The Saudi Dental Journal 36 (2024) 1051–1057

Contents lists available at ScienceDirect

The Saudi Dental Journal

journal homepage: www.ksu.edu.sa
www.sciencedirect.com

Review Article

Immediate implant placement and simultaneous bone grafting with bone cement in extraction sockets: A systematic review

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ARTICLE INFO

Keywords:
Immediate implant
Bone grafting
Bone cement
Extraction sockets
Systematic review

ABSTRACT

Background: The placement of immediate dental implants intrinsically displays crestal gaps, which may compromise implant osseointegration. Several grafting materials have been used to overcome this issue. Of the available materials, the use of bone cement is relatively new in oral implantology. This study aimed to examine the available literature on the utilization of bone cements in immediate placement of dental implants and assess its potential in oral implantology.

Objectives: To synthesize evidence for appraising the impact of bone cements on implant stability and bone-to-implant contact (BIC) of dental implants placed immediately after extraction in humans and animals after 3 months of healing from tooth extraction.

Methods: A systematic search was conducted in PubMed, Medline, and ScienceDirect for relevant studies published from inception to September 2021 using relevant search terms. Of the 1624 studies, 4 were selected for this systematic review.

Results: Three of the four studies concluded that bone cements enhanced implant stability and/or BIC with better quality and/or quantity of bone surrounding the immediate dental implant. The conclusion drawn by one article remained indecisive. Meta-analysis could not be performed owing to the presence of substantial heterogeneity.

Conclusion: Bone cement is a promising treatment alternative as it augments implant stability and/or BIC in immediate dental implants. Nonetheless, further prospective human clinical trials are required to establish its clinical effectiveness and arrive at a definitive conclusion to recommend its clinical use.

1. Introduction

Immediate implant placement is a therapeutic approach introduced as an alternative to the classic delayed implant placement (Schulte and Heimke, 1976). This method has gained popularity owing to its advantages over conventional therapy, such as reduced hard and soft tissue resorption, decreased treatment time, improved function, aesthetics, and patient acceptance (Schropp et al., 2003; Quirynen et al., 2007). In fact, this protocol has been reported to achieve success and survival rates similar to those of delayed implant placement after socket healing (Gökçen-Röhlig et al., 2010; Malchiodi et al., 2016; Lang et al., 2012). Nevertheless, the placement of implants into fresh extraction sockets intrinsically results in the formation of a crestal gap between the implant periphery and the surrounding bone (Sanz et al., 2017; Meijer and Raghoebar, 2020). Known as the "jumping distance," this crestal gap compromises implant stability, which is of paramount importance for the successful osseointegration of dental implants (Albrektsson and Zarb, 1993). When the gap exceeds 2 mm, autografts, xenografts, allografts, and alloplasts are used to provide a structural base of osseous tissue for dental implants (Verket et al., 2018; Ortega-Martínez et al., 2012; Hallman and Thor, 2008; Aghaloo and Moy, 2007). Despite being considered the gold standard in bone regeneration owing to their osseoconductivity, osseoinductivity, and osseogenicity, autogenous bone grafts exhibit certain limitations, such as restricted donor sites and

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https://doi.org/10.1016/j.sdentj.2024.05.011
Received 27 November 2023; Received in revised form 7 May 2024; Accepted 23 May 2024
Available online 24 May 2024

possible harvesting morbidity (Sakkas et al., 2017). On the contrary, allografts have a higher failure rate because of the prolonged period required for bone regeneration, which can increase the possibility of infection and rejection (Brown and Carter, 2018). In addition, xenografts exacerbate the risks of eliciting immune responses and transmissible diseases. An alternative approach is to utilize bone cement, which is known to induce bone regeneration although it does not necessarily resemble its natural structure (Fukuba et al., 2021). Since their introduction in 1958 for hip replacement surgery, bone cements have been widely applied in orthopedics because of their optimal mechanical properties (Charnley, 1960). Other types of commercially available bone cement, such as calcium phosphate cements and glass polyalkenoate cements have also been successfully developed for use in orthopedic and trauma surgery (Zhang et al., 2014; Vaishya et al., 2013). However, the use of bone cement has been relatively sparse in oral implantology. In this research, the impact of bone cements on the stability and bone-to-implant contact (BIC) of implants placed immediately after extraction with a healing period of at least 3 months from extraction was evaluated. Furthermore, prospects of the use of bone cements in oral implantology have been discussed.

