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Research Article

Osseointegrated Dental Implants as an Anchorage Method. A Systematic Review

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Abstract

Osseointegrated dental implants can provide optimal anchorage in orthodontic movements due to the absence of mobility under this type of force. In addition, rehabilitation with fixed prostheses on implants has reported good long-term results, being then a safe and predictable method.

The objective of this systematic review is to determine the success of implants used as an anchoring method in an orthodontic treatment. In partially edentulous patients who need orthodontic treatment, dental implants may offer many advantages. Although the results are promising, more randomized controlled studies are needed to evaluate the follow-up of prosthetically loaded implants previously used as an anchor in orthodontic treatments.

Keywords: Osseointegrated Dental Implants; Anchorage Method; Orthodontic Treatments

Introduction

There's nowadays a lot of patients asking for orthodontic treatment for functional and/or aesthetic concerns. Nevertheless, not in all the cases we do have a dentition that allows us to obtain an orthodontic anchorage: partially edentulous patients, patients with congenital dentofacial disorders, etc [1].

In the 60's, Brannemark., *et al.* [2] reported biocompatibility of titanium implants in bone, establishing the osseointegration concept. Some decades later, Roberts., *et al.* proved *in vitro* that the use of implants as an anchor in orthodontic treatment was an effective method [3].

Pure titanium is the most used material in implantology, it consists of 99.5% titanium and 0.5% of other elements (carbon, oxygen, hydrogen, nitrogen, etc). Its mechanical characteristics meet the required requirements; it has excellent tensile and fracture resistance that allows it to withstand the forces of chewing and orthodontic forces [4]. Related to the type of force applied to implants, there are differences between occlusal and orthodontic forces. The forces during an orthodontic treatment are mostly horizontal, continuous, of low magnitude (< 3N) and are normally applied in a single direction. While occlusal forces are intermittent, more intense and multidirectional (may vary between 200 - 700N). We must not forget that 1 N/cm is equivalent to 102g of force approximately [5,6].

During orthodontic treatment, dental movement causes a reciprocal movement of the tooth or teeth used as an anchor [7]. Therefore, the control of the orthodontic anchor is essential; defined by Proffit., *et al.* as resistance to unwanted movement [6]. When natural teeth are used as anchoring units, they are equally susceptible to movement than active teeth. The most common in natural dentition is that the anchor units are greater in number than the teeth that are intended to be mobilized [9]. The mechanisms used can be intraoral or extraoral. The intraoral anchorage can be complemented with splinting, elastic, transpalatal arches or other methods to try to achieve absolute anchorage; facial mask and extraoral arch can be used as extraoral devices; among others. Extraoral apparatus is a more predictable method but it has some limitations: patient collaboration, discomfort, device size, etc [9,10].

Different surgical techniques have been proposed to help strengthen the anchor in orthodontic treatment; for example, the use of conventional osseointegrated mini-implants or implants [1,4,5,7-10]. The absence of periodontal ligament confers absolute immobility to these new anchoring systems, achieving absolute anchorage that increases the predictability and effectiveness of the treatment [1-9].

They can serve as direct or indirect anchorage. Direct anchorage on osseointegrated implants consists of applying forces on a screwed provisional crown that will be replaced by a definitive one after orthodontics. Indirect anchoring involves using a temporary device that will be removed at the end of the treatment. Mini implants are frequently used. Its diameter ranges between 1 - 2 mm and length of 6 mm. Its advantages include easy insertion as well as the multiple locations in which they can be inserted, like retromolar, interradicular, palatal and subapical [4,9].

In partially edentulous patients, osseointegrated implants can be a good anchoring alternative to achieve correct dental alignment and rehabilitation of occlusion [1,4,5,7,9]. It is also important to highlight the advantages related to time and cost of treatment because the osseointegrated implant will be used later in prosthetic rehabilitation [11,12].

