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REVIEW ARTICLE

Role of bone graft materials for cleft lip and palate patients: A systematic review

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Abstract Cleft lip and palate is a congenital anomaly. Its management requires a long term commitment, multidisciplinary and structured treatment. Treatment is initiated at infancy and continues till adolescence. Bone grafting is performed in order to provide bony stabilization for cleft maxillary alveolar arch and room for subsequent canine tooth eruption. The aim of this review was to discuss the success of various bone graft materials in managing unilateral and bilateral cleft lip and palate patients. For this purpose, a detailed literature search was performed using available electronic databases for peer reviewed papers published in English language. The review is based on published papers reporting the use of various bone graft materials for managing cleft lip and palate patients. The success of bone grafts was studied using the grading scales measuring the bone height at the grafted sites. Various types of bone graft materials including autogenous and allogenic were reviewed. Implant placement in cleft lip and palate patients required bone grafting after orthodontic expansion because of deficient bone in the anterior maxillary region. The grafted bone consequently provides stability and support to the maxillary alveolar arch. Success of bone graft as well as dental implants is multifactorial and therefore depends upon the type of bone graft, bone quality at cleft site and severity of cleft lip and palate.

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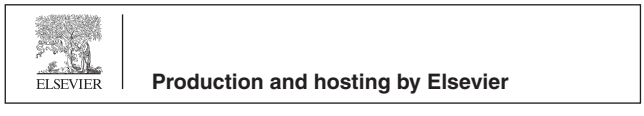

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1. Introduction

Cleft lip and palate is a developmental anomaly that has a significant genetic diversity. Inherited genetic mapping demonstrated distinct craniofacial morphologies like unilateral cleft lip palate, bilateral cleft lip palate, cleft of lip, cleft of alveolus or isolated cleft palate defects.[1–7] Cleft lip and palate patients present with a number of complaints such as wide alveolar bone defects, congenitally missing teeth (hypodontia), supernumerary teeth, hypoplastic and impacted teeth. The treatment planning and clinical care of such patients are challenging and start at a very early stage of life. The ultimate goals of this treatment are to improve the functional capability and quality of life of these patients. The practical management is complex and may involve multidisciplinary approaches [such as dental, maxillofacial, orthodontics, prosthodontics, plastic surgery, speech therapy and psychological departments]. The orthodontists have an extensive role that starts on day one during infant orthopedic nasoalveolar molding and continues until comprehensive orthodontic treatment at adolescence. Orthodontic space closure is the treatment of choice with concomitant esthetic restorative contouring.[1–7]

Endosseous dental implant along with bone graft can be used for the replacement of missing teeth.[3–5,7] The closure of the bony defects and stability of the maxillary arch are the crucial elements of the treatment plan. Bone grafting is performed preferentially during the orthodontic treatment to enhance the stability of maxillary arch and success of dental implants. Bone grafting can be performed using autogenous and/or allogeneic grafts followed by dental implant placement. It supports the tooth in alveolar arch, establishing maxillary basal bone morphology and ensuring stability after orthodontic treatment. This also increases alveolar bone support for the dentition, nasal alar cartilage and maintains functional bone volume with soft tissues for dental implant placement.[2–6,8–11] The success of bone graft and bone quality is assessed using various grading systems (Table 1) based on parameters such as amount of bone formation, intact bone or bone level from amelocemental junction (ACJ).

Table 1 Various grading systems used for the assessment of alveolar bone grafts.

Bergland scale (for erupted canine)[2–9]	
Type I	Normal interdental bone level
Type II	Bone level more than 75% of normal height
Type III	Bone level less than 75% of normal height
Type IV	No bone bridge achieved
Modified Bergland index (secondary alveolus grafting)[2–9]	
Grade A	Intact alveolar bone graft
Grade B	Marginal deficiency up to 1/4th of root length
Grade C	Marginal deficiency greater than 1/4th of root length
Grade D	Bone graft failure
Grade E	Nasal defect greater than 1/4th of root length
Grading system for grafted bone in cleft lip and palate patients[2–10]	
Grade 0	Bone bridge is undetectable
Grade 1	The vertical height of bone bridge is 0–5 mm
Grade 2	The vertical height of bone bridge is 5–11 mm,
Grade 3	The vertical height of bone bridge is more than 11 mm
Bone bridge evaluation with reference to Amelo-Cemental Junction (ACJ)[2–4]	
Category A	The bone bridge covering more than 75% of root surface from ACJ
Category B	The bone bridge covering less than 75% of root surface from ACJ
Category C	The bone bridge covering less than 50% of root surface from ACJ
Category D	The bone bridge covering less than 25% of root surface from ACJ
Category E	No bone bridge at either the apical or the amelocemental level.
Category F	Has 75% or greater uncovered root surface from ACJ

