MASTEROPPGAVE:

Bone modifying techniques in the anterior maxilla prior to implant placement - A literature review

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Abstract:

Objective: The aim was to describe the different bone enhancing techniques for improving the alveolar bone and gingival characteristics prior to implant placement
Material and methods: A MEDLINE and PubMed English language peer-reviewed literature search was conducted. Hand searches of the reference lists in some selected articles were also conducted. The literature search was sorted into five different topics; autogenous bone graft, guided tissue regeneration, orthodontic extrusion, and distraction osteogenesis.
Results: Forty-seven articles were considered for the review. All, except one, of the selected articles were case reports or case series describing the bone-modifying techniques. Significant improvements in alveolar bone were reported in all cases, resulting in satisfying implant sites.
Conclusions: For all five techniques presented there is a need for more research and more precise procedure protocols.

Key words: Implant site development, anterior maxilla, autogenous bone graft, guided tissue regeneration, decoronation, orthodontic extrusion, distraction osteogenesis

Contents

Introduction

Loss of front teeth may be devastating for the patient, both functionally and aesthetically. Complex anatomy, functional and aesthetic demands often make reconstruction very challenging as well as the multitude of complications that can arise during or after treatment.

Traditionally removable prosthesis (dentures) or fixed partial dentures (bridges) have been the treatment of choice in order to replace tooth loss permitting restoration of chewing function, speech and aesthetics. A systematic review by Pjetursson *et al.*[1] revealed a 10-year FPD survival rate of 92%. Ceramic alternatives have also been introduced during the last two decades. Prospective clinical studies have reported high survival rates, between 100 % and 97 % after 5 years [2, 3]. The disadvantage with tooth-supported FPDs is that one has to prepare the adjacent teeth. Especially if these are intact, an implant-supported single tooth can be a good alternative.

Since the mid-1990s dental implants has offered an alternative for single tooth replacement. These implants are placed into the jawbone to support a dental prosthesis and are retained because of the intimacy of bone growth on their surface. Brånemark *et al*. [4] was the first who described the direct structural and functional connection between living bone and implant surface, termed osseointegration. This is considered one of the most significant scientific breakthroughs over the past 30 years. It has been reported a 91% survival rate after 5 years [5] for implant supported single crowns, which is equivalent with the survival rate of tooth-supported PFDs.

Frequently, however, there is a lack of supporting bone in addition to the absent teeth due to disease, atrophy or trauma. Sufficient amount of underlying bone has to be present for two reasons; to stabilize the dental implant so it can be inserted in an ideal bucco-linugal and mesio-distal position with good axial inclination and to make it possible to reshape the soft tissue contour, especially the interdental papillae.

There are a variety of indications, methods, and biologically active biomaterials for bone reconstruction. A multidisciplinary approach to treatment planning, necessary surgery in the form of implants and follow-up is therefore essential.

The aim with this master thesis is to present the most common techniques for bone reconstructions in the maxillary anterior region preceding implant installation, and discuss possibilities, limitations and any complications related to such treatment.

Materials and Methods

- Data Collection:
  A MEDLINE and PubMed English language peer-reviewed literature search was conducted for this review as well as hand searches of the reference lists of the selected articles. Details of the search methodology and selection process are described as follows:
- Data extraction strategy:
  Search limits on general database: studies done on humans in English limited to dental journals, and a publication date from 1990/01/01 (except from guided tissue regeneration where search limits are from 2000/01/01) furthermore we divided the data into five groups based upon what technique was to be discussed, and only original articles were selected:
    - Autogenous bone grafts
    - Guided Tissue Regeneration
    - Decoronation
    - Orthodontic Extrusion
    - Distraction osteogenesis

Finally a data matrix was constructed for each part:

° Autogenous bone graft:

Limits activated in PubMed: Humans, Male, Female, English, Dental Journals, Publication Date from 1990/01/01

Search words: Autogenous bone graft (584) + maxilla (35) + implant (29) + anterior (6) - included 5

Hand search: articles found relevant using reference list of chosen articles: four included

° **Guided tissue regeneration:**

Limits: Humans, English, Dental Journals, Publication date 2000/01/01.

Search words: Guided tissue regeneration (1947) + membrane (1190) + maxilla (136) + anterior (22) - 6 articles included.

° **Decoronation:**

Limits: Humans, English, Dental Journals, Publication Date from 1990/01/01.

Search words: Decoronation (16), Removed 6 articles due to irrelevance, one due to duplication – 9 articles included.

Hand search: Added three articles based on reference list of former articles.

° **Orthodontic Extrusion**:

Limits Activated: Humans, English, Dental Journals, Publication Date from 1990/01/01.

Search words: Orthodontic extrusion (300). Implant site development (34) meshed together: Orthodontic extrusion + Implant Site Development (8 articles).

Hand search: articles found through reference lists and through the use of recognized author names provided by our supervisors. The search resulted in 17 articles, three of them removed due to duplicates and one removed due to irrelevance and three removed because of reviews, yielding 10 articles.

° **Distraction osteogenesis:**

Limits Activated Humans, English, Dental Journals, Publication Date from 1990/01/01.

Search words: Distraction osteogenesis (732) + maxilla (271) + anterior (65) + implant (18) - 8 articles included.

Hand search: articles found relevant using reference lists: 1 article included.

Results

Autogenous bone grafting

Autogenous bone grafting is a technique where the bone donor and receiver is the same individual. It is used to enhance bone volume in the maxilla and mandible before implant placement. In the 1970´s endosseus implants inserted in grafted bone for reconstructive purposes were introduced [4]. Since then there has been a lot of research in the field, regarding implants used, and what type of grafted bone is used to reconstruct oral and craniofacial defects. Today autogenous bone grafting is a well-documented treatment method for this purpose.

Autogenous bone can be harvested from a variety of areas - the anterior/posterior crest of the ilium, calvarium, tibia, fibula, scapula, ribs, maxillary tuberosity, mandibular retromolar area [Figure 1-2], ramus, and the mandibular symphysis [6, 7]. It has been shown that membranous bone tissue grafts have less resorption than endochondral transplants. Therefore intraoral bone grafts for the maxilla and mandible are favoured [8]. The grafts should be oversized with thick resorption-resistant cortex to maintain enough graft volume after the resorption phase is over. This can allow long implants with good stability [9].