Among its indications we could highlight: dental intrusion and extrusion movements, closing of spaces, retraction and alignment, correction of the midline, crossbite, anterior open bite, stabilization of periodontally affected teeth, anchorage to achieve an orthopedic movement (e.g. palatine expansion) and in partially edentulous patients as an anchoring method and subsequent prosthetic rehabilitation [1,4,7]. Many studies have focused on assessing the survival of osseointegrated implants against occlusal forces (immediate or delayed loading) [13-15]; but very few authors have performed quantitative and objective analysis of the effect of orthodontic anchorage on osseointegrated implants [16,17].

Materials and Methods

We asked ourselves the following question to conduct this systematic review, following the PICO system: do orthodontic forces affect the success of the implant treatment?

P (patient) = partially edentulous patients undergoing orthodontic treatment; I (intervention) = implant placement and use as an anchoring method; C (comparison) = occlusal forces vs. orthodontic forces; O (objective) = success or failure of osseointegrated implants.

Searching method

A bibliographic search is carried out from 2009 to 2019 in the Medline/PubMed database with the following keywords: "osseointegrated implants" AND "orthodontic anchorage" and ("Dental Implants" [Mesh]) AND "Orthodontic Anchorage Procedures" [Majr].

Criteria selection

All publications made between 2009 and 2019 in English or Spanish are included. The search includes: randomized clinical trial, prospective studies, multicentered studies, reports and case series. Only those *in vivo* studies that analyze the evolution of osseointegrated implants used as orthodontic anchorage and subsequent prosthetic rehabilitation in partially edentulous patients are selected. A manual search is performed in the bibliography of the articles analyzed in full text and three publications that focus on orthodontic treatment using implants as an anchoring method are added.

Publications excluded are the ones analyzing the use of mini-implants as temporary anchoring units in orthodontic treatment, those studies in which implants are placed after orthodontic treatment, and also studies in which different anchoring systems are compared (mini-implants, transpalatal arch, extraoral appliances) excluding osseointegrated implants. Those articles in which no parameters associated with the success of the implant treatment are analyzed and in which there is no follow-up period are also discarded.

The methodological quality of the included studies is analyzed following the JADAD guide for clinical trials [18]. Scores between 1 - 2 points are considered of low quality and scores of 3-5 of high quality (Table 1) Among the five publications, only two of them are randomized clinical trials, and after applying the JADAD scale we obtain that one of them is of low quality [19] and the other is of high methodological quality [20].

	Randomization	"Blind method"	Total patients	Total
Palagi LM., *et al.*	2	0	1	3
Marins BR., *et al.*	1	0	1	2

***Table 1:** Assessment of the RCT methodological quality by JADAD scale.*

Results

316 publications are found meeting the specified search parameters; from the manual search 3 articles are added for analysis because they are interesting in orthodontic anchorage through implants. After reviewing the title and abstract, 300 articles are excluded because they do not meet the inclusion criteria.

19 full-text articles are analyzed and five publications are finally included in the review: two randomized clinical trials [19,20], a prospective study [21], a case series [22] and a clinical case [23] (Figure 1). The results of the included studies are analyzed and compared (Table 2).

