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Miniscrews and Mini-Implants Success Rates in Orthodontic Treatments: A Systematic Review and Meta-Analysis of Several Clinical Parameters

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Abstract

Introduction: The aim of the following research is to conduct a systematic review in order to update the actual knowledge about miniscrews in the clinical practice, in particular about their stability and reliability.

Methods: An electronic search in the main database was performed up to February 10th, 2015 to identify articles that complied with the parameters set out in the protocol. The selection included studies showing the success rate of mini-implants for a sample exceeding 5 miniscrews, giving a definition of success, using implants with a diameter <2.5 mm and applying forces for at least 3 months. The success rate was considered as a paradigm and was divided by the following variables namely age and sex of patients, length and diameter of the miniscrew, location and method of placement of mini-implants, time and amount of loading. A meta-analysis was performed to combine comparable results.

Results: 65 clinical trials that collected 4080 patients and 8524 screws were included in the study. The mean weighted overall success rate was 86.75 ± 8.48%. The maxilla represents a better placement site for insertion than the mandible. The lengths of the miniscrews do not compromise the success rate.

Conclusions: In all 65 articles miniscrews could be used to help orthodontic treatment. The usage of miniscrews for a stable period of 3 months showed the highest success rates. Screws less than 8 mm in length and 1.2 mm in diameter should be used under restricted conditions, while miniscrews longer than 10 mm could be avoided.

Keywords: Miniscrews; Orthodontics; Systematic review; Success rate

Introduction

In most orthodontic treatments anchorage is necessary to control the reciprocal forces of tooth movement [1]. Usually this control is realized applying a force to a group of teeth or through extra-oral structures, e.g. neck or cranium. However, these techniques have important restrictions, often related to the patient's cooperation [1].

Orthodontic mini implants represent indeed a great resolution to these limitations. Their clinical advantages consist in versatility of placement site, easy insertion and removal, minimal anatomic limitations, minor surgery, increased patient comfort, immediate loading, possible use in young patients, and low costs. Unlike osseointegrated implants, these devices are smaller in diameter, have a smooth surface, and are designed to be loaded shortly after insertion.

The stability of miniscrews has become an issue because it does not depend on osseointegration but mechanical locking of the threads into bony tissues [2-4], and consequently they can hold up orthodontic loading after a short healing time. Since the determination of the specific clinical parameters that affect the clinical success has become critical, the purpose of the following research was to conduct a systematic review in order to update the actual knowledge about miniscrews in the clinical practice, in particular about their stability and reliability.

Materials and Methods

Study design

The present study is a systematic review of interventions that evaluated the stability of the miniscrews and the related influencing factors in order to define the success rate (outcome). The workflow followed the PRISMA statement. Table 1 shows the PRISMA checklist.

Study selection criteria

The selection criteria were as follows:

- human studies with minimum samples sizes of 5 (*In vitro* studies, animal studies, case reports, technique articles, opinion papers reviews and in-vitro studies were excluded).
- randomized controlled trial and nonrandomized studies with low or moderate risk of bias.
- implants with a diameter <2.5 mm (larger implants would not classify for specific orthodontic indications, e.g., interradicular positioning).
- orthodontic forces acting for a minimum of 3 months.

Success was selected as the primary outcome. An orthodontic mini-implant was considered successful when it could be loaded with orthodontic forces and fulfill its anchorage objectives during a minimum period of 4 months. Orthodontic mini-implants, that were lost or had become unusable, were considered to be failures. This

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Section/Topic	#	Checklist item	Reported on page #
Title			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
Abstract			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known.	2
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	2
Methods			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	2
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	2-3
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	2-3
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	2-3
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	2-3
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	2-3
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	2-3
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	2-3
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	2-3
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	2-3
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	2-3
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	2-3
Results			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	4-5
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	4-5
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	4-5
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	4-5
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	4-5
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	4-5
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	4-5
Discussion			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	6-8
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	6-8
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	6-8
Funding			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	9

Table 1: PRISMA checklist.

group also included implants that fractured at insertion and during orthodontic treatment. The timing for this outcome assessment was divided into 3 time frames: short term (4-6 months), medium term (6 months-1 year), and long term (1 year and longer).

Search strategy

The search process was performed independently by two examiners under the guidance of a librarian. The Cochrane Library, MEDLINE-

PubMed, ISI Web of Knowledge, EMBASE and Grey Literature (SIGLE) databases were searched for articles published until January 2015 in English or in Italian. Appropriate changes in the key words were done to follow the syntax rules of each database. The main terms used were "miniscrew", "micro screw", "microimplant", "mini-implant". The two examiners assessed the titles and the abstracts of all studies displayed. If the abstract lacked information to allow decision making with regard to selection, the full article was obtained and evaluated before decision making. Several articles appeared in more than one database but they were considered once. Any doubt about inclusion or exclusion was solved with a discussion. Screening the reference lists of the selected articles complemented the search. The selected articles were then carefully read for the quality assessment and control of bias and for data extraction.

