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Rehabilitation of Alveolar Ridge Defects by Distraction Techniques: A systematic Review

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Abstract This systematic review was aimed to assess the resorption rate and the indications of overcorrection in alveolar distraction osteogenesis (ADO), as well as evaluation of the alveolar distraction techniques, and if necessary, to follow different augmentation protocols in different sites. Online search in four electronic sources was performed to analyze and compare the outcomes of previous clinical studies of alveolar distraction osteogenesis with dental implantation in the period from January 2003 to December 2016. The search terms used, in simple or multiple conjunctions, and the clinical trials were selected according to pre-determined inclusion and exclusion criteria. The initial search yielded 1625 titles. After a subsequent filtering process, 19 studies covering 366 cases and 416 distraction procedures were finally analyzed. The mean augmentation rate was 8.218mm (range, 5-20 mm). The rate of resorption was almost similar in the included studies (15.8-25 %.). The rate of distraction was between 0.5 mm to 1mm daily. The consolidation period was 12 weeks in the almost all studies, the other studies reported various consolidation periods ranging from 6 weeks to 14 weeks. The research concluded that, alveolar distraction is not an uncomplicated procedure. The distraction protocols might be modified individually independent to position of distraction to avoid some complications. There are significant rates of resorption in vertical alveolar distraction osteogenesis for one reason or another, but sufficient overcorrection should be solving this problem.
Keywords: Alveolar bone atrophy, Alveolar bone augmentation, Distraction osteogenesis, Vertical alveolar ridge distraction, Vertical bone augmentation.

إعادة تأهيل عيوب الحافة السنخيّة بتقنيات شدّ العظم: مراجعة منهجيّة

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الملخص يهدف هذا البحث إلى تقييم معدلات ذوبان العظم السنخي (Alveolar bone) الناجمة عن العلاج بتقنيات شدّ العظم (Distraction Osteogenesis) و مدى إمكانية تعويضها و تصحيحها أثناء فترة العلاج، و ذلك من خلال إجراء دراسة منهجيّة لتجارب سريرية سابقة مع تحليل نتائجها. كما اعتمدت هذه المنهجيّة على المقارنة في تباين بروتوكولات أنظمة تقنية شدّ العظم (ADO) المتّبعة وطرق إستخدامها في هذه التجارب. حيث قام الدّارسين بالبحث عبر الانترنت في أربعة مصادر الكترونية مختلفة عن دراسات سريريّة مختصّة أجريت في الفترة ما بين كانون الثاني (يناير) 2003 إلى كانون الأول (ديسمبر) 2016. وقد تم اختيار الدراسات ذات العلاقة وفقًا لمعايير الإشتمال والإستبعاد المحدّدة مسبقًا (Inclusion and Exclusion Criteria). وخلصت نتائج البحث إلى أن بناء العظم السنخي بتقنية شدّ العظم (ADO) هي عملية غير معقّدة و مرنة تسمح بإمكانية تعديل منهجيّة البروتوكولات المتبّعة أثناء فترة العلاج بصورة فردية و مستقلة حسب كمية العظم المراد تعويضها، و بأقل مضاعفات إذا ما قورنت بعمليات بناء عظم مماثلة ذات أساليب مختلفة.

الكلمات المفتاحيّة: تقنيات شدّ العظم السنخي، عيوب عظام السنخ، إعادة بناء أو تجديد عظم السنخ.

1. Introduction

Rehabilitation of partially or totally edentulous patients with oral implants has become a routine treatment modality in the last decades, with reliable long-term results [1]. However, unfavorable local conditions of the alveolar ridge, due to atrophy, periodontal diseases, and trauma sequelae, may result in insufficient bone volume or unfavorable vertical, horizontal, and sagittal

intermaxillary relationships. This may render implant placement more complicated procedure from functional and esthetic viewpoints [2, 3]. Moreover, vertical and horizontal defects of the alveolar ridge restrict the design of dental prosthesis and may jeopardize long-term prognosis of dental implants [4, 5]. Therefore, maintaining an adequate volume of alveolar ridge is vital and necessary for successful oral rehabilitation, and the clinicians are obligated to perform the essential augmentation procedures to reconstruct atrophied bone and insert dental implants accurately in prosthetically driven position [6].