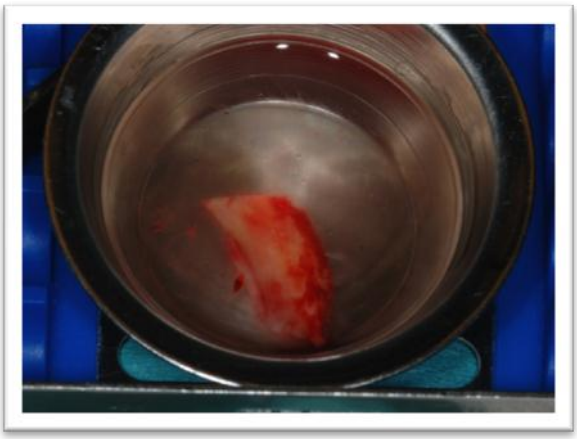

Figure 1. Graft from the mandibular retromolar area

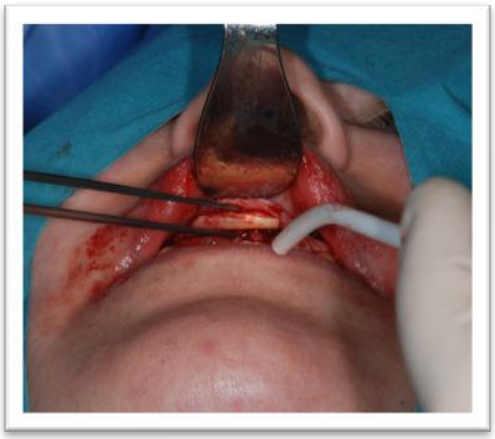

Figure 2. Testing graft fit at surgical site

There are different surgery treatment protocols depending on where the graft is harvested. The autogenous graft procedure is done simultaneously with graft placement in the maxilla. In the anterior region an incision is often made near the border between the upper lip and mucosa to achieve better coverage of the graft. The grafted bone is often trimmed to fit the recipient site, and an overcorrection in the vertical direction is

recommended because of the risk for resorption. Bone marrow and cancellous bone can be packed between the graft and the recipient bone [8]. The placement of implants can be done as a one-stage or a two-stage technique. If the implants are placed directly, the placement should penetrate the graft and go into residual bone. When the implants are placed after a healing period in (4-6 months), both the residual bone and graft should have the same properties as regular maxillary bone. The transplant is fixated with micro screws, and the wound is sutured [Figure 3-4]. The healing of nonvascularized grafts occurs with reactive sclerosis and an irregular reparative metaplastic process. In contrast the healing of vascularized grafts retains the structural differentiation of cancellous bone and cortex with unchanged bone density.

Figure 3. The graft is perforated with a bur

Figure 4. The graft is fixated with micro screws

Indications for autogenous bone grafting is when there is insufficient width or height (or both) of bone for implant placement [7, 8]. Reasons for having insufficient bone in the area can be traumatic injury, bone atrophy and periodontitis.

Advantages using autogenous bone grafting is well documented for the reconstructive treatment of bone deficiencies in the maxilla, implants can be inserted using a one stage technique, less visits for progress control and no devices are required. Disadvantages however can be longer hospitalization, administration of antibiotics, and two surgical/operational wounds. There are many complications using autogeneous bone graft where bone resorption and wound dehiscence has been shown to have the worst effect on the survival rate of the implant [9-11].

Implant survival rate shows a high rate of success, close to 90%. There are differences in the survival rate if you compare the one-stage and two-stage technique. In some studies [12, 13] it was reported a significant difference between a one-stage and two-stage

technique in favour of two-stage technique. The rationale for using a two-stage technique is to enhance revascularization and remodeling of the bone graft, and also new bone formation.

In the one-stage technique the residual bone (RB) integration was normal, but a delayed response was seen in the grafted bone (GB) because of lack of vascularization. The two-stage technique shows more normal osseointegration in the grafted bone (GB) and residual bone (RB). This is because of revascularization of the graft. The survival rate of different procedures like onlay bone grafting, sinus inlay bone grafting, and interpositional bone grafting shows no significant difference. If cancellous bone is placed around the graft it helps to get the graft revascularized. Tapered implants can be preferred for better stability [14] [Figure 5-6].

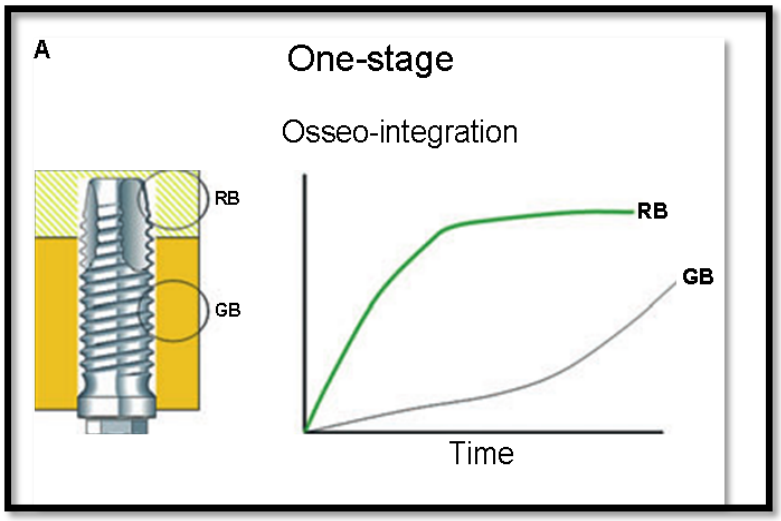

Figure 5. Displaying delayed osseo-integration in grafted bone versus residual bone .
(Lundgren *et al*. 2000)

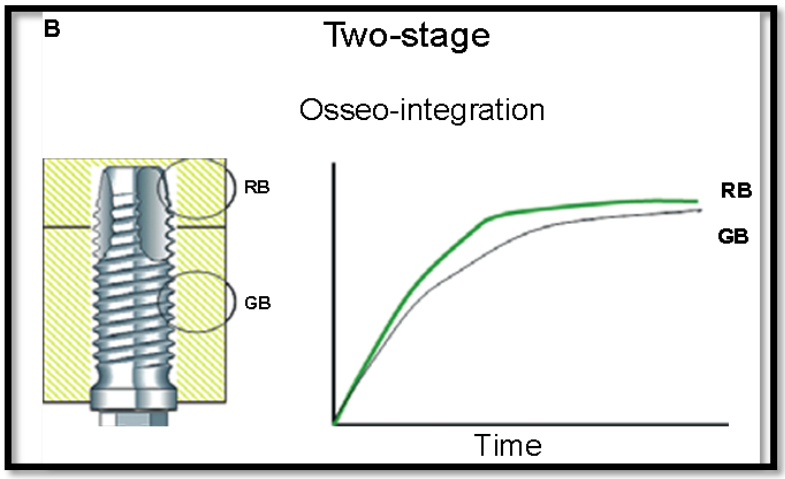

Figure 6. Displaying more similar osseo-integration in grafted versus residual bone
(Lundgren *et al*. 2000)

