3D-Printed Customized Bone Scaffolds for the Reconstruction of Osseous Defects: A Systematic Review.

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Methods

PICOS Criteria	
Population	Patients with **osseous (bone) defects** requiring bone reconstruction
Intervention	Customized 3D-printed bone scaffolds
Outcomes	Conventional bone reconstruction techniques:
Study design	Randomized split-mouth clinical trial,

Research question

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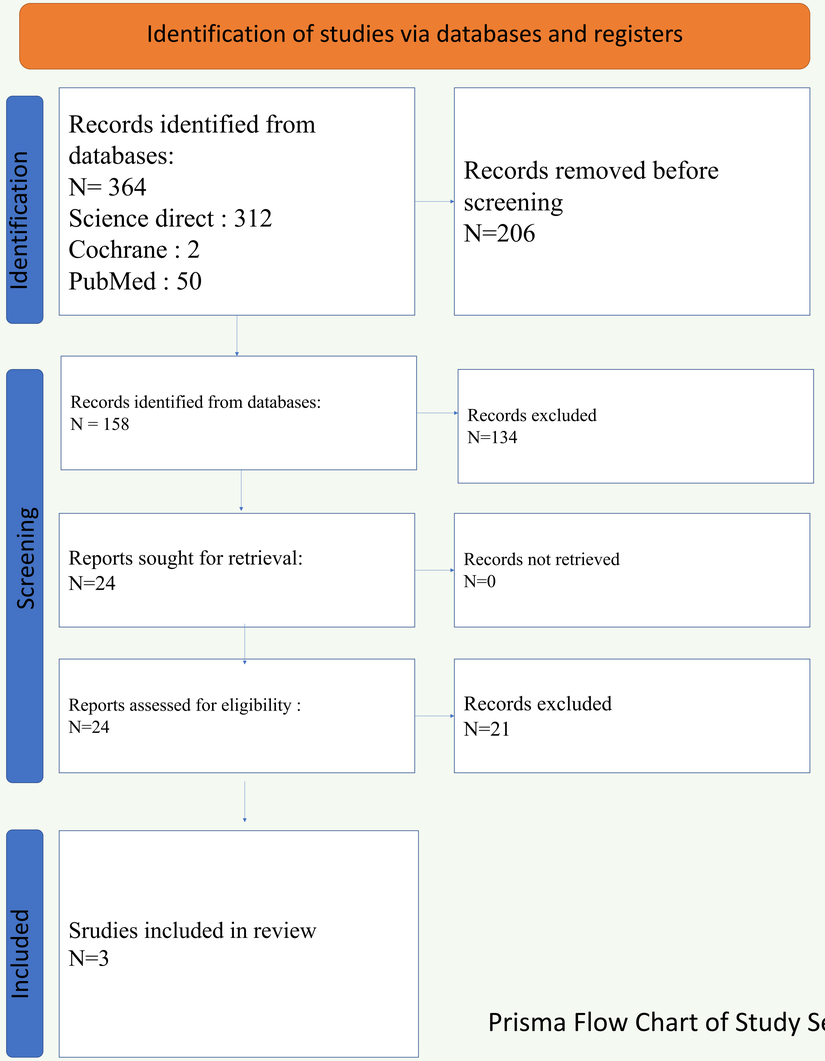
Strategy Research

Inclusion criteria	• **Studies involving patients with osseous defects requiring bone reconstruction.** • **Human clinical studies, including:** • **randomized controlled trials (RCTs)** • **controlled clinical trials** • **prospective or retrospective cohort studies** • **case series with ≥5 patients.** • **Studies reporting at least one clinical, radiographic, or histological outcome, such as:** • **bone regeneration (bone volume, height, width)** • **implant survival or success (when applicable).** • **Studies with a minimum follow-up of 3 months.** • **Articles published in English.** • **Full-text articles available.**
Exclusion criteria	• **In vitro studies, animal-only studies, or purely preclinical investigations (unless explicitly included in a separate analysis).** • **Studies evaluating non-customized or prefabricated bone scaffolds.** • **Studies not involving 3D-printing or additive manufacturing techniques.** • **Case reports and case series with fewer than 5 patients.** • **Narrative reviews, systematic reviews, meta-analyses, editorials, letters to the editor, or expert opinions.** • **Studies lacking quantitative or qualitative outcome data related to bone regeneration or clinical performance.**