Reconstruction of resorbed alveolar ridges has become a goal and a challenge for dental clinicians to optimize outcomes of prosthetic dental implants [4]. As the field of the implant dentistry is dynamic, many implantologists are searching for advanced preprosthetic surgical procedures that are less inconvenient to the patients and still possess the ability to create optimal circumstances for implant placement [7-9]. In most cases, alveolar bone defects can be regenerated horizontally and vertically; being the vertical bone atrophy is the most challenging to regenerate because of the physiologic limitations and the healing capacity that may produce a minor vascularisation, and the need of a hermetic primary closure of the wound [10, 11].

Generally, treatment of alveolar ridge defect consisted of four strategies; Bone replacement grafts, Bone manipulation procedures, Distraction osteogenesis (DO), and Bone bioengineering [1]. To create enough bone housing during implant therapy, a variety of regenerative techniques have been proposed to compensate for the reduced bone volume, this including but not limited to ridge splitting, onlay or particulate bone grafts with or without membranes and distraction osteogenesis (DO) [12-15].

Distraction osteogenesis (DO) is a clinical approach of tissue engineering performed for bone regeneration where the divided bone segments are stretched apart with a mechanical device. Many tissues beside bone have been observed to form under tension stress, including mucosa, skin, muscle, tendon, blood vessels, and peripheral nerves. The first description of DO was mentioned by Codivilla [16] in 1905, but the procedure did not gain popularity until Ilizarov who has developed an external device for bone lengthening as a new technique in 1950 [17, 18].

Alveolar distraction osteogenesis (ADO) posses a number of advantages in comparison with other bone augmentation modalities such as no morbidity of donor area, simplicity of the surgical procedures, increase of graft survival and less possibility of bone exposure, more predictable volume of hard and soft tissue obtained, shorter bone consolidation period, reducing total treatment time and inclusion of teeth or implants in the transported fragment and hence the prosthetic unfavourable implant can be corrected [19, 20].

Nowadays, multiple alveolar distractors are available for correction of the vertical defects in the alveolar bone before implant placement [21]. According to their bone localization, two types of distractors can be categorized; Intraosseous and extraosseous distracters, and according to the direction of bone regeneration, the device can be applied either for vertical or horizontal osseous augmentation [22-24]. The reports regarding alveolar distraction osteogenesis are inconclusive [20-23]. Therefore, more studies are needed to analyze and compare the outcomes obtained from many variable applied protocols.

2. Study Objectives

The present study was aimed to review and analyze the outcomes of previous retrospective and prospective clinical studies conducted on alveolar bone distraction osteogenesis in the period between 2003 and 2016. It was carried out to evaluate the used techniques, the distraction protocols, and the various accompanied complications.

3. Materials and methods

3.1 Search Strategy

A comprehensive literature search was done to identify articles and evaluate the efficacy of different techniques of alveolar bone distraction with dental implants placement, and assessment of their related complications. This systematic review has been performed according to "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) guidelines [25]. Table 1 shows the individual parts of the PICO question. An online search for randomized clinical trials was performed using four medical electronic sources included; Science Direct, PubMed, Scopus and Cochrane data bases for relevant clinical studies published only in the English language and covering the period from January 2003 to December 2016.

Two independent reviewers (MAR and KMA) conducted an Internet search in Search Direct, PubMed (MEDLINE), Cochrane Library and Scopus databases in February 2018. The search terms (key words) were alveolar bone distraction or distraction osteogenesis or alveolar bone augmentation or vertical alveolar ridge distraction or vertical bone augmentation and alveolar bone atrophy or atrophic jaws. The online Search found 1526 relevant papers; these researches were screened to eliminate the studies that fail to meet the eligibility inclusion and exclusion criteria.

First, they selected publications by titles and abstracts and finally, by reading the full-text of relevant articles to include them in the systematic review. Any disagreement regarding inclusion was resolved by discussion between the two investigators.

3.2 Inclusion criteria:

- Randomized controlled clinical trials, prospective and retrospective clinical studies.
- The mean follow up time should be at least one year.