2. Materials and Methods

2.1. Design

The literature was thoroughly searched to identify human and animal studies evaluating the clinical implications of bone cements on implant stability and BIC during immediate dental implant insertion in fresh extraction sockets. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards were followed in this systematic review. This systematic review was registered on the PROSPERO platform under the registration number CRD42021277279.

2.2. Research questions

The following research questions were developed for the human and animal systematic reviews:

2.2.1 Research question 1: In humans and animals, does the placement of immediate implants and simultaneous bone grafting with bone cement in extraction sockets result in improved stability and BIC as those placed without bone cement after at least 3 months of healing from extraction?

2.2.2 Research question 2: If there is an association, how strong is it?

2.3. Research objective

The objective of this study was to synthesize data to evaluate the impact of bone cements on implant stability (defined as the absence of clinical mobility) and BIC (defined as the percentage of implant surface touching the bone at a microscopic level) of dental implants placed immediately after extraction.

2.4. Population Intervention Comparison outcomes (PICO)

The following PICO statements were developed for the human and animal systematic reviews:

2.4.1 Population: Humans and animals.

2.4.2 Intervention: Placement of immediate implants and simultaneous bone grafting with bone cement in extraction sockets.

2.4.3 Comparison: Placement of immediate implants without bone cement in extraction sockets.

2.4.4 Outcomes: Implant stability and BIC after at least 3 months of healing from extraction.

2.5. Search strategy and search terms

Studies published in scientific journals from inception up to September 2021 and could be accessed from databases, such as Medline, ScienceDirect, and PubMed, were included in this study. “Cochrane Database Syst Rev” filters were added in Medline to identify relevant articles. The search was restricted to English Language publications. The keywords used for searching were “immediate implant” OR “intraosseous dental implant” AND “bone cements” OR “bone graft” AND “osseointegration” OR “implant stability” AND “bone-to-implant contact” AND “tooth extraction” OR “fresh sockets.”

2.6. Screening process with inclusion and exclusion criteria

The authors screened the studies independently at the title, abstract, and full-text levels, and those that did not meet the inclusion criteria were excluded. Any difference of opinion among the authors was resolved via conversation.

2.6.1. Inclusion criteria

Animal and human randomized controlled trials and observational studies, implants placed immediately with simultaneous bone grafting using bone cements in extraction sockets, clinical measurement of implant stability, and histologic analysis of BIC after at least 3 months of healing period.

2.6.2. Exclusion criteria

Case reports/series; congress/conference papers; letters to the editor/editorials; reports based on retrospective chart reviews, interviews, or questionnaires; papers appraising restorative/endodontic cements; non-English articles.

2.7. Data extraction methodology

The data from all the involved studies were extracted and entered in an Excel Table (Table 1). One person entered the data, and a second individual verified the entries.

2.8. Quality assessment

Syrcle’s RoB tool was utilized for the risk of bias (RoB) analysis (Hooijmans et al., 2014). This tool is based on the Cochrane RoB tool for evaluating the risk of bias in randomized trials (Higgins et al., 2011). A two-person team independently performed bias assessment of each study. Subsequently, one person from the team reconciled any discrepancies with input from the second individual via discussion (Fig. 1).

3. Results

A total of 1624 studies were retrieved after electronic literature search from PubMed, Medline, and ScienceDirect, of which 362 duplicate studies were excluded. Subsequently, 1262 studies were screened using PICO and eligibility criteria, which yielded 84 studies. After application of inclusion and exclusion criteria, four studies were finally incorporated in the systematic review (Fig. 2). The reasons for the exclusion of studies were lack of detailed information on bone cement and articles describing implant surfaces, absence of control group, non-inclusion of implant stability and/or BIC, no immediate implant placement, <3 months of follow-up time.

3.1. Title and year of publication

The four studies included were published between 2004 and 2014.

Table 1
Data extraction summary.