Bone grafting materials such as autogenous cortico-cancellous iliac crest, bone morphogenetic proteins and recombinant human protein have shown good success rate in long term but this require further research.[3–10] Considering a remarkable research related to the subject and updating the knowledge of dental practitioners accordingly, there is an intense need of reviewing the outcome of research studies conducted recently. The main objective of this review was to discuss the success of various bone graft materials in managing unilateral and bilateral cleft lip and palate patients. In addition, various factors affecting the prognosis were highlighted.

The aim of this review was to discuss the success of various bone graft materials in managing unilateral and bilateral cleft lip and palate patients.

2. Material and methods

2.1. Focused question

What is the outcome of bone grafting prior to dental implants in cleft lip and palate patients?

2.2. Eligibility criteria

The inclusion criteria were based on peer reviewed papers published in English language [prospective clinical trials, original, clinical and experimental studies only]. Studies related to: (a) non syndrome unilateral and bilateral cleft lip and palate; (b) orthodontic treatment; (c) alveolar bone grafting and endosseous dental implant placement for missing teeth were included. The studies published on syndrome patients, interrupted treatment, immunocompromised, autoimmune diseases, re-implant procedures, completely edentulous arches, biased results, systematic metabolic diseases and isolated cleft palate cases were also excluded.

2.3. Search strategy

In order to address the focus question, a search was performed using PubMed/Medline (National Library of Medicine, Bethesda, Maryland) and Cochrane electronic databases for articles published from January 2000 to December 2013. Following keywords were used; ''Unilateral and bilateral cleft'', ''endosseous implant and bone grafting'' and ''cleft and orthodontics''. The initial search was comprised of 519 published papers. During the screening process, duplicate papers (n = 219) and papers not fulfilling the inclusion criteria (n = 261) were excluded (Fig. 1). The filtered papers fulfilling our criteria were read and analyzed against the selection criteria and the focused question. This review is based on 39 studies, which met the basic inclusion criteria.