Table 1. Autogenous bone graft – 9 articles included

Author	Type	Comments
6. Balaji *et al*. 2002	Case report	Intraoral donor sites were found to be convenient sources of autogenous bone in alveolar reconstruction. The advantage of this method includes its intraoral access, proximity of the donor site, and low morbidity. These grafts require short healing periods, exhibit minimal resorption and maintain their dense quality.
7. Kao *et al.* 2007	Case report	An autogenous bone graft can provide needed bone volume. The mandibular symphysis can function as a reliable graft.
8. El-Askary *et al.* 2000	Case report	Autogenous bone grafting is an accurate grafting procedure, soft tissue contouring by applying mild pressure to the tissues using acrylic resin temporary crowns, by soft tissue or grafting sculpturing.
9. Lundgren *et al.* 1997	Clinical analysis of 20 cases	The most common complications are postsurgical pain and gait disturbance when the graft is harvested from the ilium. Most of graft resorption takes place during the first 6 months. Cortical thicknesses of donor bone and donor bone density are factors influencing bone resorption. Oversized corticocancellous grafts, with a thick resorption-resistant cortex should be harvested in order to maintain enough graft volume after the initial resorption phase. This will allow for long implants with good stability.
10. Nyström *et al.* 1995	Case report and analysis	The one-stage technique is most useful in patients with normal relationships between the jaws. Success rate of implant survival 88.7% and 100% prosthetic stability.
11. Keller *et al.* 1999	Case report	Implant loss is more frequent with Le Fort 1 down fracture group. Medical risk factors contribute to implant loss. Implant loss is observed more frequent with natural opposing teeth rather than an opposing implant supported prosthesis. Implant loss is related to failure in achieving initial osseointegration, rather than failure to maintain osseointegration during function. Endo-osseus implant type and length affected implants survival.
12. Lundgren *et al*. 2000	Review	Autogenous bone grafting with two-stage technique gives predictable and successful rehabilitation. Refinement of bone harvesting techniques from the iliac crest has reduced the number of graft complications and morbidity. It is possible to speed up bone graft incorporation because healing and remodeling are preprogrammed biological processes. It is probably possible to reduce the healing time after implant placement, or even using immediate-loaded implant protocols. Further research needed.
13. Fukuda *et al.* 2000	Case report	The two-step procedure is best for patients with insufficient alveolar bone. Chin bone as a donor site; topographic accessibility, reduced morbidity, and the absence of visible scars, and less resorption of grafted bone compared with that of extra orally harvested bone.
14. El Askary *et al.* 2003	Case report	Tapered implants give better implant stability, using two-stage technique protects healing of graft, and interdental papilla preservation and reduced chance of scar tissue formation. The flapless, immediate placement technique maintained the hard and soft tissue contours and eliminated the severe postoperative ridge resorption associated with tooth extractions.

Guided tissue regeneration

Guided tissue regeneration has gradually been introduced as patient and dentist have further emphasized aesthetic dentistry. As the phrase implies, it is a way of helping the human cells to migrate and proliferate around and within xenogenic tissue thus generating new human tissue. Guided tissue regeneration is an essential part of modern implant site development since it can provide proper bone for implantation in almost any situation [15].

Guided tissue regeneration can be subdivided into two major subgroups; I. As membranes for protection of the surgical site; II. As bone filling material. Bone filling material now comes in a wide variety of chemical compositions ranging from molecular-sized plastic materials, hydroxyapatite, tricalcium phosphate, through platelet rich plasma, growth factors, bovine bone and freeze dried bone allografts [16-20]. Common to all of the above-mentioned materials, and the many others, is that they are placed directly in or filling the surgical site underneath a mucoperiosteal flap [Figure 7-8].

Figure 7. Bio-Oss mixed with the patient's blood

Figure 8. Bio-Oss placed at the surgical site

A latency period of 4 to 7 months is common before placing an implant in the grafted site, and then another 2 to 4 months before loading of the implant to allow for proper osseointegration [16]. Even though a latency period is the normal way to proceed, researchers are now trying to place implants immediately, given enough apical bone is available to minimize treatment time and surgical interventions [16].

The use of membranes to cover the surgical sites, preventing inflammation, promoting cell-proliferation and providing for growth space has undergone an evolution. In the 1990`s the non-resorbable GORE-TEX® membrane was the gold standard. The GORE Company™ has now taken their Polytetrafluoroethylene medical

membranes off the market. But there are still companies producing expanded Polytetrafluoro-ethylene (ePTFE) membranes. The ePTFE membrane became popular because it had the ability to minimize graft resorption. The difficulty to fixate and the placement technique, harbors a certain risk of wound dehiscence with increased membrane exposure rate and subsequent site infection [17] [Figure 9-10].

Figure 9. Bio-Gide membrane

Figure 10. After suturing

Nowadays membranes with less side effects has been preferred, in which collagen membranes have been a popular contributor. They are easier to handle and does not have to be removed with a second surgery, as with the ePTFE. The collagen membrane has limits showing decreased longevity because of resorption, giving a decreased barrier function 17. In the articles given in table 2 there is no conclusive evidence for the use of membranes in implant site development.

Table 2. Guided Tissue Regeneration – 6 articles included

Author	Type	Membrane/Bone augmentation used	Comments
15. Meijndert *et al.* 2008	Prospective Randomized Clinical trial with 93	- Bio-Gide Collagen membrane (Geistlich GA) - Bio-Oss spongiosa granules (Geistlich GA)	- Study group was divided into 3. Group 1: Particulate chin bone was placed around fixed block graft. Group 2: Chin bone covered by Bio-Gide. Group 3: Bio-Oss spongiosa granules mixed with blood around the block graft, covered by Bio-Gide membrane. - The marginal bone and gingiva loss were not significantly related to the surgical procedures for augmentation and implantation.
16. Fagan *et al.* 2008	Case series with 37 subjects	- ePTFE- membrane (W.L. Gore and associates, Flagstaff, AZ) - Collagen (BioMet, Warsaw, IN) - Collagen (ACE Surgical, Brockton, MA) - Collagen (Ossix, ColBar Life Science, Hezliya, Israel) Freeze-dried mineralized bone allograft (FDBA), pediculated connective tissue graft (PCTG)	- The specific guided bone regeneration membrane used does not seem to significantly influence obtaining an adequate amount of hard tissue. - Bone grafts are believed to be essential for osseous regeneration. The primary reason for bone regeneration is closure obtained by a pediculate connective tissue graft that seals the site.
17. von Arx *et al.* 2006	Case series with 42 subjects	- Bio-Gide (Geistlich GA) - Anorganic Bovine bone material surrounding autogenous bone blocks	- Combination of autogenous blocks and Anorganic Bovine bone material covered with Collagen membrane provided horizontal ridge gain in crest width of 4,6 mm. - Low complication rate and no sign of infections.
18.Yassibag-Berkman *et al.* 2007	Case series with 25 subjects	- Bio-Gide Collagen membrane (Geistlich Pharma, Wolhusen, Switzerland) Tricalcium Phosphate Platelet Rich Plasma	- 12-month clinical results failed to demonstrate the superiority of Platelet Rich Plasma-induced regeneration in grafting alone or with Guided Tissue Regeneration using a membrane. - The study did not prove any superiority of Platelet Rich plasma.
19. Hansson 2007	Case series with 7 subjects	- Collagen membrane (Biomend Extend, Zimmer Dental, Carlsbad, CA) - Bovine bone graft (Bio-Oss; Geistlich) in combination with placement of a resorbable collagen membrane.	- Minimal invasive procedure that does not require a second site for bone harvesting if a allogenic, or xenogenic graft is used. The authors had complete success with bovine grafts although other graft materials are possible to use, they do however claim the necessity of a collagen membrane to achieve success.
20. Meijndert *et al.* 2005	Case series with 15 subjects	- Bio-Gide (Geistlich GA - Autologous chin bone in combination with Bio-Oss spongiosa granules (Geistlich, Wolhusen, Switzerland)	- At the time of placement of implants the grafting material is still not fully replaced by new vital bone. In case of Bio-Oss, most of the grafting material is even still present. Despite these differences, the 1-year clinical results were very good and comparable between the various grafting techniques applied.