Data extraction

Two examiners extracted and tabulated the following issues from the selected articles:

a) author, year of publication and journal

b) number of patients

c) number of miniscrews

d) total success rate (or failure rate)

e) mean age and standard deviation

f) length of the miniscrews

g) success rate related to the length of the miniscrews

h) number of miniscrews placed in the mandible

i) number of miniscrews placed in the maxilla

j) success rate in the mandible

k) success rate in the maxilla

Meta-analysis

A meta-analysis was performed to combine comparable results. Studies were alternatively grouped according to the site of placement (maxilla or mandible) and the length of the miniscrews (short: <8 mm; standard: 8-10 mm and long: >10 mm). The software used in the analyses was STATA 12 (StataCorp. 2011. Stata: Release 12. Statistical Software. College Station, TX: StataCorp LP). The odds ratio (OR) from each study and for each group was calculated and used in order to obtain the success rate when raw data were not reported. Results were pooled using the random effects method because the studies compared were not considered to have the same effect size. The random effects model is generally indicated when studies are gathered from the published literature. The effect size could vary among the studies because they might differ for several reasons. The effect sizes in the studies included in the meta-analysis represent a random sample distributed about some mean. Results were expressed in forest plots figuring the studies included and the overall odds ratio for the computed analysis which indicates the leaning for the effect size. The relation between the overall OR and the value OR=1 which is marked with a vertical line is discussed.

Results

As of January 2015, the PubMed search with the terms "((((((((miniscrew or mini screw) or mini-screw) or micro screw) or micro-screw) or microimplant) or micro implant) or micro-implant) or mini-implant) or mini implant" returned 3172 results. Embase showed 525 hits, and Google Scholar over 3000. Of all those, 65 articles matched all criteria and were considered (Table 2). The flow diagram describes the results of search queries (Figure 1). Overall, the analyzed data comprised 4080 patients treated with 8524 miniscrews. Each study treated a number of patients varying from 7 to 308 with a number of miniscrews varying from 14 to 480. The success rate reported ranged from 0% to 100%, but in most studies, the success rate was above

id	Authors	Title	Journal	Year
6	Kim et al.	Cone-beam computed tomography evaluation of mini-implants after placement: is root proximity a major risk factor for failure?	Am J Orthod Dentofac Orthop	2010
13	Moon et al.	Relationship between vertical skeletal pattern and success rate of orthodontic mini-implants	Am J Orthod Dentofac Orthop	2010
33	Motoyoshi et al.	Factors affecting the long-term stability of orthodontic mini-implants	Am J Orthod Dentofac Orthop	2010
43	Basha et al..	Comparative study between conventional en-masse retraction (sliding mechanics) and en-masse retraction using orthodontic micro implant	Implant Dent	2010
60	Lee et al.	Survival analysis of orthodontic mini-implants	Am J Orthod Dentofac Orthop	2010
129	Santiago et al.	Correlation between miniscrews stability and bone mineral density in orthodontic patients	Am J Orthod Dentofac Orthop	2009
133	Antoszewska et al.	Five-year experience with orthodontic miniscrew implants: a retrospective investigation of factors influencing success rates	Am J Orthod Dentofac Orthop	2009
136	Wu, K & Wu	Factors associated with the stability of mini-implants for orthodontic anchorage: a study of 414 samples in Taiwan	J Oral Maxillofac Surg	2009
174	Luzi et al.	Guidelines for success in placement of orthodontic mini-implants	J Clin Orthod	2009
181	Upadhyay	Dentoskeletal and soft tissue effects of mini-implants in Class II division 1 patients	Angle Orthod	2009
202	Kokitsawat et al.	Clinical effects associated with miniscrews used as orthodontic anchorage	Aust Orthod J	2008
214	Upadhyay et al.	Mini-implant anchorage for en-masse retraction of maxillary anterior teeth: a clinical cephalometric study	Am J Orthod Dentofac Orthop	2008
230	Motoyoshi et al.	The effect of cortical bone thickness on the stability of orthodontic mini-implants and on the stress distribution in surrounding bone	Int J Oral Maxillofac Surg	2009
263	Thiruvenkatachari et al.	Comparison and measurement of the amount of anchorage loss of the molars with and without the use of implant anchorage during canine retraction	Am J Orthod Dentofac Orthop	2006
288	Garfinkle et al.	Evaluation of orthodontic mini-implant anchorage in premolar extraction therapy in adolescents	Am J Orthod Dentofac Orthop	2008
306	Kinzinger et al.	Anchorage efficacy of palatally-inserted miniscrews in molar distalization with a periodontally/ miniscrew anchored distal jet	J Orofac Orthop	2008
307	Justens & De Bruyn	Clinical outcome of mini screws used as orthodontic anchorage	Clin Impl Dent Relat Res	2008
316	Baek et al.	Success rate and risk factors associated with mini-implants reinstalled in the maxilla	Angle Orthod	2008