3.3 Exclusion criteria:

- In vitro and animal studies, as well as case reports or case series studies.
- Studies in a language other than English or without an English abstract.
- When multiple reports of the same study were identified, only the most recent report was included.

3.4 Selection of parameters

The identified studies were searched for specific parameters under defined inclusion criteria. These included numbers of the patients, total number of ADO per patient, total numbers of the implants were placed in the distracted bone. Specific protocol parameters recorded were: duration of latency period before active phase of distraction, rate and rhythm of activation, rate of distraction and duration of consolidation phase.

A flow chart summarizing the search process was made according to PRISMA guidelines (Fig. 1). The selected articles were classified into different levels of evidence following SORT criteria [26]. Furthermore, the risk of bias of each article was determined with the "Cochrane Handbook for Systematic Reviews of Interventions, version 5.1.0" [27]. Finally, a qualitative synthesis of the results of the included studies was performed and demonstrated graphically. The registered variables were the total number of patients and implants placed, latency period, rate of distraction, rate of augmentation and consolidation period. If necessary and possible, data for the outcome variables as presented graphically were calculated by the authors based on the information provided by each individual selected study.

Table 1: PICO question: P= population; I= intervention; C= control group; O= outcomes.

PICO question	
Population	Health patients with Alveolar bone atrophy who need bone regenerative treatment to enable dental implants placement.
Intervention	Alveolar distraction osteogenesis with insertion of dental implants.
Control Group	Comparison between different protocols of alveolar distraction osteogenesis with dental implantation.
Outcomes	Latency period. Rate of distraction. Rate of activation. Consolidation period. Survival rate or success of the dental implants placed in the distracted bone. Complications.

4. Results

Only limited number of literature was available to carry out this study. A total of 19 articles that met the study criteria were reviewed, considering 416 distraction procedure performed in 366 patients, the number of the implants placed after ADO were 792 in 300 patients (Table 2) [28-46].

4.1 Types of distractor used in Alveolar bone distraction osteogenesis

According to their insertion techniques, the alveolar distractors may be classified as Intraosseous (endosseous) and Extraosseous (Juxtaosseous) distractor. Intraosseous distractor was used in five studies [32, 34, 35, 36, 37, 43]. Etxtraosseous type was applied in nine studies [28, 29, 31, 35, 38, 41, 44-46]. A combination technique of using both intraosseous and extraosseous distractors was applied only in four studies [33, 39, 40, 42]. One research had compared between intra osseous and extraosseous ADO approaches [30]. The authors [30] reported 61.5% and 50% of overall complication rates in the Intraosseous and extraosseous group's respectively.