Decoronation

To remove an ankylosed tooth by conventional extraction often leads to unwanted invasive surgery involving bone removal and later, bone loss. This is always a drawback, but especially pronounced in growing individuals. Trauma is most common in the incisor region, and thus, the loss of bone very often affects an esthetically sensitive region.

Decoronation is a technique developed by Malmgren *et al.* in 1984 [21], a conservative surgical treatment method for ankylosed and infrapositioned reimplanted incisors in adolescents. A flap will facilitate removal of the crown two millimeters below the cervical margin [22, 23]. The root filling, or pulpal tissue, is then removed with an endodontic file or bur perforating through the apical constriction [Figure 11]. Blood coming through the former canal and from the alveolar bone proper will aid in resorption of the root remnant and in bone remodeling [24] [Figure 12].

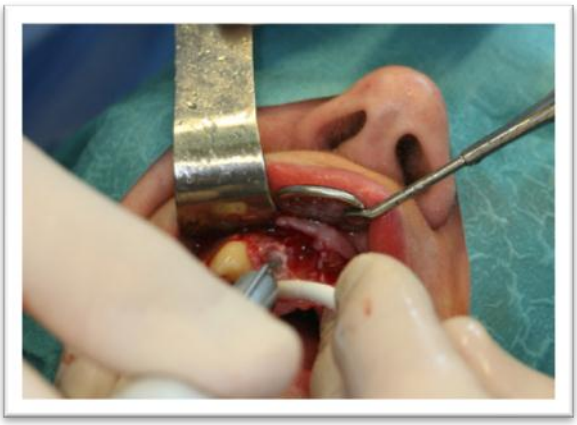

Figure 11. Perforating the root apex

Figure 12. Blood visible in root canal

The flap is reattached covering the width of the tooth, which provides a matrix for bone growth, and alveolus so that healing can commence [Figure 13-14].

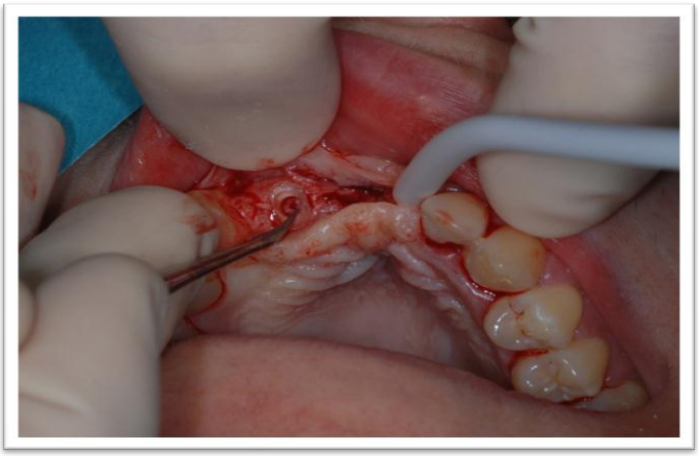

Figure 13. Matrix of bone in the former root canal.

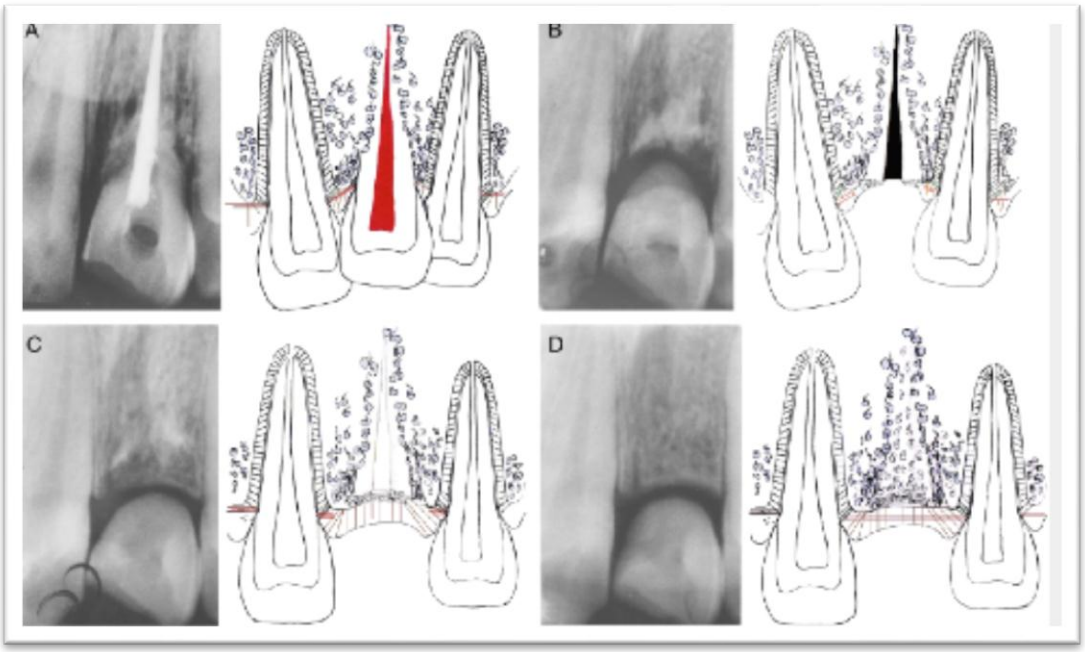

Figure 14. Bone growth after decoronation. Alveolar bone development after decoronation of ankylosed teeth – Malmgren et al[27].

Ankylosis is a condition where a tooth has been affected by external resorption and replacement of lost root substance by bone. It can be diagnosed by a high resonant tone heard on percussion. This metal like sound appears after approximately 20% of the root is affected by replacement resorption [25, 26]. It has been well documented that decoronation maintains the width and height of the alveolar process [27- 31].