id	Authors	Title	Journal	Year
328	Moon et al.	Factors associated with the success rate of orthodontica miniscrews placed in the upper and lower posterior buccal region	Angle Orthod	2008
330	Chaddad et al.	Influence of surface characteristics on survival rates of mini-implants	Angle Orthod	2008
356	Motoyoshi et al.	Effect of cortical bone thickness and implant placement torque on stability of orthodontic mini-implants	Int J Oral Maxillofac Implants	2007
398	Hedayati et al.	Anchorage value of surgical titanium screws in orthodontic tooth movement	Int J Oral Maxillofac Surg	2007
399	Motoyoshi et al.	Application of orthodontic mini-implants in adolescents	Int J Oral Maxillofac Surg	2007
412	Kuroda et al.	Root proximity is a major factor for screw failure in orthodontic anchorage	Am J Orthod Dentofac Orthop	2007
437	Kuroda et al.	Clinical use of miniscrews implants as orthodontic anchorage: success rates and postoperative discomfort	Am J Orthod Dentofac Orthop	2007
446	Berens et al.	Mini- and micro-screws for temporary skeletal anchorage in orthodontic therapy	J Orofac Orthop	2006
489	Chen et al.	The use of microimplants in orthodontic anchorage	J Oral Maxillofac Surg	2006
509	Tseng et al.	The application of mini-implants for orthodontic anchorage	Int J Oral Maxillofac Surg	2006
513	Chen et al.	Removal torque of miniscrews used for orthodontic anchorage - a preliminary report	Int J Oral Maxillofac Implants	2006
528	Motoyoshi et al.	Recommended placement torque when tightening an orthodontic mini-implant	Clin Oral Impl Res	2006
615	Fritz et al.	Clinical suitability of titanium miniscrews for orthodontic anchorage - preliminary experiences	J Orofac Orthop	2004
623	Liou et al.	Do miniscrews remain stationary under orthodontic forces?	Am J Orthod Dentofac Orthop	2004
643	Cheng et al.	A prospective study of the risk factors associated with failure of mini-implants used for orthodontic anchorage	Int J Oral Maxillofac Implants	2004
1019	Upadhyay et al.	Treatment effects of mini-implants for en-masse retraction of anterior teeth in bialveolar dental protrusion patients: a randomized controlled trial	Am J Orthod Dentofac Orthop	2008
1020	Park et al.	Treatment effects and anchorage potential of sliding mechanics with titanium screws compared with the tweed-merrifield technique	Am J Orthod Dentofac Orthop	2008
1022	Park et al.	Group distal movement of teeth using microscrew implant anchorage	Angle Orthod	2005
1025	Park Hyo-Sang	Clinical study on the success rate of microscrew implants for orthodontic anchorage	Korea J Orthod	2003
1027	Park et al.	Factors affecting the clinical success of screw implants used as orthodontic anchorage	Am J Orthod Dentofac Orthop	2006
1029	Miyazawa et al.	Accurate pre-surgical determination for self-drilling miniscrew implant placement using surgical guides and cone-beam computed tomography	Eur J Orthod	2010
1031	Freudenthaler et al.	Bicortical titanium screws for critical orthodontic anchorage in the mandible: a preliminary report on clinical applications	Clin Oral Impl Res	2001
1035	Manni et al.	Factors influencing the stability of miniscrews. A retrospective study on 300 miniscrews	Eur J Orthod	2011
1036	Miyawaki et al.	Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage	Am J Orthod Dentofac Orthop	2003
1037	Luzi et al.	A prospective clinical investigation of the failure rate of immediately loaded miniimplants used for orthodontic anchorage	Prog Orthod	2007
1038	Wiechmann et al.	Success rate of mini- and microimplants used for orthodontic anchorage: a prospective clinical study	Clin Oral Impl Res	2007
1042	Gelgor et al.	Intraosseous screw-supported upper molar distalization	Angle Orthod	2004
1043	Gelgor et al.	Comparison of 2 distalization systems supported by intraosseous screws	Am J Orthod Dentofac Orthop	2007
1045	Polat-Ozsoy et al.	Miniscrews for upper incisor intrusion	Eur J Orthod	2009
1046	El-Beialy et al.	Loss of anchorage of miniscrews: a 3-dimensional assessment	Am J Orthod Dentofac Orthop	2009
1047	Wang and Liou	Comparison of the loading behavior of self-drilling and predrilled miniscrews throughout orthodontic loading	Am J Orthod Dentofac Orthop	2008
1048	Blaya et al.	Patient's perception on mini-screws used for molar distalization	Rev odonto cienc	2010
1051	Maddalone et al.	Utilizzo delle miniviti nelle meccaniche ortodontiche di intrusione	Dental Cadmos	2010
1052	Takaki et al.	Clinical study of temporary anchorage devices for orthodontic treatment - Stability of micro/mini-screws and mini-plates: experience with 455 cases	Bull Tokyo Dent Coll	2010
1053	Viwattanatipa et al.	Survival analyses of surgical miniscrews as orthodontic anchorage	Am J Orthod Dentofac Orthop	2009
1054	Bayat et al.	Effect of smoking on the failure rates of orthodontic miniscrews	J Orofac Orthop	2009

Table 2: Studies included in the analysis.

80%. The overall success rate, weighted by the number of miniscrew, amounted to 86.75 ± 8.48%.

The gender variable showed no significant differences in general, except in two studies giving conflicting results, where the success rate was found significantly higher in the female group [5] or in the male group [6].

Lee et al. found a significant association between success rate and age: increasing age is a decisive factor for the survival of the implant [7]. In fact, the estimated probability of implant failure decreased 0.925 times with each year of the patient's age. Even in the study of Motoyoshi et al. immediate loading of mini-implants showed significantly higher success rates in adults than adolescents [8].