Authors	N	Groups	Implants	Values	Follow-up	Success rate
Palagi LM., *et al.* [19] RCT	20	- A (n=11): inmediate orthodontic load* - B (n=9): delayed load (4 m).	Surface etched with acid Ø = 4 mm. Length = 13 mm.	C.B.= 2nd loop (n=18) MOB. : n= 2 P.I. = NE B.I. = NE P.D. = NE K.M.W. = NE ISQ = NE	2 years	- Group A: 90.9% - Group B: 88.9%
Marins BR., *et al.* [20] (RCT)	50	- A (n=26): orthodontic attachment. ** - B (n=24): prosthetically loaded.	Ø = 3.75, 4 mm. Length = 8, 10, 11.5.	C.B.: A (m= 2.36 ± 0.92/d= 2.58 ± 1.19), B (m= 2.14 ± 0.63/d= 2.39 ± 0.79) MOB.: n= 0 P.I. = A (0.08 ± 0.27), B (0) B.I. = A (0), B (0.01 ± 0.05) P.D.: A (2.39 ± 0.45 mm), B (2.21 ± 0.47) K.M.W.: A (1.56 ± 0.51 mm), B (1.51 ± 0.47 mm) ISQ = NE	3 years	- Group A and B: 100%
Rugani de Cravero M., *et al.* [21] (Prospective review)	93	- A (n=16): 22-42 y-o*** - B (n=15): 42-53 y-o*** - C (n=7): 53-64 y-o***	Surface machined (3 mm) + acid treatment Ø = 4, 5, 6 mm. Length = 10, 11.5, 13 mm	C.B.: A (0.02 ± 0.43), B (- 0.01 ± 0.21), C (0.01 ± 0.27) MOB. : 0 G.I.: n.i. (n=26), l.i. (n= 54), m.i. (n= 13) P.D.: n=80 (< 3 mm), 13 (3 mm) K.M.W.: NE ISQ: initial (66.26), final (68.26)	2 years	- Group A, B, C: 100%

Kato S., *et al.* [23] (Clinical case)	5	- A (n=2)**** - B (n=3)	Surface TiUnite Ø = 4, 5 mm Length = 10, 13 mm	C.B.: A (0.8, 0.65 mm), B (0.7, 1, 0.75 mm) MOB.: 0 P.I.: NE; B.I.: NE P.D.: NE K.M.W.: NE ISQ: A (initial = 85,87; final = 85,83); B (initial = 78,87,87; final = 75,79,83)	19 months	100%
Kato S., *et al.* [22] (Case series)	43	- A (n=27): ITI TPS (7), ITI SLA (12), TiUnite (8)***** - B (n=16): ITI TPS (2), ITI SLA (11), TiUNite (3)	-ITI TPS: Ø (4.1 mm), length (6, 8 mm) -ITI SLA: Ø (3.3, 4.1), length (8, 10, 12) -Nobel TiUnite: Ø (4.0, 5.0), length (7, 10, 13, 15 mm)	B.R.: A (ITI TPS = 0.3 mm, ITI SLA = 0.3, TiUnite = 0.4 mm), B (ITI TPS = 1.2, ITI SLA = - 0.5 mm, TiUnite = 0.6 mm) MOB.: 0 P.I.: NE B.I.: NE P.D.: NE K.M.W.: NE ISQ: NE	- ITI TPS = 4.4- 6 years - ITI SLA = 3- 4.4 years - TiUnite = 0.8 -3 years	86%

Table 2: *Results of the analyzed reviews. *Force = 60-200g; **F= 200 CN; ***F=100-200g; ****F= 400g (vertical); *****F = 150-400g. C.B.: Crestal Bone; B.R.: Bone Remodelation; MOB.: Mobility; P.I: Plaque Index; B.I.: Bleeding Index; G.I.: Gingival Index (Loe and Silness); P.D.: Probing Depth; K.M.W.: Keratinized Mucosa Width; ISQ: Implant Stability Quotient; n.i.: No Inflammation; l.i.: Mild Inflammation; m.i.: Moderate Inflammation.*

In total, 211 implants placed in patients between 22 - 64 years old are analyzed. A total of 18 men and 45 women are treated in the studies [19-23].

For orthodontic treatment, forces are applied in a range of 60 - 400g (4 N/cm) [19-23]. The force applied in the studies is usually 200g [20,21], although in one of the studies a vertical force of 400g is applied to obtain intrusion movements [23]. Forces are applied after a period of osseointegration in most studies, varying from 1 to 7 months [19-23]. In one of the clinical studies [19] orthodontic force is applied immediately without waiting for the implant to osseointegrate, it compares early orthodontic anchoring in non-osseointegrated implants versus anchoring with implants after a period of osteointegration of 4 months [19].