	Cuisinier et al.	Han et al.	Hasturk et al.	Hasturk et al.	Sehlke et al.
Title of the study	Immediate implant placement using injectable CPHC in dogs	Alveolar bone regeneration around immediate implants using an injectable nHAC/CSH loaded with dBMPC: an experimental study in the dog mandible	The use of light/chemically hardened PPCH in combination with PA around implants in minipigs: Part I: immediate stability and function	The use of light/chemically hardened PPCH in combination with PA around implants and extraction sockets in minipigs: Part II: histologic and micro-CT evaluations	The use of a magnesium-based bone cement to secure immediate dental implants
Study design	Animal study	Animal study	Animal study, pilot study	Animal study	Animal study
Year of publication	2004	2011	2011	2014	2014
Type of bone cement	CPHC	dBMPC + nHAC/CSH and nHAC/CSH	PPCH, PA, PPCH-PA	Light/chemical hardening technology with newly formulated PPCH plus PA PPCH-PA	Magnesium-based bone cement, OsteoCrete
Type of procedure (flap/ flapless)	Undisclosed	Flap	Flap	Flap	Flap
Stability	PTV of test implants: 1.75 PTV (range: 04 ± 06) Control implants: PTVs were not measured as the mobility exceeded the maximum value that can be measured using the Periotest	N/A	STV: PPCH-PA: −2.5 ± 1.4 PA: −2.0 ± 1.4 PPCH: −1.5 ± 1.3 Control implants: −2.3 ± 2.0 Comparison between PPCH-PA and control at 12 weeks (p value 0.04*) Comparison between PPCH-PA and PPCH at 12 weeks (p value 0.03*) Comparison between PPCH-PA and PA at 12 weeks (p value 0.004*)	N/A	Test implants: 6/8 achieved clinical stability Control implants: 7/ 8 achieved clinical stability Test implants: 6/8[#] implants survived Control implants: 8/ 8 implants survived
BIC	Test implants: 74.7 ± 16.7 mm Control implants: 60.7 ± 3.8 mm	Test implants (nHAC/CSH): 33.13 % ± 7.29 % Control implants: 18.27 % ± 2.15 % Test implants (nHAC/CSH + dBMPC): 65.03 % ± 3.13 % Control implants: 18.27 % ± 2.15 %	N/A	Greater BIC surface was achieved in PPCH-PA and PA groups compared with PPCH and control groups	Test implants: 51.7 % ± 13.7 % Control implants: 43.7 % ± 8.1 %
Mean follow-up time	Implant stability: 10 min BIC: 9 months	12 weeks	2, 6, and 12 weeks	12 weeks	Implant stability: 1, 2, 3, and 4 months BIC: 4 months
Implant position	Mandibular first premolars	Mandibular premolars	Maxillary and mandibular premolars	Maxillary and mandibular premolars	Mandibular third premolars and first molars
Implant dimension	3.3-mm-diameter, 12-mm-long ITI titanium plasma-sprayed Straumann implants	3-mm-diameter, 10-mm-long B-type cylindrical titanium alloy shape implants	Parallel-wall, screw-type, 3.25-mm-diameter, 11.5- or 13-mm-long titanium implants	Parallel-wall, screw-type, 3.25-mm-diameter, 11.5- or 13-mm-long titanium implants	Standard plus 4.1-mm-diameter, 8-mm-long SLActive (Straumann USA)
Implant–abutment connection	Undisclosed	Undisclosed	Abutments (4-mm collar height) were used	Abutments (4-mm collar height) were used	Healing abutment (animal 1) and closure screw (animals 2 to 4) were used

(*continued on next page*)

Table 1 (*continued*)

	Cuisinier et al.	Han et al.	Hasturk et al.	Hasturk et al.	Sehlke et al.
Loading protocol	Immediate loading	Undisclosed	Immediate loading	Immediate loading	Undisclosed
Presence of buccal bone wall	Present	Present	Present	Present	Undisclosed

Calcium phosphate hydraulic cement (CPHC); nano-hydroxyapatite/collagen and calcium sulfate hemihydrate (nHAC/CSH); nano-hydroxyapatite/collagen and calcium sulfate hemihydrate plus dog blood-acquired mesenchymal progenitor cells (nHAC/CSH + dBMPC); polymethylmethacrylate, polyhydroxyethylmethacrylate, and calcium hydroxide (PPCH); polyanhydride (PA); polymethylmethacrylate, polyhydroxyethylmethacrylate, and calcium hydroxide plus polyanhydride composite graft material (PPCH-PA); Periotest value (PTV); bone–implant contact (BIC); stability test value (STV); international team for implantology (ITI); computed tomography (CT).

* Indicates statistical significance ($p < 0.05$).

Two of the test implants failed owing to inappropriately designed study protocol and were excluded from the analysis. The study protocol was modified for the remaining test (n = 6) and control (n = 8) implants.

Fig. 1. Risk of bias analysis.

3.2. Study design

All included studies were of animal study design.

3.3. Type of bone cement

The included studies used four commercially available bone cement types: calcium phosphate hydraulic cement; nano-hydroxyapatite/collagen and calcium sulfate hemihydrate plus dog blood-acquired mesenchymal progenitor cells (nHAC/CSH + dBMPC); polymethylmethacrylate, polyhydroxyethylmethacrylate, and calcium hydroxide plus polyanhydride composite graft material (PPCH-PA); and the magnesium phosphate cement OsteoCrete (Cuisinier et al., 2004; Han et al., 2013; Hasturk et al., 2011; Hasturk et al., 2014; Sehlke et al., 2013).