An important accent was focused on the site of surgery. As showed in Figure 2, a larger number of implants were placed in the maxilla rather than in the lower jaw, thus increasing the success rate in the maxilla in all but ten studies [6,9-17].

Another significant factor has been the length. Six studies included mini-implants of different lengths in order to compare the different success rates [9,16,18-21]. The comparison between short mini-implants (< 8 mm) and standard mini-implants (> 8 mm and < 10 mm) is

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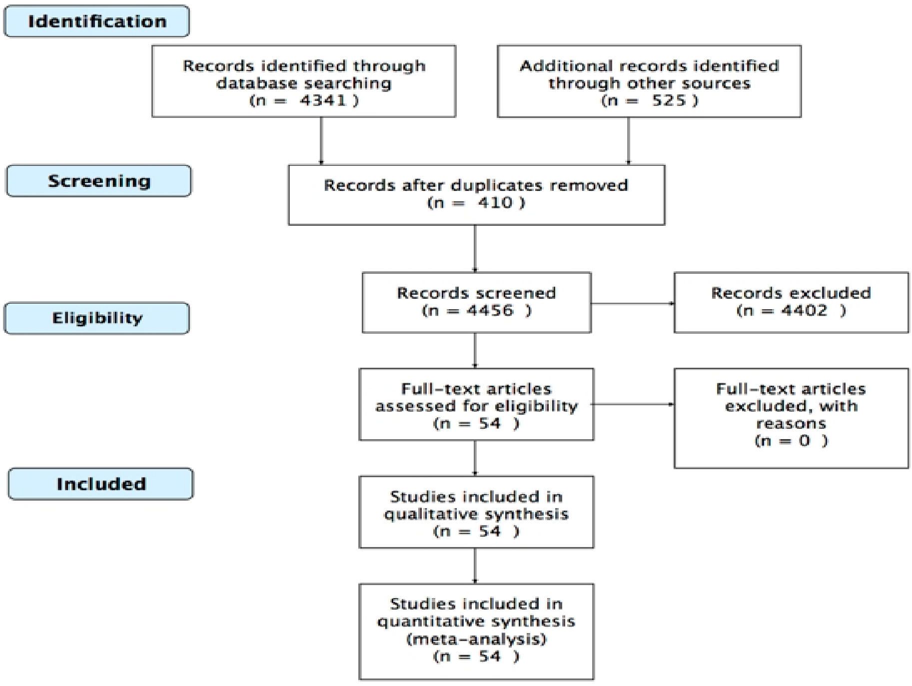
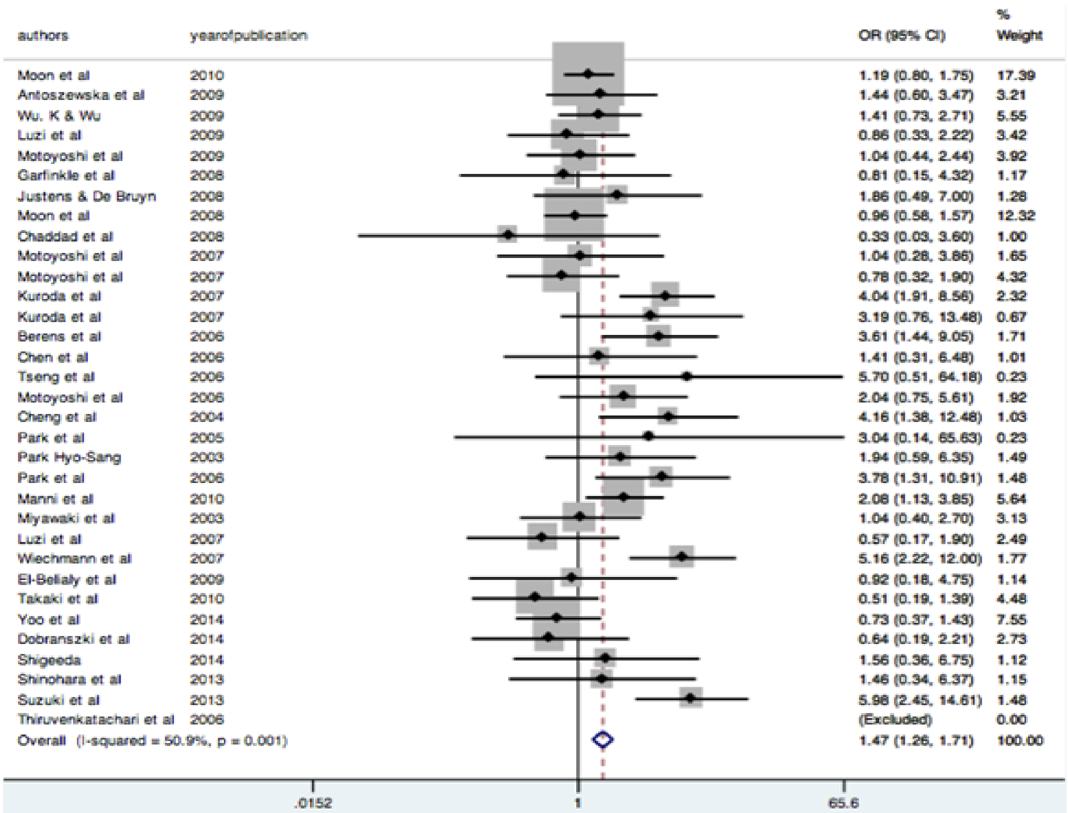