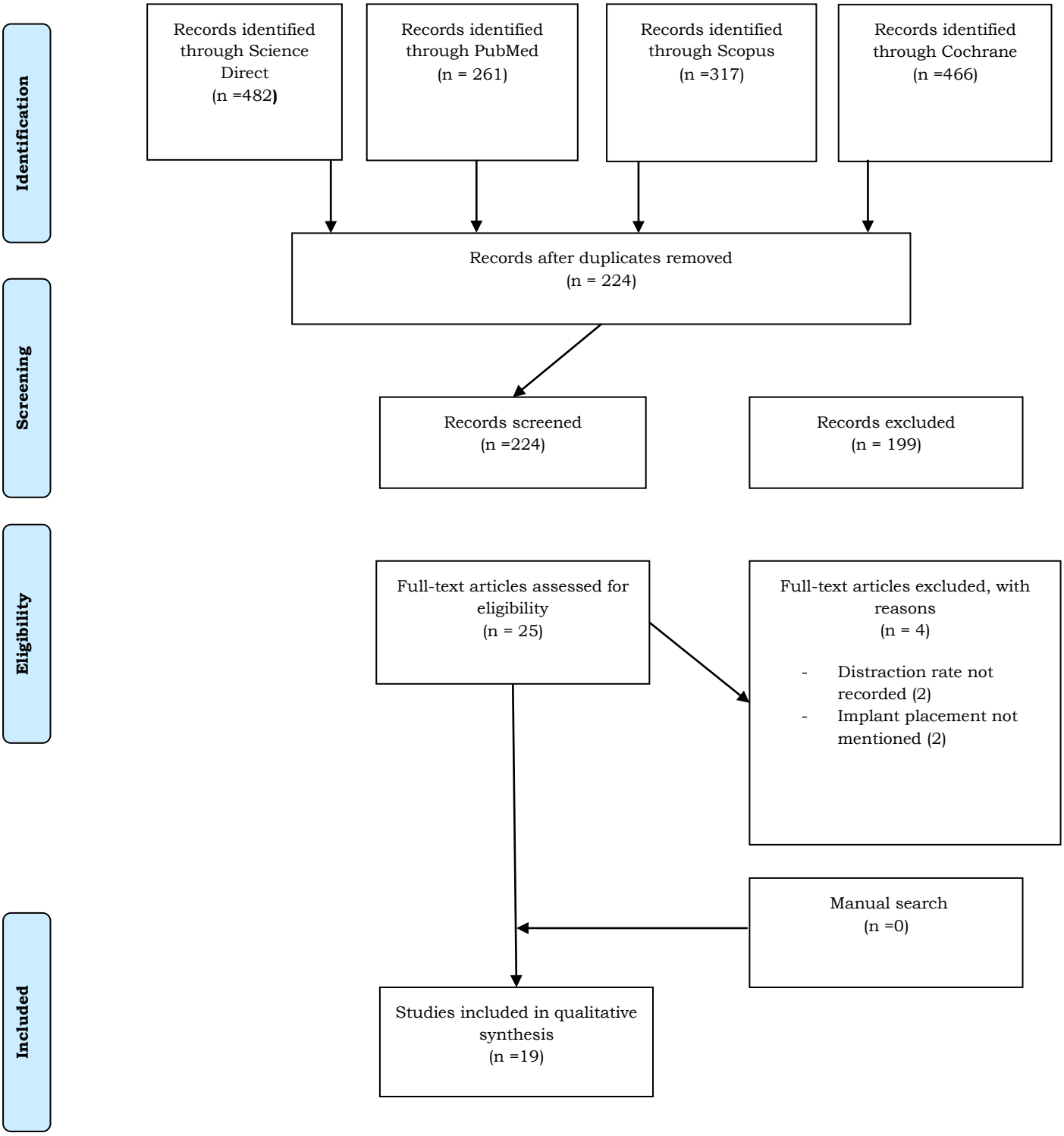

Fig. 1: Preferred Reporting Items for Systematic Reviews and Meta-analysis PRISMA flow chart of the study inclusion process**.**

4.1.1 Intraosseous (endosseous) distractors

The Intraosseous distractor is placed through the transport segment of bone and fixed to the basal segment by micro plates toward the vector of distraction. The brand Lead System (LS) intraosseous distractor was used in the selected nine studies; (five for intraosseous approach [32, 34, 36, 37, 43] and four for combination approach [33, 39, 40, 42]. During the operation step of insertion the thread distracted rod, if the crestal bone was knife edged, a minimal shaving of the crestal bone was recommended by Rachmiel [32].

Following osteotomies and distraction plate adaptation, a 3 to 4-mm gap is left between the transport and basal bone immediately after insertion of the device [34]. This distance is equal to 3 to 4 days of activation in the case of extraosseous distractor. This space may result in a deficient bone formation during consolidation phase [34].

4.1.2 Extraosseous (subperiosteal) distractors

The Extraosseous distractor is placed over the buccal surface of alveolar bone and inserted subperiosteally. Martin distractor (KLS Martin, Tuttlingen,Germany) and Medartis distractor (Modus; Medartis AG, Basel, Switzerland) were the most commonly used types. They were used in 7 studies. [28, 29, 31, 35, 38, 41, 45]. Medartis distraction designed in two types of subperiosteal distractors: Uni-directional distractor, this type of device was used only in studies which followed extraosseous protocol. Bi-directional distractor had been used to provide combined bone regeneration in both vertical and horizontal movements (combination protocol).

