The Impact of Novel Alveolar Bone Graft Materials on Orthodontic Tooth Movement: A Review

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Introduction

- Sufficient alveolar bone is a determinant in the outcome of orthodontic treatment, as orthodontically moving the tooth into bone defects could cause periodontal complication or tooth loss.
- Bone grafting is often indicated before orthodontic treatment to enhance bone regeneration in pre-conditions such as periodontal bone resorption, alveolar cleft, bone defects due to long-term tooth loss/trauma, and thin biotype.
- Many new types of bone graft materials are being developed and tested, yet their efficacies on bone regeneration and orthodontic tooth movement remain unknown.
- This study aims to review novel bone graft materials with potential applications in orthodontics, and to evaluate their osteogenic potential and effects on tooth movement.

Methods

- We conduct a comprehensive literature search (published between 2010 and 2022) in PubMed and other databases with keywords "orthodontics," "tooth movement," "graft," and "regeneration."
- After initial quality assessments, 81 publications are collected on this topic, among which 27 publications are carefully compared and 12 of them are considered as the key studies.
- Properties including impacts on regenerated bone volume/density, cellular response, tooth movement rate, and adverse effects are evaluated.

Results

Table. The alveolar bone regeneration efficiency and the orthodontic impactions of the alveolar bone grafting materials.

Materials	Type of Study	Combinatory Materials	Bone Regeneration Efficiency			Impact on Orthodontics		References
			Volume	Cellular Activity	Side Effects	Rate	Side Effects	
BMP2	Animal (dog)	poly[$_{D,L}$-(lactide-*co*-glycolide)]/gelatin sponge complex	Significantly greater than autograft	More osteogenic activities with rhBMP2	N/A	Similar to autograft and normal bone	Root resorption on pressure side with rhBMP2	Kawamoto et al., 2002
	Clinical (secondary alveolar cleft repair)	DBM scaffold	Comparable as autograft	N/A	Self-limited	Similar to autograft	N/A	Hammoudeh et al., 2017
	Clinical (PAOO)	N/A	Significant density increase compared to corticotomy	BMP-2 stimulated osteoclast differentiation	Not significant	Reduced treatment time	N/A	Chandra et al., 2019
	Animal (dogs)	BMP2-functionalized BioCaP granules	Enhanced bone formation and density compared to xenograft	BMP-2 mediated osteogenesis-angiogenesis	Reduced inflammation compared to xenograft	Slightly reduced rate than bovine	Less resorption compared to bovine	Jiang et al., 2020
β-TCP	Animal (goats)	N/A	Slightly more bone ingrowth than autograft	Not significant difference compared to β-TCP and autograft	Not significant	No significant difference compared to β-TCP and autograft	Minor apical root resorption	de Ruiter et al., 2011
	Animal (mice)	N/A	Similar healing compared to allograft and no graft	Increased osteoclast recruitment compared to allograft	No adverse response	β-TCP and allograft both slowed ortho rate compared to no graft	N/A	Klein et al., 2019
Bioactive Glasses	Clinical (extraction socket preservation)	N/A	Better contour and healed with vertical trabeculae and vascularized marrow	Enhanced stem cell recruitment	No adverse response	N/A	N/A	El Shazley et al., 2016
	Clinical (PAOO)	N/A	Significant higher density than no graft	Attracted greater osteoprogenitor cells and osteoblast	N/A	Significant reduction in treatment time compared to no graft	No statistical difference on root resorption	Shoreibah et al., 2012
	Clinical (PAOO)	N/A	Similar to xenograft and significantly higher than no graft	Hemostatic effect in addition to osteoprotection	No adverse response	No difference among bioactive glass, bovine and no graft	No significant difference in root length in all bioactive glass, bovine, and no graft	Bahammam, 2016
PRF	Clinical (extraction socket preservation)	N/A	Significantly higher than no graft	Contains growth factors, cytokines, and enzymes	Post-injection pain	Accelerated treatment	N/A	Tehranchi et al., 2018
	Animal (rabbits)	N/A	N/A	Significantly greater osteoblasts and blood vessels	Not observed	Accelerated treatment	No orthodontic appliance-related discomfort was observed	Sar et al., 2019
BMMSCs	Animal (dogs)	N/A	Significantly greater bone than hydroxyapatite	Osteogenic differentiation and vessels formation	N/A	Exhibited consistent rate	Not observed	Tanimoto et al., 2015

(rhBMP-2: recombinant human bone morphogenetic protein-2; DBM: demineralized bone matrix; PAOO: periodontally accelerated osteogenic orthodontics; β-TCP: beta tricalcium phosphate; TAMP scaffold: tailored amorphous multiporous scaffold; PRF: platelet-rich fibrin; BM-MSC: bone marrow-derived mesenchymal stromal cells; OTM: orthodontic tooth movement)

Conclusions

- Optimizing the aesthetics, providing functional and comfortable occlusion and overall health are the goals of successful orthodontic treatment, and preservation of the alveolar bone is a crucial determinant in the treatment outcome.
- Most novel materials listed in this review share a trend in accelerating orthodontic tooth movement, which would shorten the treatment duration and make the therapy more cost friendly, especially for patients with longer treatment time such as those in need of tooth extractions and additional periodontal support.
- Although a quantitative report of the findings was not possible, qualitative approaches in analyzing the preclinical novel materials still improve the current understanding of relevant studies on regenerative orthodontics.
- However, high-quality randomized controlled trials, larger sample size, and longer follow-up periods are required for further investigation.
- Future research is in need to enable the translation of biological concepts into clinical practice. Special attention should also be drawn on how those novel graft materials may impact teenager/adult's growth and development, and potential complications in the long term.

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