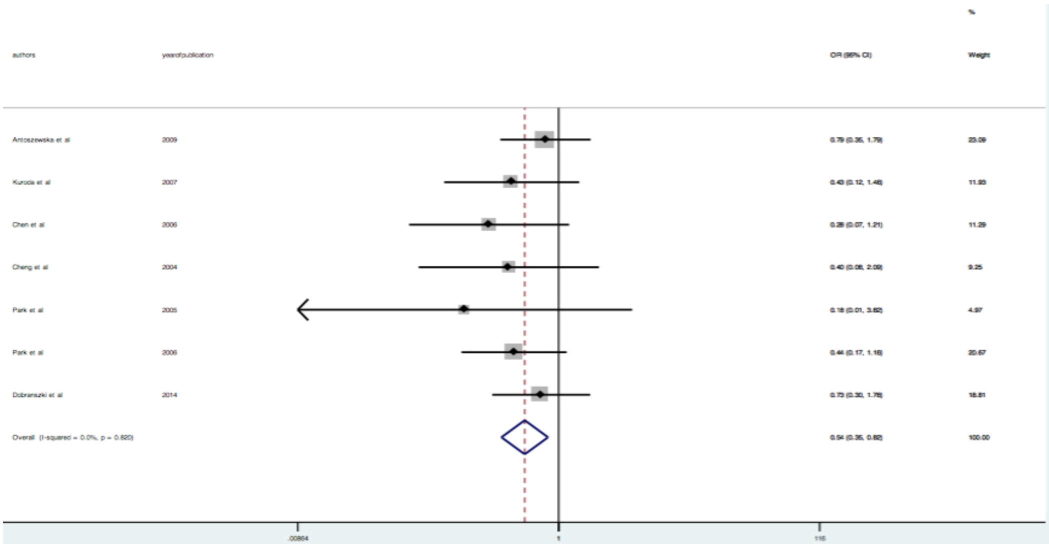
Figure 1: Flow diagram of the literature search.



The centre of the figure reports data regarding the site of placement of the mini-implants for each study. The vertical line (OR=1) means no difference between maxilla and mandible. Lower values (OR<1) are associated with data from studies with more mini-implants placed in the mandible. Overall shows the leaning. On the right of the figure are reported the confidence interval and the weight of the effect size for each study.

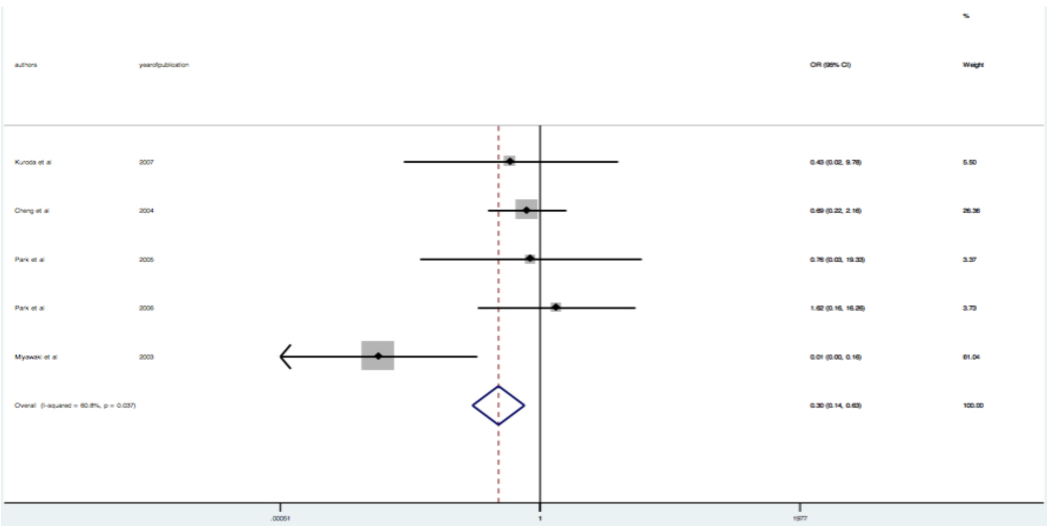
Figure 2: Site of placement of mini-implants.