This is especially important in the maxillary front, where you often see a buccal alveolar bone collapse after the extraction of a tooth. Malmgren *et al.* [21] also reported that the alveolar bone above the affected teeth showed vertical growth after the teeth had been decoronated. In a later article by Malmgren it was pointed out that vertical

bone apposition could be seen in patients treated before the pubertal growth spurt [32]. The vertical growth of the alveolar bone is dependent on collagen fibers, in between neighboring teeth, bridging the decoronated socket. As the bone around the decoronated tooth grows, a vertical pull on the gingival collagen fibers and surrounding alveolar bone will be provided, thus encapsulating the decoronated tooth in newly formed alveolar bone [figure 14].

Table 3. Decoronation – 6 articles included. Only case studies are included in table. The other articles are clinical guidelines and growth studies (References no. 22, 23, 25, 27, 30, and 32).

Authors	Type and Number of subjects	Patients age when decoronated	Follow-up time	Comments
21. Malmgren *et al.* 1984	24	11 to 19 years old	1.5 year	- After 18 months the remnants of the root were still present in 13 patients, while in 11 patients only normal alveolar bone was seen in the radiographs - Removal of the crown and a part of the root to which the circular ligament was attached may have enabled the alveolar segment to adapt to further maxillary development. - Treatment should be considered for patients with a rapidly progressing infraposition, tendency to buccal displacement of the tooth and a risk of tilting neighboring teeth - Discomfort of wearing a temporary appliance should be weighed against the benefits of early treatment to ensure successful prosthetic treatment later.
24. Cohenca *et al.* 2006	1	15 years old	3 years	- Skeletal maturation and not chronological age should be taken into consideration to avoid unacceptable esthetics of the implant supported final prosthetics. - The efforts from the dental practitioners should be focused on prevention of dental trauma and to implement up-to date treatment guidelines for health practitioners.
26. Díaz *et al*. 2005	1	9 ½ years old	3 years and 8 months	- Decoronation is less traumatic than surgical extraction. - Should be considered when orthodontic space closure and bicuspid auto transplantation is not feasible for a tooth affected by replacement resorption. - Decoronated crown as a temporary adhesive pontic is well accepted by the patient.
28. Sapir *et al.* 2008	1	12 years old	4 years	- Indications for decoronation: 1. A person diagnosed with an ankylotic permanent incisor, and a future rehabilitation with an implant or bridge is planned. With no medical, surgical or orthodontic contraindications. 2. The root is not expected to resorb within a year.
29. Sapir *et al.* 2009	1	12 years old	7 years	- Decoronation is reliable in height and width preservation of the alveolar process. - Simpler and more reliable than ridge augmentation. - Vertical bone apposition is possible.
31. Filippi *et al.* 2000	1	16 years old	9 months	- Ankylosed teeth should be removed in adolescents to avoid interference with localized jaw development. - In children 12-14 years old, autotransplantation is advocated. In patients older than 14 decoronation is recommended. - Root canal filling material must be completely removed.

Orthodontic Extrusion

Orthodontic extrusions is the use of a fixed orthodontic appliance to mechanically and slowly extract or extrude a tooth, taking advantage of well-known biological mechanisms to regenerate lost alveolar bone. Mechanical pull on the apical periodontal ligament fibers leads to a deposition of bone at the area undergoing the greatest tension[33]. The ability to affect the environment through mechanical manipulation is maintained along the entire attachment surface of the root, as long as the residual apical attachment is still fairly healthy [34].

The use of orthodontic extrusion in implant dentistry was first described by Salama *et al.* [35] as a method to enhance the predictability of subsequent implant placement and thereby avoid the need for further augmentive surgical interventions.

Orthodontic fixed appliances are often part of the early treatment plan as a way of generating new bone tissue for future implant placement. Distraction and orthodontic extrusion are methods using light mechanical force to manipulate the body's own biological response into forming new- and/or regenerating bone in the area of interest. Orthodontists have utilized these processes for decades correcting malocclusions. However, unlike classic orthodontics the brackets are aligned in relation to the bone level, not the incisal edges [36] [Figure 15]. According to some sources a force of just 30-75g is effective enough to extrude the tooth and not compromise the biologic mechanisms responsible for new bone deposition [37]. As a consequence it is required to shorten the incisal part of the tooth accordingly by grinding.

Figure 15. Illustration showing the placement of brackets during extrusion - aligned with bone level

There are other examples where brackets are used in combination with a modified guided splint or even novel methods of gaining interproximal bone through root tipping, but still achieving comparable results to "conventional" extrusion methods [38, 39]. It is

essential in extrusion that it is done within the central axis of the alveolus, to prevent the loss of buccal cortical bone as this would necessitate further augmentive surgery.

Effects on oral mucosa

The beneficial effects from orthodontic extrusion do not only concern the alveolar bone, but also the surrounding soft tissues including the marginal gingiva.
Several cases treated with orthodontic slow extrusion exhibit the formation of new interdental papillae even in cases where the papillae were missing and replaced by so called "black triangles" approximally. Initially the tooth will move coronally for some distance before the epithelium follows, and then it will appear as red unkeratinized epithelium surrounding the tooth - usually named a "red patch" [33,40,41]. This is supposed to be due to the sulcular epithelium everting or "peeling" as the tooth moves coronally. However, this patch becomes keratinized and gains the appearance of normal gingiva after approximately 1 to 1.5 months through redifferentiation of implanted prickle cells to basal cells with an inward to outward migratory cell pattern.

This orthodontic extrusion method is a good example where the remnants of healthy periodontium of a "hopeless" tooth planned for extraction can first be utilized through orthodontic extrusion to improve and prepare the site for later implant placement [Figure 16].

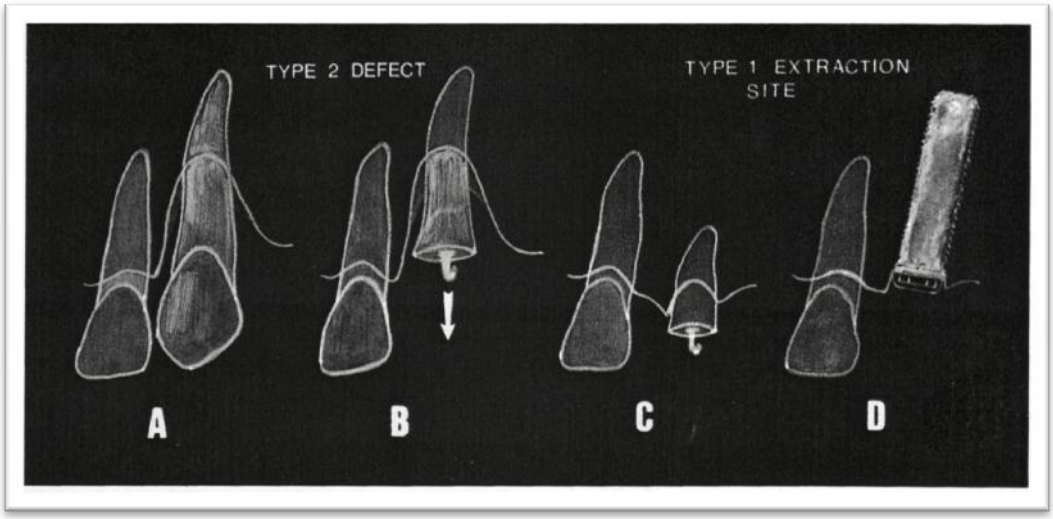

Figure 16. The effect of orthodontic extrusion on alveolar bone (from Salama *et al.* [35])

This option preserves the alveolar dimensions and facial cortical plate for later root extraction and immediate implantation after completion of growth and joint maturation, as indicated by i.e. palm radiography, but also requires the patient to have reached full facial skeletal maturity [30, 42]. The increase in the vertical alveolar bone height might assure the preservation or even improvement of the interdental papillae and in that way lead to a better esthetic end-result [38, 43].