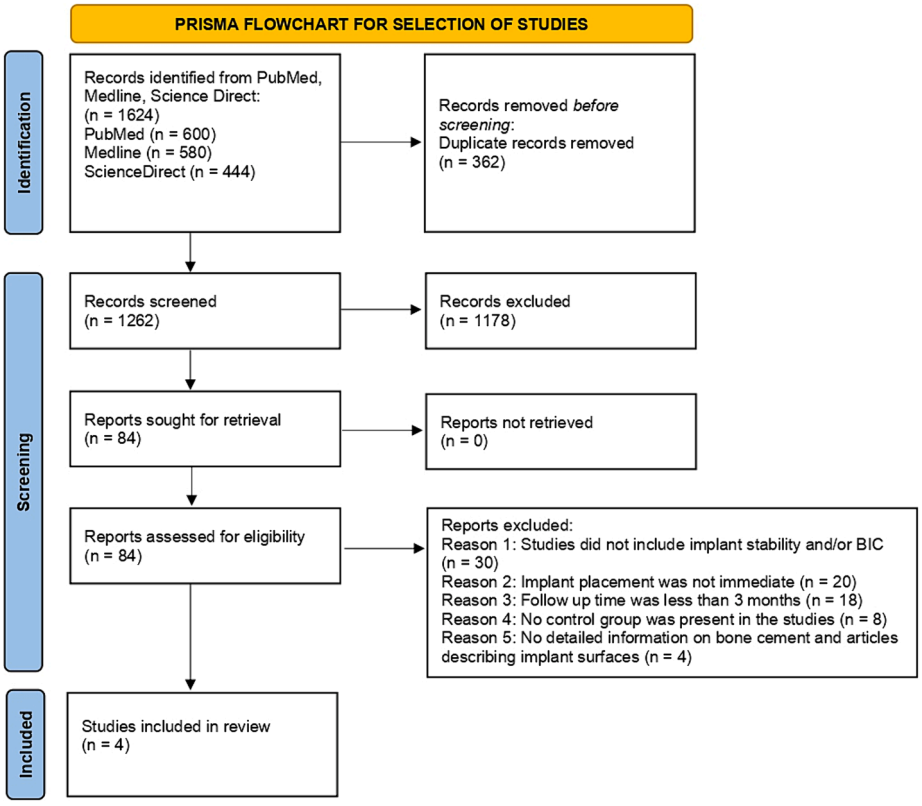

Fig. 2. PRISMA flowchart.

3.4. Type of procedure

3.4.1. Mucoperiosteal flap

In three studies, mucoperiosteal flaps were elevated during the placement of dental implants (Han et al., 2013; Hasturk et al., 2011; Hasturk et al., 2014; Sehlke et al., 2013).

3.5. Mean follow-up time

Based on the mean follow-up time for determining the outcomes, the studies were categorized into two groups. Group 1: The first outcome of implant stability was reported in three studies with a mean follow-up time of 10 min–4 months (Cuisinier et al., 2004; Hasturk et al., 2011; Sehlke et al., 2013). Group 2: The second outcome of BIC was reported in all four studies with a mean follow-up period of 12 weeks–9 months (Cuisinier et al., 2004; Han et al., 2013; Hasturk et al., 2014; Sehlke et al., 2013).

3.6. Implant position

In all studies, the implants were placed at the site of mandibular premolars, except for one study in which they were placed at the maxillary premolar site too (Cuisinier et al., 2004; Han et al., 2013; Sehlke et al., 2013; Hasturk et al., 2011; Hasturk et al., 2014). On the contrary, one study also included the mandibular first molars along with the mandibular premolars (Sehlke et al., 2013).

3.7. Implant type

The included studies reported on implants with an average diameter of 3 mm and a length of 8–12 mm.

3.8. Implant–abutment connection

In this review, two studies discussed screw-retained abutments (Hasturk et al., 2011; Hasturk et al., 2014; Sehlke et al., 2013). However, no information regarding abutment was available in the other two studies (Cuisinier et al., 2004; Han et al., 2013).

3.9. Loading protocol

Of the four selected studies, two (Cuisinier et al., 2004; Hasturk et al., 2011; Hasturk et al., 2014) used the immediate loading protocol, whereas the other two did not mention the loading protocol used (Han et al., 2013; Sehlke et al., 2013).

