bias?/Yellow Color: Some Concerns−/Red Color: High Risk of Bias

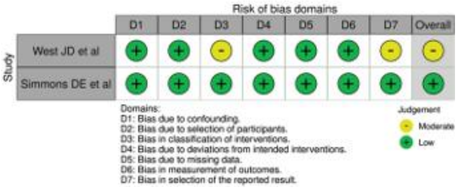

Figure 3: ROBINS-I tool "Summary Plot" Distribution of Risk of Bias Among The Studies

4. DISCUSSION

The present systematic review evaluated the influence of implant macrogeometry, specifically tapered and parallel-walled implants, on primary stability in fresh extraction sockets. Immediate implant placement has become a predictable treatment modality due to its ability to preserve alveolar architecture, reduce treatment time, and minimize the number of surgical interventions required.[1,20] The included studies consistently demonstrated that both tapered and parallel implant designs can achieve successful osseointegration and favourable clinical outcomes when appropriate surgical and prosthetic protocols are followed.[7, 11] High implant survival rates were reported irrespective of implant design, supporting the clinical predictability of both systems.[15,16,20]

Several studies reported higher insertion torque values and improved primary mechanical engagement with tapered implants. Torroella-Saura et al. observed significantly greater insertion torque values and reduced early marginal bone loss in tapered implants compared with cylindrical implants.[15] Similarly, Waechter et al. demonstrated superior mechanical engagement with tapered implants, particularly in areas with thinner cortical plates and reduced bone density.[16] Simmons et al. also reported higher insertion torque values for tapered implants at placement, indicating enhanced initial fixation.[11] Despite these findings, resonance frequency analysis (RFA) and implant stability quotient (ISQ) measurements generally demonstrated comparable stability patterns between tapered and parallel implants during the healing phase.[7,11,16]

Marginal bone level changes were evaluated in several studies and showed no consistent long-term differences between implant designs. Although reduced early marginal bone loss was reported with tapered implants in some investigations,[15] long-term clinical studies have demonstrated comparable crestal bone behaviour between tapered and straight implant designs.[17,18] Radiographic investigations further suggest that marginal bone remodelling is influenced by several biologic and biomechanical factors, including peri-implant tissue adaptation, loading conditions, and maintenance protocols, rather than implant shape alone.[39]

The reviewed studies also highlighted the importance of factors beyond implant macrogeometry in determining primary stability. Bone density and cortical bone thickness remain major determinants of insertion torque and implant stability.[22, 23] Thread geometry has also been shown to influence mechanical engagement, with thread depth, pitch, and compactness affecting the magnitude of micromotion at the bone–implant interface.[24,25] In addition, implant surface characteristics contribute significantly to osseointegration and long-term clinical success.[5,26] Recent advances in guided and dynamic navigation-assisted implant placement have further improved surgical accuracy and may reduce the influence of implant macrogeometry on clinical outcomes.[1]

Overall, the available evidence suggests that tapered implants provide a biomechanical advantage during implant placement and the early healing phase, particularly in fresh extraction sockets and areas of compromised bone quality.[11,15,16] However, this advantage does not consistently translate into superior long-term stability, marginal bone preservation, or implant survival.[17,18] Both tapered and parallel-walled implants demonstrate predictable clinical performance when appropriate case selection, surgical technique, and prosthetic principles are followed. [20,27,28,40]

5. CONCLUSION

This systematic review evaluated the effect of implant macrogeometry on primary stability in fresh extraction sockets by comparing tapered and parallel-walled implants. The evidence indicates that tapered implants achieve higher insertion torque and improved bone engagement, providing superior primary stability, particularly in extraction sockets, soft bone, and immediate loading situations. However, after osseointegration, both implant designs demonstrate comparable survival rates and peri-implant bone stability. Therefore, implant selection should be based not only on macrogeometry but also on factors such as bone quality, socket morphology, aesthetic requirements, and loading protocol. Furthermore, atraumatic extraction, proper implant positioning, osteotomy preparation, and regenerative procedures play a critical role in treatment success irrespective of implant design. Overall, while tapered implants offer biomechanical advantages during the early healing phase, both tapered and parallel-walled implants can achieve predictable long-term outcomes when appropriate surgical and prosthetic protocols are followed.

6. Source of Funding

None.

7. Conflict of Interest

None.

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