Orthodontic extrusion is a fairly time consuming method that requires the patient to adhere to a very frequent visit regime during the extrusion phase. A fortnightly regimen to undergo occlusal and orthodontic wire adjustments is necessary, but extrusion is usually a rapid process that is undertaken over a period of just 6-8 weeks. Following the period of extrusion, there is a stabilization period that mirrors the extrusion phase in time to ensure stability of the tooth and surrounding tissue, around 8-10 weeks [38, 41].

If the results are satisfying a direct implant is placed post extraction and then another period of healing is expected until the final porcelain restoration is placed depending on what method was chosen.

As the tooth is extruded some challenges arise in the process. The more coronally the root is displaced the dimension becomes narrower in comparison to the neighboring teeth. This shortened circumference will impact the decision for the implant dimension; a narrow platform implant will later place a demand for a very flared prosthetic replacement.

Table 4. Orthodontic extrusion – 10 articles included

Authors	Type of Study	Comments
33. Mantzikos *et al.* 1997	Case study	Extrusion is a non-surgical technique for improving the three-dimensional topography of the implant site before extraction. A periodontically compromised tooth moved coronally by orthodontics will reveal a "red patch" in the papilla as the junctional epithelium everts with the tooth.
34. Zuccati *et al.* 2003	Case report	Healthy apical conditions are crucial for successful bone fill and osseointegration.
35. Salama *et al.* 1993	Review article	Introduces the concept of implant site development by orthodontic extrusion, calling it orthodontic extraction and a classification system for extraction sockets.
36. Salama *et al.* 1996	Case	Highlights the importance of orthodontics in developing the foundation for health, function and aesthetic results in restorative implant therapy.
38. Kim *et al*. 2011	Case report	Good effect of an interocclusal appliance with orthodontic hooks to extrude teeth in question with elastics.
39. Uribe *et al.* 2010	Case report	Lateral tipping of a tooth might provide a means of achieving adequate bone width and interproximal papilla development. An additional benefit of this method was that immediate implant loading could be implemented after alveolar bone development.
40. Mantzikos *et al.* 1998	Case report	The "red patch" shows later in patients with deeper pockets and is directly related to the pocket depth. Keratinization of the patch occurs in about a month.
41. Holst *et al.* 2009	Case review	Orthodontic extrusion with mini implants can only be justified when the clinical situation allows for minimally invasive extraction and implant placement without the necessity for autogenous bone grafting.
42. Zachrisson 2008	Case Report	Combination of space closure and implants may give the most satisfying results. Interdisciplinary teams crucial for optimal results.
43. Danesh-Meyer *et al*. 2000	Case report	Good treatment option, but patients with periodontal disease needs vigilant follow up with oral hygiene measures.

Distraction osteogenesis

Distraction osteogenesis is a technique used to form new bone and soft tissue in patients with atrophic bone. It utilizes the body's own mechanism of healing by regenerating soft and hard tissue. The technique is dependent on tension-stress in the distracted area and the influence of mechanical load and vascular supply [44]. Gavriel Ilizarov was the one who greatly advanced the technique of distraction osteogenesis in the 1940-50´s. The basic principle that was used in long bones is used in today's distraction of both maxilla and mandible, except from different distractor devices [45].

Careful and individual based treatment planning is of high importance before starting the treatment. The bone is cut using an oscillating saw at the base of the alveolus, and where there is sufficient thickness of bone [44]. The bone fragments can be separated by a handchisel, small hammer or osteotome [46]. The distraction gap is filled with callus that forms the new bone segment [47]. Then a distraction device is mounted and the incision closed. Alveolar devices are either endosseus or extraosseus. Horizontal distraction using an orthodontic technique attaching the transport segment by special fixation screws is also a possibility [48].

Distraction osteogenesis is often divided in 3 phases [Figure 17]

1. Latency phase – time from placing the distraction device to the active distraction. This is a healing period without activation of the distraction device. The latency period is approximately 7 days [49].
2. Distraction phase – active distraction that causes the segments to separate [44], and new hard and soft tissue formation occurs. The rate of distraction per day is approximately 1 mm. It is necessary to overcorrect the bone distraction because of resorption of the transport segment. Recommended level of overcorrection is between 15-20%. If the distraction rate is too slow the segments can be unified to early and this will not permit further distraction. The opposite occurs if the rate is too rapid, then the bone segments fail to unify. The distraction distance depends on how much new bone is required.
3. Consolidation phase – stabilization of the distracted bone and ossification. The consolidation period is approximately 3 months [46]. After this phase the distraction device is removed and the implants can be placed. The time of implant placement

varies, and it depends on the bone quality after the distraction process. Often there is a need for bone graft if the horizontal bone level is insufficient.

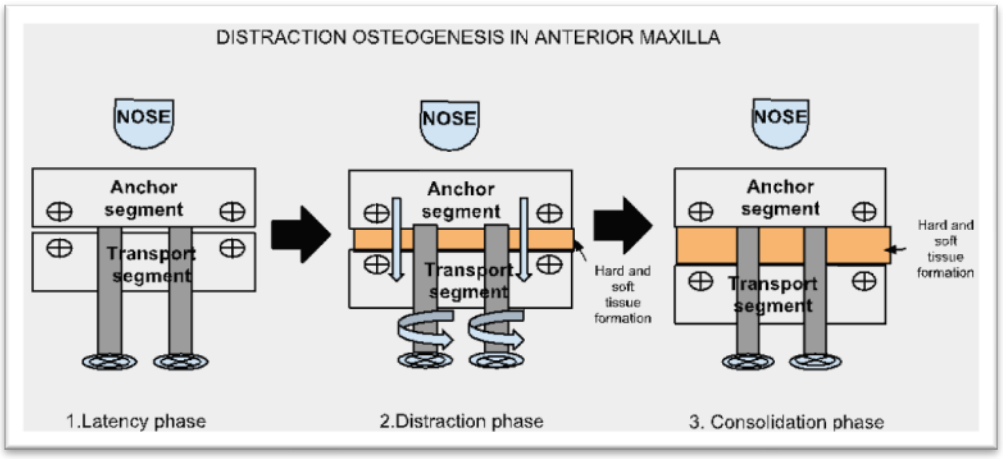

Figure 17. Schematic drawing of the different distraction phases (Y Åkre©).