3.10. Presence of the buccal wall

The presence of buccal bone walls was reported in three studies (Cuisinier et al., 2004; Han et al., 2013; Hasturk et al., 2011; Hasturk et al., 2014).

3.11. Assessment of outcome measures

The outcomes were categorized into implant stability and BIC. Of the four studies, two assessed both implant stability and BIC (Sehlke et al., 2013; Hasturk et al., 2011; Hasturk et al., 2014). Implant stability was not evaluated in one study (Han et al., 2013). Moreover, the implant stability measured by another study was not considered because the parameter was assessed 10 min after implant placement and bone grafting, which did not fulfill the inclusion criteria of this review (at least 3 months of healing from extraction) (Cuisinier et al., 2004). Regarding the other parameter, BIC was determined via histomorphometric assessment in all reviewed articles (Cuisinier et al., 2004; Han et al., 2013; Hasturk et al., 2014; Sehlke et al., 2013).

3.12. Effect of bone cement

Two of the four studies supported the use of bone cement in enhancing implant stability during immediate implant loading (Hasturk et al., 2011; Sehlke et al., 2013). Higher stability test values (STVs) were recorded at 12 weeks in test sites grafted with PPCH-PA in comparison with other test and control sites (Hasturk et al., 2011).

In terms of BIC, one study demonstrated differences between the two groups (Cuisinier et al., 2004). Injectable tissue-engineered bone created using nHAC/CSH + dBMPC improved the osseointegration and bone regeneration of dental implants (Han et al., 2013). Additionally, BIC was evidently enhanced in the test groups augmented with bone cement as opposed to the control groups (Hasturk et al., 2014; Sehlke et al., 2013). The mean and standard deviations of BIC of the included studies are listed in Table 1.

4. Discussion

The recommended minimum time duration for osseointegration to occur is 3 months, which was demonstrated by the included studies (Cuisinier et al., 2004; Han et al., 2013; Hasturk et al., 2011; Hasturk et al., 2014; Sehlke et al., 2013). In this systematic review, two studies established the use of bone cement for enhancing implant stability (Hasturk et al., 2011; Hasturk et al., 2014; Sehlke et al., 2013). The efficacy and safety of all three types of bone cements—PPCH, PA, and PPCH-PA—in providing stabilization and aiding in bone formation at the crestal area of immediate implants for a 3-month period following immediate loading were proven (Hasturk et al., 2011). The findings agree with the data reported by a study regarding STVs while following the immediate loading protocol (Esposito et al., 2006; Esposito et al., 2007). In the closed environment, magnesium-based cement offers stability for immediate dental implants (Sehlke et al., 2013). Continuous contact of the bone cement with saliva and bacterial contaminants softens and dissolves it and results in the discoloration of the cement surface. Based on this clinical experience, the implant placement approach was modified in subsequent animal studies, and the cement functioned as expected.

All four studies concluded that simultaneous bone grafting with bone cement during immediate implant placement enhanced the BIC (Cuisinier et al., 2004; Han et al., 2013; Hasturk et al., 2014; Sehlke et al., 2013). One study advocated the use of bone cement composed of nHAC/CSH + dBMPC in immediate implant placement (Han et al., 2013). The degradation of calcium sulfate hemihydrate to calcium ions created an osteoconductive surface that stimulated the recruitment of osteoblasts. Furthermore, the production of angiogenetic growth factors, such as transforming growth factor-β, platelet-derived growth factor-BB, bone morphogenic protein-7, and bone morphogenic protein-2, was promoted (Walsh et al., 2003; Murashima et al., 2002). However, it is worth mentioning that the result could have been influenced by the addition of dog blood-acquired mesenchymal progenitor cells. The biological properties of these cells could have acted as a stimulus in the reparation or regeneration of the osseous defect around immediate implants, thus promoting angiogenesis and the production of extracellular matrix proteins (Han et al., 2013). Crestal support has been shown to be provided by PPCH-PA owing to its ability to cover the space between the socket walls and the implant while maintaining the expanse and hence improving BIC (Hasturk et al., 2014). This support, in turn, promoted the localization and shaping of the soft tissue around the neck of the implant because of the guidance provided at the crestal level.

The difference in BIC between the test and control sites in the two studies was not significant although the benefits of bone cement could not be denied as the BIC achieved was within the acceptable range in comparison with human studies (Cuisinier et al., 2004; Sehlke et al., 2013). The lack of difference between the groups in these papers could be attributed to the limited number of sites and animals. Only two implants that served as controls were not used for statistical analysis because of fibrous encapsulation (Cuisinier et al., 2004; Sehlke et al., 2013). The authors hypothesized that the prolonged healing time, which allowed complete bone dynamic remodeling, could have also contributed to this difference.