Prisma Flow Chart of Study Selection

Results

Author (Year)	Study Design	Population	Intervention	Outcome Measures
Malzoni et al. (2021)	Randomized split-mouth clinical trial (**study protocol**)	Adult patients with atrophic anterior maxilla	Patient-specific 3D-printed bioceramic block graft (β-TCP; Plenum® Oss 3Dβ fit)	Graft volume gain and maintenance; quality of newly formed bone (CBCT, histology) superior volumetric stability and bone quality for the customized synthetic graft at 8 months
Thammanoonkul et al. (2025)	Randomized controlled clinical trial	21 patients (22 maxillary sinuses)	Polycaprolactone-impregnated 3D-printed nano-hydroxyapatite (3DPHA-PCL)	Dimensional stability (CBCT), percentage of new bone formation (histomorphometry, micro-CT), implant survival. Similar reduction in augmented height and volume in both groups ($p > 0.05$). New bone formation was significantly lower in the 3DPHA-PCL group (≈16–17%) compared with BB (≈25–26%) ($p < 0.05$). Two implant failures occurred in the 3DPHA-PCL group
Laurent Venet (2017)	Prospective case series	6 patients (11 onlay grafts) with atrophic anterior maxilla	Customized cortico-cancellous allogeneic bone blocks fabricated using 3D-printed hardcopy maxillary models and placed via minimally invasive subperiosteal tunneling	Graft adaptation, surgical time, complications, graft integration (CBCT). Excellent adaptation of grafts to defect morphology, reduced surgical time, and uneventful healing. One case of graft resorption related to prosthetic instability. Successful implant placement after 6 months

Discussion

Patient-specific 3D-customized bone grafts offer several advantages for maxillary reconstruction. By precisely replicating the patient's anatomy, these grafts ensure **accurate adaptation**, minimizing gaps between graft and host bone. This precision allows for **minimally invasive placement**, reduces operative time, and lowers postoperative morbidity.

The customized design also improves **graft stability**, supporting vascularization and bone integration while reducing resorption. Compared to conventional particulate or non-customized grafts, 3D-customized blocks simplify surgical procedures, avoid the need for multiple interventions, and can accommodate complex anatomical defects with predictable outcomes.

Overall, the use of 3D-customized grafts provides **enhanced surgical control, predictable bone regeneration, and potential improvements in long-term implant success**, making them a promising approach for reconstructive implant dentistry.

Conclusion

Patient-specific 3D-customized bone grafts provide **precise anatomical fit, improved surgical efficiency, and enhanced stability**, leading to predictable bone regeneration with minimal resorption. These grafts allow for **minimally invasive placement**, reduce operative time, and may improve long-term implant success. Overall, **3D-customized grafts represent a promising approach for maxillary reconstruction**, though further clinical studies are needed to confirm long-term outcomes.

References

- Thammanoonkul P, Limpattamapanee S, Thammarakcharoen F, Suwanprateeb J, Lim HC, Buranawat B. Polycaprolactone Impregnated 3D Printed Nanohydroxyapatite for Sinus Augmentation: A Randomized Controlled Trial. Clin Exp Dent Res. 2025 Oct;11(5):e70237.
- Venet L, Perriat M, Mangano FG, Fortin T. Horizontal ridge reconstruction of the anterior maxilla using customized allogeneic bone blocks with a minimally invasive technique - a case series. BMC Oral Health. 2017 Dec 8;17(1):146
- de Almeida Malzoni CM, Gonçalves V, Possari J, Junior EM. The use of 3D ceramic block graft compared with autogenous block graft for rehabilitation of the atrophic maxilla: a randomized controlled clinical trial. Trials. 2022 Oct 23;23(1):903