Indications for alveolar distraction are traumatic injury, bone atrophy, periodontitis, resection procedure, congenital malformation, ankylosis and post grafting. Contraindications can be patient who has been irradiated, and there must be sufficient amount of bone to mount the distractor device [50].

There are many advantages of alveolar distraction, among them: (I) no need of an autogenous bone harvest (in some cases), (II) reduced morbidity, (III) reduced hospitalization time, (IV) bone lengthening can be controlled, (V) soft tissue and hard tissue is regenerated simultaneously, (VI) bone resorption reduced, (VII) reduced infection risk (VIII) and satisfies esthetic demands [47, 51].

The main disadvantages are that there is need of patient compliance, although the patient must be monitored during distraction period. Thus, the treatment takes time and it is important with careful patient selection [44]. There also must be a minimum quantity of bone, and the two different bone segments must have enough strength to withstand the expansion. The expansion occurs only in the direction of the transport segment. It is also complicated with the rigid control of the segments during the distraction [51].

Complications with distraction are often device related (breakage, wrong transport vector, patient chewing on the device), but also fracture of the bones or resorption may occur. The smaller the segment to be moved the more likely resorption occur. Mainly because of complicated screw fixation and devascularization. Other complications are infection, premature union, unfavorable osteogenesis with fibrous union, occlusal interferences and wound dehiscence [52].

Table 5. Distraction osteogenesis – 9 articles included

Authors	Type of study	Comments
44. *Herford et al.* 2005	Case report	DO is a predictable method for restoring alveolar ridges prior to implant placement. DO is ideally suited for recreating missing tissue in the anterior esthetic zone.
45. Braidy *et al.* 2011	Case report	The vertical deficiency was corrected with DO, followed by onlay bone graft. DO is a viable treatment option to expand the height of the residual ridge.
46. Hürzeler *et al*. 2002	Case report	DO combined with immediate implant placement and provisionalization appears to have great potential in preserving and enhancing the hard and soft tissues required for restoring natural esthetics around dental implants. Key points: reduced number of surgical interventions, shortened treatment time. Also stated that immediate loading of single implants resulted in an increased failure, and that a clinical investigation is needed.
47. Gozneli *et al.* 2010	Case report	The new bone structure formed by DO has the same quality and morphology as the maxilla. Concluded that DO with immediate implant placement and provisionalization have great potential for reconstruction of lost soft and hard tissue.
48. Jensen *et al.* 2002	Clinical Study	All failed implants had been placed in poor quality bone that needed bone grafting. Horizontal distraction using an orthodontic technique attaching the transport segment by special fixation screws. 90.4% survival rate. DO procedures can now be considered a predictable adjunct in dento-alveolar restoration. In half of cases bone grafting was needed. The risk of the surgical procedure may possibly be greater than conventional grafting procedures.
49. Zahrani *et al*. 2007	Case report	DO per se may not always be satisfactory improving the anatomical alveolar anatomy. It can improve height and also expand soft tissue. In need of onlay bone graft for ideal placement of implants. Can be used in both maxilla and mandible.
50. Dinse *et al.* 2008	Case report	DO is becoming an established method of providing additional hard and soft tissue to sites requiring implants. The fixed restorations of an anterior maxilla and the esthetic problem that was encountered due to the unpredictable final bony ridge crest position were described. Additional clinical studies are needed to provide guidelines for predictable esthetic outcomes.
51. Uckan *et al.* 2002	Case report	Implant success rate 50%. DO have many advantages (listed in result part). Complications: disposition of distracted segment, bleeding in deeply planed osteotomy, pain-related tension when the distracted segment is larger than 10 mm, segment breakage, difficulties in adapting the microplates when the rod is inserted in buccal inclination, axial displacement.
52. Wolvius *et al.* 2007	Case report	15-20% overcorrection recommendable because of resorption. A combination of onlay grafting and alveolar distraction is often needed to achieve appropriate three-dimensional reconstruction of atropic alveolar bone. Survival of dental implants inserted into distracted areas has been shown to be satisfactory.

*DO = distraction osteogenesis.

Discussion

The great challenges with bone modifying techniques are to choose among different treatment procedures for each individual to gain an optimal biological and aesthetic outcome. The lack of sufficient bone in the anterior maxilla often gives unsatisfactory aesthetics and deficient anchorage for inserting implants. There are several methods described in the literature how to improve bone dehiscences. Many of them are related, but there is currently not enough research to clarify which methods produces the best result as most of the articles concerning bone and soft tissue improvement are confined to several case reports [Table.1-5]. Problems with case reports in general, are that they mostly report successful treatments and are regarded as low evidence. Therefore it is difficult to assess what to do if the method fails, as there are no standardized protocols available. There was only one randomized controlled trial [15] that was procurable during the systematic search process, however, a manufacturer of bio medical products sponsored this particular study, hence publication bias should be considered. There were also some systematic reviews of case reports and a meta-analysis of these, but they were excluded due to the aforementioned weaknesses regarding case reports.

No article with focus on the patient perspective was found. This is unfortunate since these treatments are expensive, invasive, painful and time-consuming. It would be valuable for the clinicians as well as the patient to make a well-informed decision as to what the patient and dentist can expect before, during and after treatment. This, lack of patient perspective, is a general problem with studies connected with dental treatment and not only in implantology [5].

Only a few of the articles consider multiple treatment options [22, 25, 28, 29]. In the other studied articles it has not clearly been presented why the treatment was chosen, or if other treatments were considered an option. There seems to be a choice of treatment modality due to the authors own interest in the field i.e. orthodontics, periodontics or oral surgery rather than any objective standard. A general consensus among the authors seems to be that facial growth needs to be completed before there is an attempt at any form of implant placement as this can lead to implant infraposition. Decoronation and orthodontic extrusion procedures can be done, even with advantage, at a young age prior to implant placement.

Despite the above mentioned shortcomings in case reports, certain information was possible to deduct from the chosen articles. Prerequisites for treatment are the loss of

teeth due to trauma, congenital malformation, ankylosis and periodontal disease that has led to bone loss giving the characteristic “hour-glass” shape of the alveolar crest hence complicating the placement of implants. If there is uncertainty about treatment outcome in other bone modifying techniques autogenous bone grafting can create sufficient amount of bone. The disability with autogenous bone grafting is the insufficiency of soft tissue coverage in cases of severely atrophic maxilla, which can lead to unsatisfying aesthetics. In cases of lacking aesthetics guided tissue regeneration can come in as a supplement to the treatment, in which membranes and mucogingival surgery can increase the aesthetic outcome. The use of scaffolds, such as bone filling material, can be beneficial under autogenous bone grafting procedures to fill in and overcorrect bone insufficiencies. In distraction osteogenesis there is often not sufficient bone in the horizontal aspect thus requiring complementary autogenous bone grafts. In all cases of bone grafts there is a risk of resorption and morbidity therefore great care in ensuring good healing conditions must be emphasized.