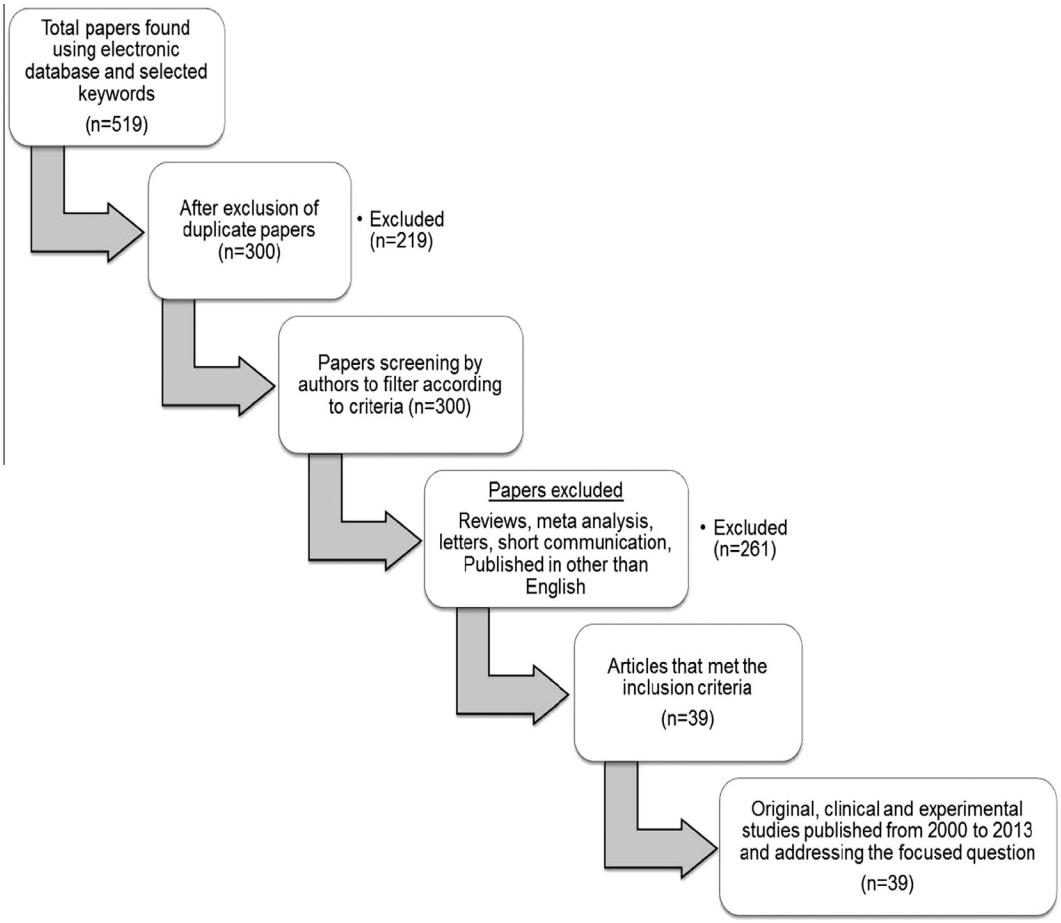

Fig. 1 A schematic presentation of the screening criteria used in this study. PubMed/MEDLINE and Cochrane electronic databases were searched for articles published from January 2000 to December 2013 using different keywords.

Table 2 Management of cleft lip and palate patients using bone grafts along with orthodontic intervention.

Researcher	Age/years	Type of graft	Research outcome/remarks
Upadya et al.[1]	13.8	AUBG/cancellous bone	Linear regression analysis shows no canine eruption as a determinant for graft success
Tanimoto et al.[2]	12.5 ± 4.2	AUIC	Significant bone bridge found in cleft jaw areas
Koh et al.[3]	NS	AUBG	96% significant result
Francis et al.[4]	NS	AUBG/rhBMP2 and AUIC	94.4% results obtained for rhBMP-2 and 84.2% success rate for iliac crest
Cho et al.[5]	14.2	Allogenic/AUBG	Autogenous graft achieved all objectives
Semb et al.[7]	MD	AUIC	Optimal results achieved
Alexander et al.6	NS	AUBG/cortico-cancellous	Provide good implant sits up < . 05
Van hout et al.[8]	MD	BMP2	Favorable results with good bone quantity
Guo j et al.[9]	> 5	BMP2 and AUIC	Insufficient evidence found for both
Walia et al.[10]	MD stage	AUIC	Provides maxillary stability
Nadal et al.11	NS	AUBG/Olecranon	Good alternative site
Barbara et al.[12]	NS	AUBG	Concluded no difference in function between orthodontic space closure and prosthetic replacement
Debarros[14]	17.6	AUBG	Good prognosis
Liou et al.13	NS	AUBG	Improved prognosis
Vagervik et al.[15]	NS	AUBG	Team care enhances chances of good prognosis
Santiago et al.[34]	MD	AUBG	Beneficial results
Arangio et al.[36]	NS	AUBG	Iliac crest is suggestive
Duskowa et al.[16]	NS	AUBG	Graft resorption increases according to gap size and low possibility of revascularization
Giudice et al.[17]	9–11	AUBG/cancellous and BMP	Functional stress exerts decisive influence on quality & volume of osteoplasty to prevent resorption
Yoshiro et al.[18]	14.6	AUBG	Optimal results achieved
Julia et al.[19]	MD	AUBG/GTR collagen	Optimal results achieved
Matsui et al.[20]	MD	AUIC	Optimal results achieved
Murthy.[40]	MD	AUBG	Optimal results achieved
Feichtinger et al.[21]	Late MD	AUBG	Optimal results achieved
Jia et al.[22]	8.4–19.9	AUIC	Optimal results achieved
Kramer et al.[23]	NS	AUIC	Optimal results achieved
Morand et al.[24]	NS	AUIC	Optimal results achieved
Kawakami et al.[25]	NS	AUIC	Skeletal morphology around nasal cavity and alveolar cleft height help in predicting the stability of bone bridge
Isono et al.[26]	21	AUBG/cancellous bone	Optimal results achieved
Buis et al.[27]	MD	AUIC	Optimal results achieved with distraction osteogenesis
Da silva filho et al.[28]	MD	AUIC	Optimal results achieved
Bakr[29]	NS	AUBG/Intramembranous	Optimal results achieved
Long et al.[30]	MD	AUBG	Optimal results achieved

* NS (not specified), ** MD (mixed dentition), *** AUBG (Autogenous bone graft), **** AUIC (Autogeneous ilian crest), Σ BMP (bone morphogenetic protein), $\Sigma\Sigma$ GTR (guided tissue regeneration).