One clinical trial [31] reported the application of Floating Alveolar Device (FAD) as type of extraosseous distractor (Floating Alveolar Device, FAD University of Udine Italy, Cizeta group). FAD was designed to distract the alveolar bone in the two directions (bidirectional osteodistraction). First, vertical distraction to correct the vertical deficiency of
alveolar ridge, Second, horizontal distraction to correct the segments vector in bucco-lingual, labio-lingual directions in the mandible or bucco-palatal, labio- palatal directions in the
maxilla. With this type of distractor, the ideal direction of the vector of distraction determined during preoperative planning was achieved in all cases [31]. The fourth type of extraosseous distractor that has been applied is Conector distractor (Conector; Conexão, Implant System, São Paulo,Brazil). In this technique, pre-bending and adaptation of the distractor was performed before the surgical drilling of the osteotomy site [35].

4.2 Common Distraction Protocol

4.2.1 Latency period

In all of the included studies, the latency period was reported. The authors suggested several intervals of latency phase. The latency period was 7 days in 10 clinical trials [34-43]. The justification was to permit healing of mucoperiosteum, reduce the risk of wound dehiscence and to avoid premature union of the bone. Another research [31] started to activate the distractor after the healing period of 15 days. The shortest latency period was reported by Rachmiel [32], the distraction in this study was started on the fourth postoperative day. Some other clinical studies followed protocol of latency period commenced from5-10 days postoperatively (Table 2).

4.2.2 Rate of distraction

The rate of distraction was mentioned in all included articles. Generally, the rate of distraction was from 0.5 mm to 1mm daily. In sixteen studies, the distraction rate was 0.8-1mm. The rhythm of distraction activation was performed either once daily, or in intermittent manner of two or three or four times per day.

Günbay [39] studied the complications of ADO in 7 patients. All patients demonstrated well tolerance of the surgical procedures, except one case. In addition, Günbay had increased the frequency of activation and repeated the distraction rate as many as four times daily. Günbay reported that, the patient's discomfort, pain and tension could be relieved by multiple activations of the device.

Garcia et al [43] performed seventeen clinical alveolar distraction osteogenesis procedures in twelve patients; the rate of activation was 1mm daily in the mandible and 0.5mm daily in the maxilla. Lindeboom et al [36] studied the biological effect of activation rate on the morphology of micro vascular soft tissue during ADO. They summarized that, a fixed distraction rate was better set at 1mm/ day, and the increase in vascular response and capillary density during distraction osteogenesis mainly occurs in the activation phase of distraction. They have also reported that, ideal results of new bone formation are best obtained at moderate distraction rate. Moreover, if the distraction rate is increased more than 1mm/day, the newly formed blood vessels will be jeopardized and disrupted with increasing the possibility of hemorrhage and necrosis. On contrary, in case of decreasing the distraction rate to 0.5mm/day, faster or premature osteogenesis process may occur in the distraction gap.

4.2.3 Rate of Augmentation

Rate of bone augmentation was reported in sixteen studies of the literature body. However, some researches [21, 22, 25] did not mention any value regarding to the amount of the augmented bone. The mean augmentation rate in the included studies was 8,218mm. The maximum value of the vertical bone gain was reported by Adolphs et al [28], it was 16.7mm. Their research was conducted on six patients who were suffering from critical mandibular heights following marginal resection of the mandible. The aim of their study was to resolve this bone deformity through vertical distraction osteogenesis prior to implants insertions. The minimum value of augmentation (5 mm) was reported by Garcia et al [34] who investigated the efficacy of alveolar distraction for reducing of crown height (length ratio) in the posterior part of the mandible.

4.2.4 Consolidation Period

The researchers followed different schedules of consolidation period in the included studies. In nine studies [30, 34, 35, 38, 42-46], the consolidation phase was 12 weeks. Other studies reported various consolidation times ranged from 6 to 14 weeks.

Ugurlu [37] compared different time protocols of consolidation phase in ADO, and evaluated the effects of time factor on bone formation. Eighteen patients divided in two groups which underwent vertical distraction procedures under the same protocol, except for the consolidation time. The consolidation period was 5 weeks for group one and 14 weeks for group two. At the end of consolidation periods, the mean bone relapse was 0.832±0.135mm in group 1 and 0.738±0135 mm in group 2. After 6 months, the mean of bone relapse was 1.38 ± 0.144 mm in group 1 and 1.112 ± 0.144 mm in group2. They concluded that there was no significant difference existed between the two groups at any time.