Implants with diameters from 3.3 to 6 mm, and lengths of 6 to 15 mm are placed. In their study, Palagi., *et al.* [19] implants of 4 mm diameter and 13 mm length were used. Marins., *et al.* [20] place implants of 3.75 and 4 mm in diameter, and implants of 8 to 11.5 mm in length. Kato., *et al.* 23 place implants of 4 and 5 mm in diameter and 10 and 13 mm in length in the study of Cravero., *et al.* 10 - 13 mm long and 4 - 6 mm diameter implants are also placed [21]. And in the Kato., *et al.* [22] case series they use 15 mm long implants and 3.3 to 5 mm diameters. Different implant surfaces are also analyzed, assessing whether there are differences between the different treatments: acid etching, TPS, SLA, TiUnite, etc [22].

The level of marginal bone and the absence of peri-implant radiolucency are analyzed radiographically. All included studies analyze the level of peri-implant crestal bone [19-23]. The clinical parameters analyzed are: plaque index, bleeding at probing, probing depth and keratinized mucosa width. Only two studies are studied; Marins., *et al.* [20] in their randomized study analyzes all parameters, and in the study by Cravero., *et al.* [21] they do not assess plaque index or keratinized mucosa width.

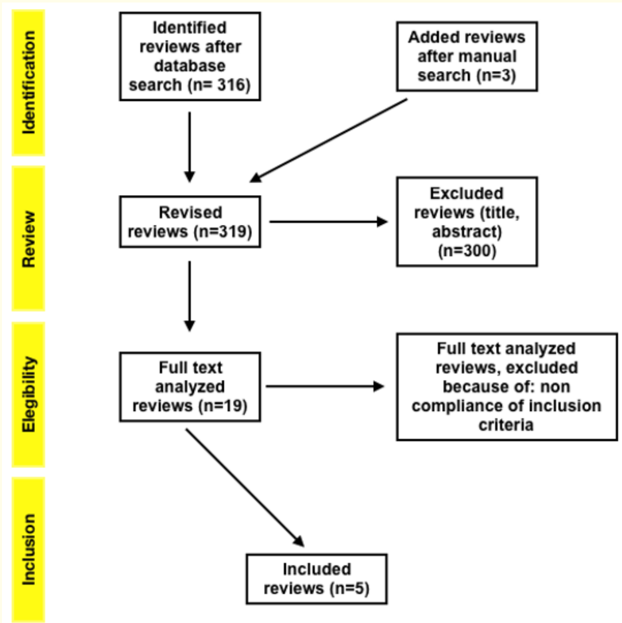

Figure 1: *Research process and results diagram.*

Stability is also assessed with the ISQ index, as well as the mobility of the implant [19-23]. In their prospective study Cravero., *et al.* [21] assesses the ISQ index of the 93 implants placed, also Kato., *et al.* in their clinical case [23]. Neither of the authors obtain significant results. Only mobility of two implants is reported in one of the studies [19].

The follow-up period of the implants is from 19 months to 6 years; Kato., *et al.* [22] is the one that reports the longest follow-up, from 4.4 to 6 years in the ITI TPS implant group in their case series. A total of 203 implants show no signs or symptoms of pain, infection or mobility [19-23]. There is also no sign of peri-implant radiolucency in radiographies. Two implants fail due to excessive mobility (lack of osseointegration) in one of the studies; one belonging to the test group and the other to the control group [19]. In one of the studies a success rate of 86% is reported, since six implants do not meet the criteria [22]. The success rate of the implants is 100% in three out of the five studies [20,21,23].

In the included studies [19-23], the evaluation of the implant treatment is carried out applying the Karoussis [24] success criteria:

1. Absence of mobility of the implant.
2. Absence of subjective perceptions (pain, foreign body sensation and/or dysesthesia).
3. Absence of probing depth greater than 5 mm.
4. Absence of probing depth equal to 5 mm and bleeding.
5. Absence of peri-implant radiolucency.
6. Vertical bone loss < 0.2 mm/year after the first year of functional load.