3. Results

The success and performance of grafted materials were assessed using various assessment criteria such as Bergland and modified Bergland scales, location of bone bridge and bone grading (Table 1). According to the inclusion criteria, all studies[1–39] were experimental or clinical involving the implant graft materials in cleft lip and palate patients. All researchers[1–39] performed bone grafting using either autogenous bone grafts (AUBG), bone morphogenetic proteins (BMP), autogenous iliac crest (AUIC) or allergenic bone grafts. General information and outcome of included studies have been summarized in Tables 2 and 3. A few studies[31–39] reported the use of various bone grafts without mentioning any details regarding orthodontic management (Table 3). In terms of patient's age, most researchers[1,2,5,7–10,17,19–22,27,28,30–32,34,38,40] performed bone grafting during or just after the mixed dentition period and a few performed at adult age.[14,22,26,32] A number of studies[3,4,6,11–13,15,16,23–25,29,36] did not specify patient's age.

Different researchers have reported optimal results using AUIC[7,20,22,24,24,27,28] and AUBG.[19–21,26,29,30] Bone morphogenetic proteins such as BMP-2 resulted in stimulation of stem cells leading to better prognosis.[39] There are few studies reporting disappointing outcome of bone grafts for cleft patients. Upadya et al.[1] used AUBG (cancellous bone) and reported no canine eruption as a determinant for graft success. No significant benefits were reported for using allogeneic bone grafts.[32]

4. Discussion

The benefits of using bone grafts after orthodontic expansion in cleft lip and palate patients are well documented. The major benefits include bringing the tooth in alveolar arch, establishing maxillary basal bone morphology and ensuring stability

Table 3 Management of cleft lip and palate patients using bone grafts without mentioning the orthodontic intervention

Researcher	Age/years	Type of graft	Researcher's outcome/remarks
Pena et al.[31]	8–11	AUBG	Good survival rates
Goudy et al.[32]	7–25	Allogenic bone graft	No statistical benefit
Morselli et al.[33]	NS	AUBG	Optimal results in 50% cases
Santiago et al.[34]	MD	AUBG	Beneficial results
Rawashdeh et al.[35]	NS	AUBG	Ideal graft
Arangio et al.[36]	NS	AUBG	Iliac crest is suggestive
Gimbel et al.[37]	NS	AUBG	Gold standard Autogenous iliac crest
Dempf et al.[38]	MD	AUIC	Optimal results achieved
Fallucco et al.[39]	NS	BMP-2	Improved prognosis highly effective stem cell stimulation

* NS (not specified), ** MD (mixed dentition), *** AUBG (Autogenous bone graft), Σ AUIC (Autogeneous ilian crest), $\Sigma\Sigma$ BMP (bone morphogenetic protein).

after orthodontic treatment. In addition, bone grafting is also required for reinforcing alveolar bone support, nasal alar cartilage support and osseointegration of dental implants.[2–6,8–11] Success of bone grafting is assessed radiographically using Bergland and modified Bergland indices (Table 1). A number of radiographic views [periapical X-rays, panoramic radiograph or cone beam computed tomography] can be used for radiographic assessment.

Unilateral and bilateral cleft lip/palate patients need comprehensive orthodontic and surgical management. Long term stability is needed to prevent relapse. For this reason, life time retention after orthodontic phase is recommended as an essential part of the treatment protocol.[19,40] The stability of bone graft is a multifactorial phenomenon related to factors such as cleft width, unilateral/bilateral and cleft to nasal cavity ratio.[34] For example, wide alveolar cleft, inadequate primary wound closure, post-operative wound dehiscence with infection and deficient attached gingiva may lead to failure.[16] Missing tooth at the alveolar cleft side is either replaced by orthodontic space closure or prosthetic tooth replacement. Certain factors such as canine position and cleft width may affect the prognosis of bone graft materials however this statement needs further confirmation. Canine is moved orthodontically to replace missing lateral incisor frequently. Hence, the spontaneous eruption of canine is the most favorable factor for alveolar bone graft prognosis. In contrast, orthodontic extrusion of un-erupted canine may yield a significant bone loss particularly in the buccopalatal direction hence compromising the prognosis of bone grafts.[1]