Three protocols have been proposed for the loading of implants, namely, immediate loading (within 1 week of implant placement), early loading (1 week and 2 months), and conventional loading (after 2 months from implant placement) (Esposito et al., 2007). Dental implants were immediately loaded when placed in fresh extraction sockets in two of the four papers (Cuisinier et al., 2004; Hasturk et al., 2011; Hasturk et al., 2014). When compared with conventional loading, a multicenter study with dental implants loaded immediately obtained an impressive implant survival rate of 98 % (Ganeles et al., 2008). Furthermore, a systematic review that discussed dental implants loaded immediately reported a survival rate of 95.6 % (Del Fabbro et al., 2006).

The major limitation of this study is the lack of randomized controlled trials in humans. The findings should be interpreted cautiously as human teeth in the functioning oral cavity behave differently under controlled and standardized in vitro experimental conditions. Moreover, considerable variation was noted among the studies in terms of outcome measures or variables considered and the type of cements used. The four animal studies assessed different materials as “bone cements” for stabilizing dental implants via histological assessment of BIC. The materials used, surgical procedures, implant sizes, and loading protocols were heterogenous, and hence, *meta*-analyses could not be performed. In addition, the searches were limited to only three databases, which could have potentially resulted in missing some articles.

5. Conclusion

Bone cement is a viable alternative as a grafting material for bone regeneration as it improves implant stability and achieves BIC in immediate dental implants. Apart from overcoming the drawbacks of autologous bone grafts, such as unpredictability and secondary surgical site morbidity, bone cement minimizes the risk of evoking immune responses and transmissible diseases as in allografts and xenografts. Furthermore, bone cement may be a more economically viable option because the fabrication of allografts and xenografts requires complex processing and sterilization/disinfection protocols. However, further prospective clinical trials in humans are required to draw a definitive conclusion on the clinical efficacy of this material. The recommendations for clinical research are to conduct more randomized controlled human clinical trials for the use of bone cement in immediate dental implant placement. Such studies are necessary to assess its clinical efficacy and to establish valid conclusions clinically for endorsing its use. Moreover, different healing times should be evaluated and long-term follow-up must be performed for bone cement used in the oral cavity for immediate dental implant insertion, both in animal and human trials. Finally, more investigations are required to determine the ideal bone cement that possesses biological and mechanical properties similar to those of the human alveolar bone from the commercially available ones.

Ethical Approval and/or Institutional Review Board (IRB) Approval

International Medical University Joint-Committee of the Research and Ethics Committee, Kuala Lumpur, Malaysia. Grant No: BDS I-01/2021(12).

CRediT authorship contribution statement

Tanay V. Chaubal: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Validation, Project administration, Writing – review & editing. **Wei Chun Yeoh:** Data curation, Formal analysis, Investigation,

Methodology, Resources, Software, Visualization, Writing – original draft. **Cynthia Kai Shien Phua:** Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Visualization, Writing – original draft. **Ranjeet Bapat:** Conceptualization, Formal analysis, Methodology, Supervision, Validation, Project administration, Writing – review & editing. **Shaju Jacob Pulikkotil:** Conceptualization, Formal analysis, Methodology, Supervision, Validation, Project administration, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

International Medical University Joint-Committee of the Research and Ethics Committee, Kuala Lumpur, Malaysia. Grant No: BDS I-01/2021(12).

References

Aghaloo, T.L., Moy, P.K., 2007. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int. J. Oral. Maxillofac. Implants. 22 (Suppl), 49–70 (Erratum in: 2008. Int. J. Oral. Maxillofac. Implants. 23 (1), 56).

Albrektsson, T., Zarb, G.A., 1993. Current interpretations of the osseointegrated response: clinical significance. Int. J. Prosthodont. 6 (2), 95–105.

Brown, M.J., Carter, T., 2018. ACL Allograft: Advantages and When to Use. Sports. Med. Arthrosc. Rev. 26, 75–78. https://doi.org/10.1097/JSA.0000000000000194.

Charnley, J., 1960. Anchorage of the femoral head prosthesis to the shaft of the femur. J. Bone. Joint. Surg. Br. 42-B, 28–30. https://doi.org/10.1302/0301-620X.42B1.28.

Cuisinier, F.J., Schaaf, J.F., Van Landuyt, P., Roth, D., Lemaitre, J., Tenenbaum, H., 2004. Immediate implant placement using injectable calcium phosphate hydraulic cement in dogs. J. Appl. Biomater. Biomech. 2 (2), 88–95.