Discussion

Plaque index and bleeding

In the Rugani de Cravero., *et al.* [21] study, Loe and Silness [25] index reveals absence of inflammation in 26 implants (28%), mild inflammation in 54% (54 implants) and moderate inflammation in 13 implants (14%). Similar results are obtained in the study by Rezende Marins., *et al.* [20], in which no significant differences between groups are observed when evaluating the modified bleeding rate and plaque index [26].

Probing depth

There are no significant differences in the probing depth between both groups in the randomized clinical study by Rezende Marins., *et al* [20]. In the test group the mean probing depth is 2.39 ± 0.45 mm and in the control group values are 2.21 ± 0.47 mm after three years of prosthesis insertion [20]. Cravero., *et al.* don't obtain probing depth values greater than 3 mm in 93 implants placed in the maxilla and the mandible after a 2-year follow-up, either [21].

Keratinized mucosa

Rezende Marins., *et al.* [20] report that keratinized mucosa width values remain stable between groups. After three years, the values are 1.51 ± 0.47 for the control group and 1.56 ± 0.51 mm for the test group [20]. Clinical and radiographic controls do not reveal changes neither in the biologic response of gingival tissue nor in the bone tissue when applying orthodontic forces to implants, with regard to the control group.

Peri-implant crestal bone

In their randomized clinical study, this same group proves that there are no statistically significant differences between the two groups regarding remodeling of the crestal bone [20]. Kato., *et al.* [22] obtain similar results in their study by comparing 27 implants used as orthodontic anchorage and 16 implants loaded prosthetically. Similar results are obtained by Kato., *et al.* in the report of a clinical case where there are no differences in bone remodeling when comparing the test group (n = 2) with the control group (n = 3) during a follow-up period of one year [23]. The results obtained by Palagi., *et al.* in their randomized clinical study (n = 20) are favorable, 18 implants remain osseointegrated with a level of crestal peri-implant bone at the level of the second implant loop [19]. In their prospective study, Rugani de Cravero., *et al.* obtain a slight bone gain in those implants used as orthodontic anchorage (n = 15) by applying 100 - 200g forces. It should be noted that in this study (n = 93) orthodontic forces are applied to all of the implants [21].

Implant stabilization (ISQ)

Rugani de Cravero., *et al.* [38] place implants to 38 patients before orthodontic treatment and wait for an osseointegration time of 6 months in the maxilla and 4 months in the mandible to apply orthodontic forces. Implants are assessed to meet the success criteria mentioned above and also have ISQ values of 50 or higher. Compressive and tensile forces of 100 - 200g are applied during a period of 2 to 9 months [21].

Some parameters already mentioned, and also the stability of the implants (ISQ) before and after the application of orthodontic forces are analyzed.

There are differences in the ISQ values, being the initial value 66.26 and the final value 68.26. There are no significant differences in relation to other variables: age, sex, bone quality, location, height and width of the implants [21].

Kato., *et al.* also report differences in the ISQ values of the implants used as orthodontic anchorage in the molar intrusion movements [23].

There is a decrease in ISQ at the beginning of orthodontic movement (1 month after the second phase) and it restores after 2 months, remaining stable until the end of treatment (19 months) [23].

Surface type

Cravero., *et al.* suggest that surface treatment affects the success rate of implants used as orthodontic anchorage. All implants placed in their study have been double etched with hydrochloric and sulfuric acid [21].

Taking into account the surface treatment, Kato., *et al.* compare in their case series implants with different roughness indexes (TPS, SLA and TiUnite surfaces) used as orthodontic anchorage and prostheses, with implants not subjected to an orthodontic force [22].