Corticocancellous bone, AUIC, composite intramembranous or harvesting autologous bone grafts are recommended for the construction of unilateral or bilateral palatal defects greater than 2 mm. In case of minor clefts (<2 mm) alveolar bone grafting is not indicated. Various biomolecules such as BMP-2, platelet derived growth factor, transforming growth factor beta, insulin like growth factor, platelet rich plasma and fibroblast growth factor 2 can be added to the bone grafts. For larger grafts, lack of vascularization of alveolar bone graft is often associated with the failure. Microvascular corticocancellous bone (femur) grafts can be used to cover wider (greater than 2 cm) unilateral or bilateral cleft palates.[19–22]

Bone graft is readily provided to reinforce the dental arch after orthodontic expansion. The space is retained using a coil spring or a retainer till the implant placement. Endosseous dental implants are frequently used if orthodontic tooth movements may jeopardize tooth structures or prosthetic intervention is required to manage the hypodontia and tooth structural anomalies. The prevalence of hypodontia and hypoplasia is significantly high in both unilateral and bilateral cleft lip palate patients. There is generalized consensus that the optimal timing for secondary alveolar bone graft ranges from 8 to 12.5 years.[8–11] It is recommended to place implant within 6 months of graft, not immediately. Dental implants of various dimensions (length range; 10–15 mm and diameter range; 3.25–4.0 mm) have been used in cleft lip and palate patients. The implant neck, shoulder, body is placed in accordance with universal recommended guidelines and protocol. Implant survival analysis for unilateral cleft palate patients showed promising (94%) results.[14,16,17,31]

Primary stability of the dental implant is directly related to the bone volume. If sufficient bone volume is not available for implant placement, tertiary bone graft including nasal floor coverage may be required. Similarly, hydroxyl appetite coated dental implants have better bioactivity than smooth-surface titanium implants.[41] This high bioactivity and surface characteristics have a significantly beneficial role for implant stability and osseointegration.[41] Three dimensional bone volumetric analysis has revealed that postoperative bone resorption results in decreased interdental alveolar crest level. The prolonged period of time between the implant placement and second implant surgery might result in nonfunctioning bone atrophy. The time period reported to be 12.5 weeks was required for the bone graft to be able to provide primary stability. In addition, unfavorable positions and angulations during implant placement tend to induce marginal bone loss as a result of localized stress shielding.[18,20,23,26,27]

Heterogenetic implants or grafts [demineralized bone powder containing bone morphogenetic protein and hydroxyapatite] yielded a significant outcome and enhanced quality of the osteoplasty while used in conjunction to orthodontic treatment. Due to an increased availability of calcium and phosphate ions from the heterogenetic implants, there is an increased osteoblastic activity and reduction in osteoclastic activity[41] to prevent further resorption progressively.

Main signs and symptoms of bone graft failure are pain, inflammation and an increased osteoclastic activity at cleft site delaying the healing process. In certain situations such as severe craniofacial deformity, increased cleft width, compromised vascularization and soft tissues scarring, the stability of the alveolar bone and implant site is very challenging. An adequate bone volume and height (greater than 12 mm) are considered favorable factors for the successful prognosis of

bone grafts.[14,16–20,23,26,27,31] AUBG and iliac crest resulted in a significant bone bridge formation in the unilateral and bilateral cleft lip and palate patients. Among the reviewed studies[1–39] autogenous corticocancellous iliac crest and bone morphogenetic protein as graft materials have been suggested having better outcome. There is a need for further research to assess whether the increase of cleft severity or presence of altered physiological bone remodeling affect long term implant stability.

5. Conclusion

Prognosis of bone grafts and dental implant has been reported to be promising for both unilateral and bilateral cleft lip palate cases. Success of implant placement depends upon factors such as bone grafting, bone quality, type of cleft and severity. Autogenous bone graft materials have shown beneficial results and promising outcome for the management of unilateral and bilateral cleft palate patients.

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None.

Conflict of interests

None declared.

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