Del Fabbro, M., Testori, T., Francetti, L., Taschieri, S., Weinstein, R., 2006. Systematic review of survival rates for immediately loaded dental implants. Int. J. Periodontics. Restorative. Dent. 26 (3), 249–263.

Esposito, M., Grusovin, M.G., Coulthard, P., Worthington, H.V., 2006. The efficacy of various bone augmentation procedures for dental implants: a Cochrane systematic review of randomized controlled clinical trials. Int. J. Oral. Maxillofac. Implants. 21, 696–710.

Esposito, M., Grusovin, M.G., Willings, M., Coulthard, P., Worthington, H.V., 2007. The effectiveness of immediate, early, and conventional loading of dental implants: a Cochrane systematic review of randomized controlled clinical trials. Int. J. Oral. Maxillofac. Implants. 22 (6), 893–904.

Fukuba, S., Okada, M., Nohara, K., Iwata, 2021. Alloplastic bone substitutes for periodontal and bone regeneration in dentistry: current status and prospects. Materials (basel). 14 (5), 1096. https://doi.org/10.3390/ma14051096.

Ganeles, J., Zöllner, A., Jackowski, J., ten Bruggenkate, C., Beagle, J., Guerra, F., 2008. Immediate and early loading of Straumann implants with a chemically modified surface (SLActive) in the posterior mandible and maxilla: 1-year results from a prospective multicenter study. Clin. Oral. Implants. Res. 19 (11), 1119–1128. https://doi.org/10.1111/j.1600-0501.2008.01626.x.

Gökçen-Röhlig, B., Meriç, U., Keskin, H., 2010. Clinical and radiographic outcomes of implants immediately placed in fresh extraction sockets. Oral. Surg. Oral. Med. Oral. Pathol. Oral. Radiol. Endod. 109 (4), e1–e7. https://doi.org/10.1016/j.tripleo.2009.11.030.

Hallman, M., Thor, A., 2008. Bone substitutes and growth factors as an alternative/complement to autogenous bone for grafting in implant dentistry. Periodontol 2000 (47), 172–192. https://doi.org/10.1111/j.1600-0757.2008.00251.x.

Han, X., Liu, H., Wang, D., Su, F., Zhang, Y., Zhou, W., Li, S., Yang, R., 2013. Alveolar bone regeneration around immediate implants using an injectable nHAC/CSH loaded with autogenic blood-acquired mesenchymal progenitor cells: an experimental study in the dog mandible. Clin. Implant. Dent. Relat. Res. 15 (3), 390–401. https://doi.org/10.1111/j.1708-8208.2011.00373.x.

Hasturk, H., Kantarci, A., Ghattas, M., Schmidt, M., Giordano, R.A., Ashman, A., Diekwisch, T.G., Van Dyke, T., 2011. The use of light/chemically hardened polymethylmethacrylate, polyhydroxyethylmethacrylate, and calcium hydroxide graft material in combination with polyanhydride around implants in minipigs: part I: immediate stability and function. J Periodontol. 82 (9), 1339–1352. https://doi.org/10.1902/jop.2011.100617.

Hasturk, H., Kantarci, A., Ghattas, M., Dangaria, S.J., Abdallah, R., Morgan, E.F., Diekwisch, T.G., Ashman, A., Van Dyke, T., 2014. The use of light/chemically hardened polymethylmethacrylate, polyhydroxylethylmethacrylate, and calcium hydroxide graft material in combination with polyanhydride around implants and extraction sockets in minipigs: Part II: histologic and micro-CT evaluations. J. Periodontol. 85 (9), 1230–1239. https://doi.org/10.1902/jop.2014.120424.

Higgins, J.P., Altman, D.G., Gøtzsche, P.C., Jüni, P., Moher, D., Oxman, A.D., Savovic, J., Schulz, K.F., Weeks, L., Sterne, J.A., 2011. Cochrane Bias Methods Group; Cochrane Statistical Methods Group. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 343, d5928 https://doi.org/10.1136/bmj.d5928.

Hooijmans, C.R., Rovers, M.M., de Vries, R.B., Leenaars, M., Ritskes-Hoitinga, M., Langendam, M.W., 2014. SYRCLE's risk of bias tool for animal studies. BMC. Med. Res. Methodol. 14, 43. https://doi.org/10.1186/1471-2288-14-43.