summed up and an overall is computed. As shown in Figure 3, there are no significant differences between the success rates with the different lengths of mini-implants in each study; however the overall shows a leaning in having higher success rates with standard mini-implants. Chen et al., correlating the success rate to the implant length, found a statistically significant difference (p<0.05) between the success rate of 8 mm screws (90.2%) and those of 6 mm (72.2%) [18]. The same analysis was conducted to focus the differences between short and long mini-implants (> 10 mm). As shown in Figure 4, only five studies collected data [16,19,20-22]. The overall computed, and its confidence interval, do not comprise the vertical line, indicating a difference between long and short mini-implants. However Miyawaky et al. obtained results that influenced the analysis and created a bias [22]. In detail, the authors tested 124 long implants with a success rate of 84.4% and 10 short mini-implants that gave no success rate. Figure 5 shows the overall success rate without the dropped study of Miyawaky et al. The confidence interval and its computed overall comprise the vertical line, showing no significant differences in success rates between long and short mini-implants. Actually, because the small number of studies considered, it is impossible to draw specific conclusions about the topic. Further analyses were conducted to assess the differences in success rate between standard and long mini-implants. The forest plot reported in Figure 6 shows nine studies which present data about standard and long mini-implants [6,16,19,21,23-27]. The overall value shows that the



The centre of the figure reports for each study data regarding the success rate for short and standard mini-implants expressed in OR. The vertical line (OR=1) means no difference between the lengths. Lower values (OR<1) are associated with data from studies with higher success rate for standard mini-implants. Overall shows the leaning. On the right of the figure are reported the confidence interval and the weight of the effect size for each study.

Figure 3: Comparison between short and standard mini-implants.



The centre of the figure reports for each study data regarding the success rate for short and long mini-implants expressed in OR. The vertical line (OR=1) means no difference between the lengths. Lower values (OR<1) are associated with data from studies with higher success rate for long mini-implants. Overall shows the leaning. On the right of the figure are reported the confidence interval and the weight of the effect size for each study.

Figure 4: Comparison between short and long mini-implants.

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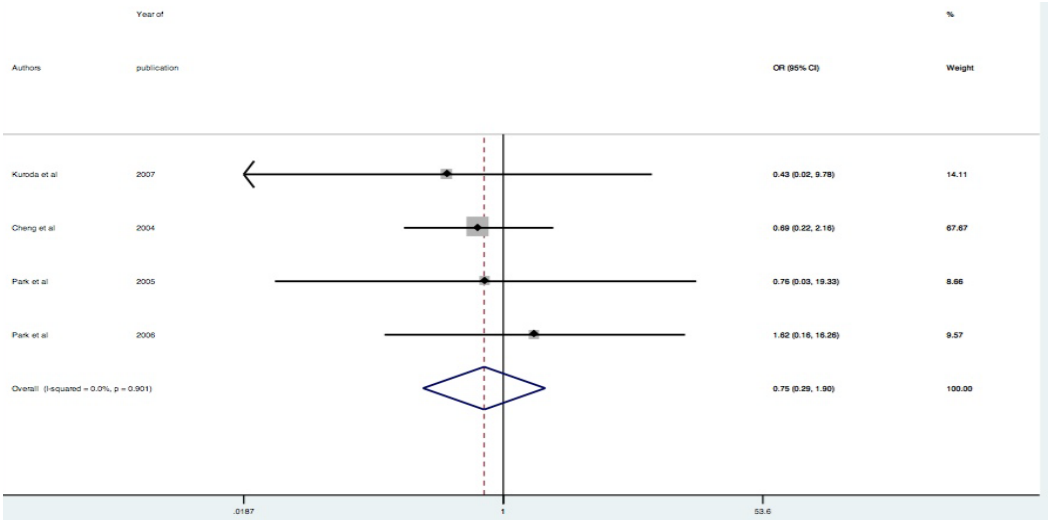
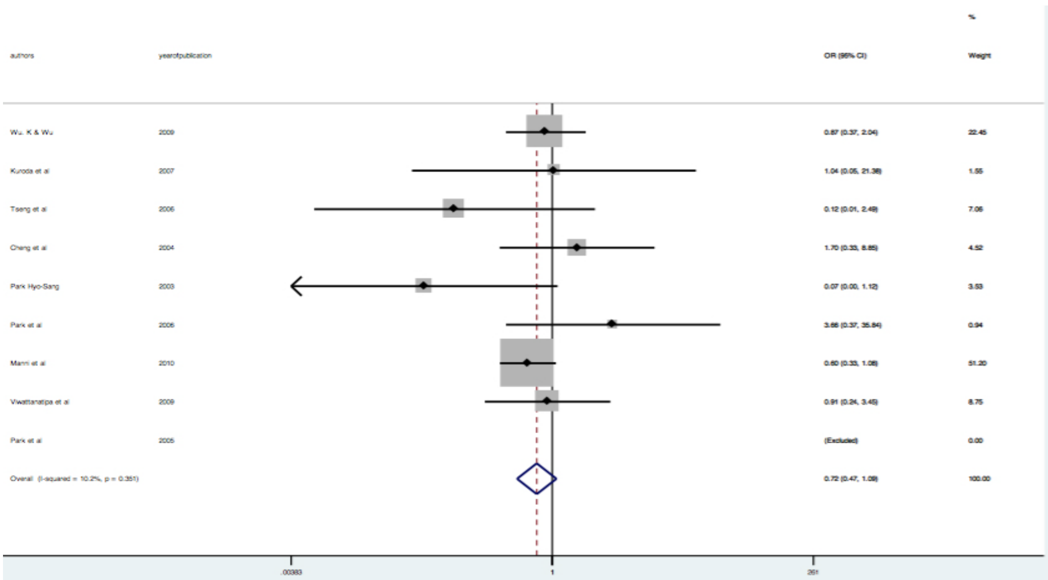


The centre of the figure reports for each study data regarding the success rate for short and long mini-implants expressed in OR. As reported in the text the study of Miyawaky et al. (2003) has been dropped. The vertical line (OR=1) means no difference between the lengths. Lower values (OR<1) are associated with data from studies with higher success rate for long mini-implants. Overall reported is significantly different from Figure 4 and here it includes the vertical line thus meaning that the success rate among the studies is not significantly different for short and long mini-implants. On the right of the figure are reported the confidence interval and the weight of the effect size for each study.