4.2.5 Rate of Resorption

One of the most common encountered drawbacks in the ADO technique is reduction of bone height after completing of the activati-

Table2: Summary of distraction protocol in the included studies.

Article Author/ Year	Patient (P)	ADO Procedure	Latency period	Rate of distraction	Rate of augmentation	Consolidation period	Implant placed (Imp)
Adolphs et al 28 2009	6	6	5-10 days	0.5mm/D	16.7mm	22.4 Weeks	23 Imp
Ettl et al 29 2009	30	36	8.1 days	0.3mm X 3/D	6.4mm	2.5 Months	82 Imp
Uckan et al 30 2007	21	23	5 days	0.25 mm X/ D	11.6mm	8-12 Weeks	42 Imp
Robiony et al 31 2004	4	4	15 days	0.5mm/D	10 mm	8 Weeks	5 Impl in 2 pt
Rachmiel et al 32 2001	14	16	4 days	0.8mm/D	10.3mm	60 days	23 Imp
Enislidis et al 33 2004	37	45	8 days	0.3mm X3/ D	8.2 mm	2.6 Months	NR
Garcia et al 34 2003	7	10	7 days	1mm/D	5 mm	12 Weeks	20 Imp
Mazzonetto et al 35 2005	55	60	7 days	1mm/D	6.27 mm	12 Weeks	74 Imp in 34 pt
Lindeboom et al 36 2008	10	10	7 days	1mm/D	7mm	6 Weeks	NR
Ugurlu et al 37 2012	18	18	7 days	0.5mm X1/ D	7 mm	5- 14 Weeks	36 Imp
Wolvius et al 38 2007	20	20	7 days	0.3mm X3/ D	6.3mm	12 Weeks	63 Imp
Günbay et al 39 2007	7	7	7 days	NR	7.8mm	6-8 Weeks	14 Imp
Saulacic et al 40 2007	23	29	7 days	1mm/d	NR	12 Weeks	NR
Ugurlu et al 41 2012	40	44	7 days	0.5mm X 2/D	NR	5-14 Weeks	74 in 38 Imp
Saulacic et al 42 2005	11	17	7 days	1mm/D	6.13 mm	12 Weeks	43 Imp
Garcia Garcia et al 43 2004	12	17	7 days	0.5mm Maxillla 1mm Mandible	5.73mm	12 Weeks	44 Imp
Hashemi et al 44 2010	6	6	5-7 days	0.5mmX 2/ D	NR	12 Weeks	NR
Türker et al 45 2007	10	10	5 days	0.8mm/D	9.6mm	12 Weeks	15 Imp
Kanno et al 46 2007	35	38	10 days	0.8-1mm/D	7.7mm	12Weeks	141 Imp
Overall	**Total= 366 P**	**Total= 416 AD**	**Mean=7.3 days**	**Mean= 0.84mm**	**Mean= 8.218mm**	**Mean= 11.10 Weeks**	**Total= 792 Imp**

on process. Rate of bone resorption was studied in details only in 5 researches [29, 37, 38, 42, 46]. The measurement of the decreased amount of bone height was carried out on panoramic radiographs; the bone height was measured from inferior border of mandible or floor of maxillary sinus to alveolar crest or nasal cavity in the maxilla [37, 38, 42]. In the other two studies [29, 46], the bone height was measured as the distance from osteotomy line in the basal bone to the top of alveolar crest. This means that the rates of alveolar resorption obtained in these researches are the amount of distracted bone resorption with involvement the resorption of transport segment. The rate of resorption was almost similar in all of the previous studies (15.8-25 %).

Kanno et al [46] studied the indications of overcorrection in the vertical ADO. They investigated thirty-five patients (17 males and 18 females, mean age 43.9 years) who underwent to thirty eight ADO procedures with successful placement of 141 dental implants. Alveolar ridge height was evaluated using digital orthopantomographic radiographs taken shortly after the end of distraction, at consolidation and before implant placement. The mean of bone reduction was 2.1mm (21%) during the consolidation period, and 3.6mm (37%) at the time of implant placement. From these results, Kanno and his colleagues recommended that 25% overcorrection in vertical ADO process should be indicated.