Lang, N.P., Pun, L., Lau, K.Y., Li, K.Y., Wong, M.C., 2012. A systematic review on survival and success rates of implants placed immediately into fresh extraction sockets after at least 1 year. Clin. Oral. Implants. Res. 23 (Suppl 5), 39–66. https://doi.org/10.1111/j.1600-0501.2011.02372.x.

Malchiodi, L., Balzani, L., Cucchi, A., Ghensi, P., Nocini, P.F., 2016. Primary and Secondary Stability of Implants in Postextraction and Healed Sites: A Randomized Controlled Clinical Trial. Int. J. Oral. Maxillofac. Implants. 31 (6), 1435–1443. https://doi.org/10.11607/jomi.4710.

Meijer, H.J.A., Raghoebar, G.M., 2020. Immediate implant placement in molar extraction sites: a 1-year prospective case series pilot study. Int J Implant Dent. 6 (1), 3. https://doi.org/10.1186/s40729-019-0201-7.

Murashima, Y., Yoshikawa, G., Wadachi, R., Sawada, N., Suda, H., 2002. Calcium sulphate as a bone substitute for various osseous defects in conjunction with apicectomy. Int. Endod. J. 35 (9), 768–774. https://doi.org/10.1046/j.1365-2591.2002.00565.x.

Ortega-Martínez, J., Pérez-Pascual, T., Mareque-Bueno, S., Hernández-Alfaro, F., Ferrés-Padró, E., 2012. Immediate implants following tooth extraction. A systematic review. Med. Oral. Patol. Oral. Cir. Bucal. 17 (2), e251–e261. https://doi.org/10.4317/medoral.17469.

Quirynen, M., Van Assche, N., Botticelli, D., Berglundh, T., 2007. How does the timing of implant placement to extraction affect outcome? Int. J. Oral. Maxillofac. Implants. 22 (Suppl), 203–223 (Erratum in: 2008. Int. J. Oral. Maxillofac. Implants. 23(1), 56).

Sakkas, A., Wilde, F., Heufelder, M., Winter, K., Schramm, A., 2017. Autogenous bone grafts in oral implantology-is it still a "gold standard"? A consecutive review of 279 patients with 456 clinical procedures. Int. J. Implant. Dent. 3 (1), 23. https://doi.org/10.1186/s40729-017-0084-4.

Sanz, M., Lindhe, J., Alcaraz, J., Sanz-Sanchez, I., Cecchinato, D., 2017. The effect of placing a bone replacement graft in the gap at immediately placed implants: a randomized clinical trial. Clin. Oral. Implants. Res. 28 (8), 902–910. https://doi.org/10.1111/clr.12896.

Schropp, L., Kostopoulos, L., Wenzel, A., 2003. Bone healing following immediate versus delayed placement of titanium implants into extraction sockets: a prospective clinical study. Int. J. Oral. Maxillofac. Implants. 18 (2), 189–199.

Schulte, W., Heimke, G., 1976. Das Tübinger Sofort-Implant [The Tübinger immediate implant]. Quintessenz. 27 (6), 17–23.

Sehlke, B.M., Wilson, T.G., Jones, A.A., Yamashita, M., Cochran, D.L., 2013. The use of a magnesium-based bone cement to secure immediate dental implants. Int. J. Oral. Maxillofac. Implants. 28 (6), e357–e367. https://doi.org/10.11607/jomi.te16.

Vaishya, R., Chauhan, M., Vaish, A., 2013. Bone cement. J. Clin. Orthop. Trauma. 4 (4), 157–163. https://doi.org/10.1016/j.jcot.2013.11.005.

Verket, A., Lyngstadaas, S.P., Tiainen, H., Rønold, H.J., Wohlfahrt, J.C., 2018. Impact of particulate deproteinized bovine bone mineral and porous titanium granules on early stability and osseointegration of dental implants in narrow marginal circumferential bone defects. Int. J. Oral. Maxillofac. Surg. 47 (8), 1086–1094. https://doi.org/10.1016/j.ijom.2018.02.007.

Walsh, W.R., Morberg, P., Yu, Y., Yang, J.L., Haggard, W., Sheath, P.C., Svehla, M., Bruce, W.J., 2003. Response of a calcium sulfate bone graft substitute in a confined cancellous defect. Clin. Orthop. Relat. Res. 406, 228–236. https://doi.org/10.1097/01.blo.0000030062.92399.6a.

Zhang, J., Liu, W., Schnitzler, V., Tancret, F., Bouler, J.M., 2014. Calcium phosphate cements for bone substitution: chemistry, handling and mechanical properties. Acta. Biomater. 10 (3), 1035–1049. https://doi.org/10.1016/j.actbio.2013.11.001.