Figure 5: Comparison between short and long mini-implants.



The centre of the figure reports for each study data regarding the success rate for standard and long mini-implants expressed in OR. The vertical line (OR=1) means no difference between the lengths. Lower values (OR<1) are associated with data from studies with higher success rate for long mini-implants. Overall shows the leaning. As reported on the right of the figure, the confidence interval for the overall comprises OR=1, thus meaning that the success rate among the studies is not significantly different for standard and long mini-implants.

Figure 6: Comparison between standard and long (on the left side) mini-implants.

success rates of mini-implants of different lengths are not significantly different. Two studies influenced strongly the analysis due to the fact that their weights (i.e. number of mini-implants tested) are much higher than the others [6,27]. Studies which reported different results have a lower weight and could be considered as outliers.

With regard to the diameter of the mini-implants, there are conflicting results: Miyawaki et al. and Wiechmann et al. concluded that screws with a diameter of 1 mm and 1.1 mm behaved significantly worse than those with larger diameters [22,28]. Instead, in the study by Manni et al., the screws of small diameter showed a significantly higher success rate [6].

It was calculated that 5159 miniscrews were used in the maxilla with an average success rate of 90.19 ± 7.01% whereas 2951 miniscrews placed in the lower jaw showed an average success rate of 83.32 ±

9.96%. In particular, the differences between upper and lower jaws are significant (p<0.05) in 3 studies according to the former [19,21,29].

There were no significant differences in success rates between flap or flapless placement technique. The amount of loading and the latency period were not statistically significant factors that could influence the success rate of miniscrews.

Discussion

As of February 10th, 2015, 65 studies were selected by computerized and manual searches in order to provide data on the success rate of miniscrews. Case reports and technical articles that describe the qualities of a specific miniscrew were excluded from the general selection criteria. Other studies were excluded because the methodology was found to be inaccurate. In the case of comparative studies, which confronted groups treated with miniscrew or mini-implants with groups treated with traditional methods, only the first groups were considered.

From the results evinced in this review, miniscrews achieved an average success rate of 86% in orthodontic patients. Similar results were obtained with the use of other temporary anchorage devices (TADs) such as palatal implants and miniplates, which reached the 90-95% of success. Although it has been included a larger number of studies with a higher number of total miniscrews, the results of this review did not substantially differ from those obtained from Crismani et al. [30].

However the concept of success varied among the studies analyzed. In fact, some authors provided general descriptions of success without specifying whether the stability of the systems was maintained; others considered successful only stable miniscrews and few others accepted mobility only if it was useful for the orthodontic movement. It is important to underline that the studies which describe a successful intervention are more likely to be published. This fact leads to overestimate the effectiveness of the treatment brings some publication bias, or, on the other hand it strengthens the concept of success. The time of evaluation of the success varied widely, some studies analyzed the success rate at specific periods of time or after a certain number of days or months; while others measured the success rate at the completion of the objectives of the anchorage or at the end of the orthodontic treatment. Thus an implant lost after 3 months could be defined as a failure or a success depending on the time of its evaluation. Moreover some authors measured the primary outcomes from the day of implant placement, and not since the beginning of the application of the orthodontic forces, thus confounding variabilities. Generally, in the studies where the distinction of success rate according to sex of patients has been made, no significant differences are noted. Manni et al. found a success rate higher in male patients (88.1%) than females (76.4%) (p<0.05) [6]. This result is difficult to be interpreted and it is in contrast with the information available in the literature [19,20,22]. One possible explanation could be the large number of miniscrews examined in this sample, the different types of screws used, as well as anatomical differences (e.g. the different thickness of cortical bone) and hormonal differences.

It could be registered as a general trend of direct proportionality between success rate and age. In the study by Motoyoshi et al. immediate loading of mini-implants showed success rates significantly (p<0.05) higher in adults than adolescents [8]. This finding probably indicates that bone density of adolescents is not sufficient to support immediate loading with orthodontic forces.

The screws with a diameter of 1.2 mm or more are used worldwide with a success rate of above 70%. The mini-implants with a smaller diameter are easier to be placed between the roots, but a small reduction in this dimension decreases significantly the torsional strength and therefore increases the risk of fracture of the implant. It is advisable to avoid the implants smaller than 1.3 mm in diameter, especially when placed in the thick cortical bone in the lower jaw. There were also reported fractures in 2 studies with implants of this size [18,21].