Decoronation is performed on ankylosed teeth with replacement resorption. Patient age is essential. Malmgren *et al* [32] concluded that if an ankylosed tooth is diagnosed at the age of 7 to 10 years, decoronation should be performed within two years. If patient age is between 10 and 12 years, individual evaluation is preferred. If infraocclusion is noticed, then decoronation should be done as soon as possible. When ankylosis is diagnosed after the age of 12 years, infraposition increase can be slow and annual follow up is important. As a general rule, decoronation should be considered when infraposition and ankylosis is detected.

Orthodontic extrusion is a minimal invasive method, which allows the cells in the periodontal ligament space to produce new bone along with extrusion of the tooth. This produces a clinical situation that allows implant placement without the necessity for an autogenous bone graft [41]. In previously periodontal diseased teeth extrusion can reduce pocket depth [33]. Moreover, successful orthodontic extrusion requires healthy marginal and periapical conditions [34]. An osteolytic process and infection at the apical part of the tooth will be detrimental to the bone regenerative capacity.

The topic of bone modifying techniques joins many different specialties ranging from periodontology, orthodontics through oral surgery and prosthodontics in a multidisciplinary effort to produce the best possible functional and aesthetic end-result for the patient.

In order to visualize the different bone enhancing techniques and their prerequisites a flow chart was produced (figure 18), but this does not highlight any of the disadvantages or advantages for each technique. Therefore a table trying to emphasize this is presented in a "pro et contra" table [Appendix 1].

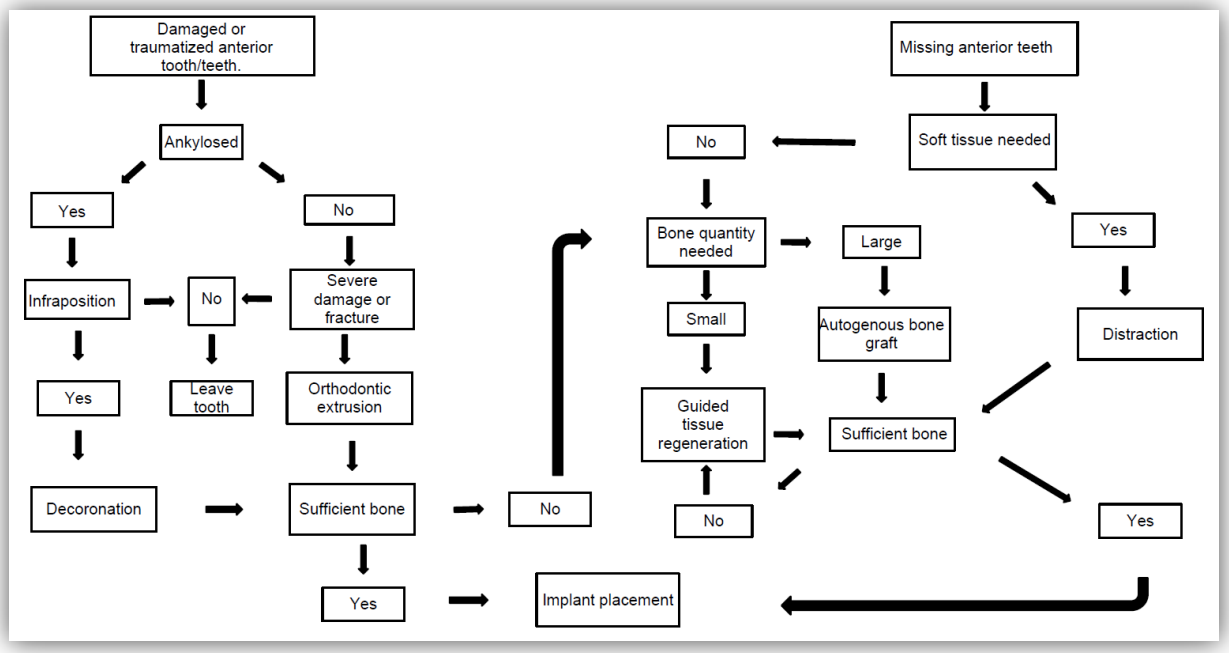

Figure 18. Flow-chart for clinical decision-making (S Ellingsen©).

Conclusion

Based on the available literature all techniques appeared useful for bone modification prior to implant placement. For all five techniques presented there is a need for more research and more precise procedure protocols. Interdisciplinary studies regarding the different techniques are needed to achieve the optimal result.

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Appendix 1

	PRO	CONTRA
Autogenous bone grafting	● One surgical session ● Immediate implant placement ● Well documented ● Easy way to improve the implant site ● Well fitted graft ● Not age dependent	● Often two surgical sites ● Overcorrection because of resorption ● Soft tissue stretching -unsatisfactory aesthetics ● No guarantee tissue vascularization ● Operator sensitive
Guided tissue regeneration	● Always available ● One surgical site ● No clear contraindications ● Well fitted graft ● No clear need for bone at the operation site ● Not age dependent	● Expensive ● No consensus for a beneficial result ● Possible risk for rejection ● Operator sensitive
Decoronation	● Treatment for ankylosed teeth ● Single surgery ● Uses bodies own regenerating abilities ● Excellent way to preserve buccal palatal width ● Maintains tissue vascularization	● Diagnosed ankylotic before treatment. No articles on vital decoronation ● Not predictable in vertical bone height ● Risk for neighboring teeth tilting towards the decoronated gap. ● Preferably done in children/adolescents
Orthodontics extrusion	● Utilizes the body's own mechanisms for regenerating bone ● Can remove a periodontal lesion ● Predictable bone gain ● Using correct vector, gains are seen in all dimensions ● Not age dependent	● Patient has to wear orthodontic braces ● Time consuming ● Expensive ● Bone regeneration might be less when the apical part of the tooth is extruded ● Vector sensitive and dependent ● Risk for neighboring teeth tilting towards the gap after extrusion is completed.
Distraction osteogenesis	● Predictable vertical bone lengthening ● Esthetics: predictable soft tissue lengthening ● Procedure maintains tissue vascularization ● Not age dependent ● Reduced morbidity ● Reduced hospitalization time ● Infection risk lowered ● Utilizes body´s own mechanisms for regenereating soft and hard tissue	● Patient compliance ● Suitable patient for treatment ● Not predictable in horizontal bone lengthening, often thin horizontal bone in the vertical lengthened bone ● Invasive surgery ● Time consuming ● May need autogenous bone grafting after distraction period ● Overcorrection needed ● Chance for fracture of the thin vertical bone ● Disturbing appliance in the oral cavity. ● Close monitering of bone segment during distraction.