The surface roughness characteristics are classified as: rough (ITI TPS) with values of Sa > 2 µm; and moderately rough (ITI SLA, TiUnite) with Sa values = 1.0 - 2.0 µm [27]. Regarding the TPS and SLA surface, an average bone loss of 0.3 mm is observed in implants used as anchors. In the control group, bone loss of the implants is 1.2 mm (TPS) and a slight increase is observed in the SLA surface (+ 0.5 mm). TiUnite surface implants used as anchors lose an average of 0.4 mm and those that are not used in orthodontic treatment have a loss of 0.6 mm. There are no significant differences in the therapeutic outcome comparing the different implant surface treatments [21].

Load type

Numerous studies have reported high success rates in the immediate loading of implants, as well as in the use of implants as an orthodontic anchoring method; but there is little data on the combination of these two variables [28-31].

The objective of the study by Palagi., *et al.* is to evaluate the success rate after applying an early orthodontic load on implants placed in posterior mandibular sectors. All implants had to have a minimum insertion torque of 40N to be included in the sample [19]. In the study group (n = 11) orthodontic forces of 60 to 200g were applied immediately, while in the control group (n = 9) immediate loading of the implants was performed without applying any orthodontic force (waiting time of 4 months). They concluded that there was no difference in the success rate of the traditional protocol (89%) with respect to the early orthodontic load of the implants (91%) [19]. There is evidence that states that applying a force to the implant is beneficial for the bone remodeling and accelerates implant stability [32,33]. It has also been shown that an implant loaded with a constant force shows a dense and cortical laminar bone, while changing forces (e.g. chewing forces) can cause bone defects and remodeling that could end in implant failure [34,35]. In its extensive systematic review, Skeggs., *et al.* report that there is evidence regarding the favorable outcome of early orthodontic implant loading; even though this evidence is limited and more controlled human clinical studies should be done for analysis [9].

Primary stability of the implant is considered very important for its subsequent use as an orthodontic anchor. Sarmah., *et al.* [36] highlight the importance of analyzing other variables that influence the peri-implant bone response: quality (mechanical properties) and bone quantity (cortical thickness, trabecular bone density), periodontal status, oral hygiene; and other factors that affect bone remodeling [36].

According to some studies there are certain cases in which the use of implants as an anchor in orthodontic treatment would be discouraged. These are the established exclusion criteria: previous bone regeneration, post-extraction dental sockets, insufficient bone width or height for implant placement, presence of residual root debris, type IV bone quality, insufficient keratinized gum, uncontrolled periodontal disease, presence of clinical signs of temporomandibular dysfunction or bruxism and systemic conditions (smokers) [19,20,22].

There are few randomized clinical studies that analyze the influence of orthodontic anchorage on osseointegrated implants. Moreover, the studies included in this review do not all analyze the same parameters, so it is not possible to compare some of the variables that define the success of the implant treatment. Only the level of peri-implant crestal bone and the mobility of the implants between studies could be compared. The lack of literature on osseointegrated implants in orthodontic treatment is due to the rising in the use of mini-implants used as anchors. This treatment option has reported good results, presenting its versatility and easy surgical management as its main advantages.

Conclusion

In partially edentulous patients who need orthodontic treatment, dental implants offer many advantages, apart from behaving as absolute anchorage units, they are subsequently used in prosthetic rehabilitation. In these cases, the treatment time is shortened, costs are reduced and effectiveness increases.

Shortening the healing period for the application of orthodontic forces does not seem to affect the success rate of osseointegrated implants used as anchors. In cases of early loading it is essential to obtain a good primary stability of the implant in order to apply orthodontic force.

Proper planning is important within a multidisciplinary team in which the orthodontist, implantologist and prosthodontist collaborate to achieve a good therapeutic resolution of the cases.

Although the results are promising, more randomized controlled studies in humans with a sample size and a longer follow-up period are needed to evaluate the follow-up of prosthetically loaded implants previously used as an anchor in orthodontic treatments.

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