Another significant factor is the length of a mini-implant, determined on the basis of several characteristics like the depth and quality of bone, the angle of the screw, the transmucosal thickness, and adjacent vital structures. Short screws in regions with thick soft tissues, such as the mucosa of the palate, could easily become unstable. In these sites are recommended longer screws. The minimum depth of placement of a mini-implant is at least 5-6 mm, but it's recommended a deeper insertion when the bone quality is low. Chen et al. found that the success rate increased from 72-90% using 8 mm long miniscrews instead of 6 mm ones [18]. It should be emphasized that by increasing the diameter and length of the screw, the risk of damaging the roots during placement increases. The miniscrews with a diameter of 1.2 mm and a length of at least 8 mm have sufficient stability with minimal risk of radicular damage [23].

The flapless method is less expensive in terms of time, but can reduce the chances of accurate placement of miniscrew. An advantage of the flapless method is the better comfort for the patients. For both flap and flapless protocols, conflicting success rates have been published. Only Herman et al. reported significantly higher success rate (100%) for miniscrews (n=10) placed with flap surgery [31]. Further research is needed to clarify the issue and provide newer data. In most of the studies important variables for the success of miniscrew as inflammation and peri-implantitis, and consequently pain and discomfort, were not analyzed. Inflammation of the peri-implant soft tissues has been described in four articles. Three studies stated that the inflammation was controlled by improving oral hygiene [32-34]. However, Tseng et al. recorded continuous inflammation in 2 of 45 implants [25]. Since these inflammatory changes had not regressed during treatment, the implants were lost or had to be removed. A similar event was described in 4 of 32 patients in the study of Chaddad et al. [35]. Santiago et al. reported severe gingival inflammation in a patient with purulent secretion, so they removed two miniscrews; however the other 28 miniscrews showed no mobility after 90 days [36]. Park et al. found inflammation in 34% of the implants, but did not specify its importance or duration. To control the peri-implantitis, these authors recommended the placement of implants in the keratinized gingiva in order to cover the miniscrew with soft tissue, and to improve oral hygiene [21].

Pain and discomfort were recorded in 4 of 19 studies. Freudenthaler et al. reported paltry pain after the placement of the miniscrew. The pain lasted for one day in 3 of 8 patients [32]. Similar results were recorded by Chaddad et al. in 2 of 10 patients [35]. Kuroda et al. analyzed the quality and the duration of pain during the first 2 weeks after placement. An hour after surgery the 95% of patients who received an elevation of a mucoperiosteal flap reported pain; while only 50% of those who were treated by flapless approach complained pain. After 2 weeks, the values reduced respectively to 10% and 0% for the two techniques mentioned above. Patients of the first group have reported a significantly more intense and longer pain than that of the second group [20]. A similar result was recorded by Miyawaki et al. in 7 of 44 patients within one week after implant placement [22].

As reported in Figure 2, only few studies set more mini-implants in the lower jaw [13-16]. Due to this fact the success rate of the screws is higher in the maxilla than in the mandible in all but eight studies. Three studies showed that the maxilla is a place more suitable for miniscrews [19,21,29]. According to all three studies, the success rate in the lower jaw is due to the overheating of the bone during placement. Particular attention should therefore be used during pilot drilling, during tightening the screws and during water irrigation. In addition, the miniscrews may be more exposed to the mandibular occlusal interferences.

Factors related to the maintenance of the implants, including the control of peri-implantitis, antibiotic prophylaxis, rinsing with chlorhexidine, oral hygiene instructions are also important; even if the possible relationship between the stability of the implants and the use of antibiotics or chlorhexidine has not been analyzed in any study. Park et al. related the control of peri-implantitis with the success of orthodontic treatment, but they did not find any correlation between oral hygiene measures and the primary outcomes [21]. They reported higher success rates on the left side of the mouth but this result is considered related to a better oral hygiene provided by right-handed patients.

Research on dental implants has shown that micro-movements greater than 100 µm are enough to impair healing and may cause fibrous encapsulation. Park et al. recommended controlling regularly the mobility of the system and the orthodontic forces which should remain less than 200 g to ensure the stability of the miniscrews [21].

The analyses conducted about the length bring to the conclusion that the standard one represents absolutely the gold standard. In fact shorter mini-implants do not improve success rates significantly, but they could be safely used in clinical cases which require less invasive instrument for different medical reasons. On the other hand long mini-implants do not provide significant improvements in success rates, thus becoming not reasonable safe for clinical use. The higher length could even increase the risk of damages to adjacent anatomical structures (i.e. root trauma, soft-tissue irritation, nerve injury, trauma to blood vessels, and sinus perforation).

Conclusions

It can be concluded that the miniscrews represent effective temporary anchorage devices. In fact, in all 65 articles considered, they were able to help ortohodontic treatment even if loaded immediately. The mean weighted overall success rate was 86.75 ± 8.48%. Screws less than 8 mm in length and 1.2 mm in diameter should be used under restricted conditions, while miniscrews longer than 10 mm could be avoided. The maxilla represents a better placement site for insertion (mean success rate, 90.19 ± 7.01%) than the mandible (mean success rate, 83.32 ± 9.96%). A positive correlation between success rate and age may be found. It could also be seen a general trend of direct proportionality between success rate and age. The flapless method should be preferred because it causes less pain and discomfort for patients and it is less expensive in terms of time but it might reduce the chances of accurate placement of miniscrew.

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