Saulacic [42] and Wolvius [38] studied the rate of resorption at the mesial and distal parts of the transport segment. The mean of bone relapse that is reported by Saulacic was 1.57±1.82mm at the mesial and 1.79±1.68mm at the distal aspects of the inserted implants. Wolvius and colleagues recorded 20% rate of bone resorption at the mesial part of the transported segment and 17% at the distal part. Saulacic et al have suggested that, 20% of overcorrection should be considered when performing vertical ADO. Both Saulacic and Wolvi's results are almost similar to the results reported by Ettl [29]. Ettl et al have analyzed the bone resorption in 30 cases subjected to 36 vertical ADO. The mean rate of bone relapse was 21.1% at the time of implant insertion

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5. Discussion

For many years, different therapeutic grafting modalities have been proposed to reconstruct alveolar bony defects that are mainly caused by periodontal diseases. This included augmentation with autogenous bone, allograft, xenogenic or alloplastic material with or without guided bone regeneration (GBR) procedures [21]. However, there is an increased risk of postoperative infection and higher incidence of wound dehiscence leading to unsatisfied gingival esthetics when allogenic materials are used [45].

The aims of this systematic review were to investigate the variable distraction protocols, as well as the rate of resorption and the indication of overcorrection in vertical ADO. Due to the heterogeneity of the studies (different observation periods, different types of studies), it was not possible to perform a statistical analysis of the collected data.

According to rate of resorption, the compared researches have shown almost similar results (Resorption rate of 15.8-25%) in term of alveolar resorption rate regardless of the position of distractor. This indicates the accuracy of the clinical methods and the obtained results by these studies [29, 37, 38, 42, 46]. It is sometimes difficult in clinical and experimental situations to exactly determine the reason of bone resorption in vertical ADO [37]. Some investigators suggested that it may be due to the pressure produced by the intact periosteum from the lingual or palatal side, or the pressure from the scars resulted from the healing process after operation in the buccal or labial side.

According to Ugurlu study [37], the impact of the consolidation period on the rate of resorption could be excluded. Whatever the reason of the resorption or relapse, the overcorrection in vertical ADO should be included in the distraction protocols. In addition, with long segments cases where two distractors should be used, the overcorrection should be planned in both mesial and distal parts of segment without exclusion.

Authors used variable distraction protocols in the included papers independent on the position of distraction. Only in one study [35], a difference existed between the distraction rates followed in maxilla and in mandible; they activated the distractor at 1 mm daily in the mandible and 0.5 mm daily in the maxilla. Unfortunately, they did not mention the reason of using different activation rates in mandible and maxilla. If their assumption was attributed to the difference in bone quality between maxilla and mandible, they should also adjust the time needed for the consolidation period in each protocol. From the collected data, it can be summarize that there was no relationship existed between these distraction protocols and the position of distractors. The distraction protocols might be modified independently of the position of distractors. This modification may help in avoidance and prevention of some complications such as pain and wound dehiscence as long as the daily activation time of distraction rate has been reduced from 3 or 4 times per day.

Conclusion

Alveolar distraction osteogenesis AOD is successful and predictable method for augmentation of dentoalveolar defects. Although its limitation in expanding the bucco-lingual width of the atrophied alveolar ridge, AOD provides many advantages when compared with standard staged conventional grafting techniques. However, the combination of different augmentation techniques in some cases is necessary. Although complications associated with vertical ADO were not rare, the use of this procedure for maxillofacial defects results in satisfactory outcomes. Early diagnosis and management of related complications are crucial for increasing the success rate of ADO procedures. These complications may be minor

which are easy to be managed, or major complications for which a special or more advanced treatment is required. In some situations, the distraction protocols might be modified individually and independent to the position of distraction device in order to avoid such complications. For one or more reasons, there are significant rates of bone resorption existing when performing vertical ADO. However, effective overcorrection should overcome and compensate the resorbed bone and solving this problem.

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