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Determinants for success rates of temporary anchorage devices in orthodontics: a meta-analysis (*n* > 50)

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SUMMARY

INTRODUCTION: The aim of this study was to review the literature and evaluate the failure rates and factors that affect the stability and success of temporary anchorage devices (TADs) used as orthodontic anchorage.

METHODS: Data were collected from electronic databases: MEDLINE database, Scopus, and Web of Knowledge. Four combinations of term were used as keywords: screw orthodontic failure, screw orthodontic success, implant orthodontic failure, and implant orthodontic success. The following selection criteria were used to select appropriate articles: articles on implants and screws used as orthodontic anchorage, data only from human subjects, studies published in English, studies with more than 50 implants/screws, and both prospective and retrospective clinical studies.

RESULTS: The search provided 209 abstracts about TADs used as anchorage. After reading and applying the selection criteria, 26 articles were included in the study. The data obtained were divided into two topics: which factors affected TAD success and to what degree and in how many articles they were quoted. Clinical factors were divided into three main groups: patient-related, implant-related, and management-related factors.

CONCLUSIONS: Although all articles included in this meta-analysis reported success rates of greater than 80 per cent, the factors determining success rates were inconsistent between the studies analysed and this made conclusions difficult.

Introduction

Anchorage is one of the most important elements for successful orthodontic treatment. Traditionally, orthodontics employed teeth and extraoral or intraoral appliances for anchorage, often relying on the patient compliance for its effectiveness. Osseointegrated dental implants were introduced to strengthen anchorage (Wehrbein and Merz, 1998; Wehrbein *et al*., 1999; Chen *et al*., 2005; Wehrbein and Gollner, 2007), but these implants present with a number of disadvantages that limit routine use.

More recently, different types of skeletal anchorage devices have been introduced, offering potential advantages compared with osseointegrated implants, including: smaller size, which in turn allows more versatile use and reduces amount of surgical intervention necessary, resulting in less patient discomfort; the possibility of immediate loading; lower costs; and ease of removal.

Mini-implants are derived from endosseous implants. They have a conical shape with a head that emerges from the mucosa and that allows connection with orthodontic appliances; mini-implants also contain a smooth transmucosal neck and an endosseous threaded body that can be manufactured with different thread designs and body shapes. Length and diameter vary widely between makes, and the surface is generally smooth, which limits osseointegration.

Mini-plates that are used for orthodontic anchorage are very similar to maxillofacial plates, consisting of a baseplate and fixation screws made of titanium. The shape and size can differ, and the number of fixations can vary from two to five screws.

Mini-screws are made of titanium and are specifically designed for orthodontic anchorage. Their shape is similar to that of mini-implants, but mini-screws are usually smaller (less than 2 mm in diameter) and sometimes more tapered. The thread can be self-drilling to allow direct insertion without the use of pre-drilling, which simplifies the insertion technique.

To encompass all of the above-mentioned devices in one definition, we decided to use the term temporary anchorage device (TAD) in this publication.

A number of factors can vary in the use of TADs for orthodontic anchorage in humans: the aim of this systematic review is to analyse the influence of the various elements on the success rate of a temporary skeletal anchorage devices.

Materials and methods

The method for this review was based on the 'Methods of Systematic Reviews and Meta-Analysis', published in the *Journal of Clinical Epidemiology* (Moher *et al*., 2009).

A computerized literature survey was conducted using different databases: MEDLINE database (EntrezPubMed, www.ncbi.nlm.nih.gov), Scopus (www.scopus.com), and Web of Knowledge (apps.webofknowledge.com). A systematic search was conducted for conference abstracts published by the most important dental scientific societies up to December 2012.

The keywords used in this literature search were combinations of four terms: screw orthodontic failure, screw orthodontic success, implant orthodontic failure, and implant orthodontic success.

The following selection criteria were used to select appropriate articles: 1. articles on implants and screws used as orthodontic anchorage, 2. data only from human subjects, 3. studies published in English, German, French, Spanish, and Italian, 4. studies with more than 50 TADs, and 5. studies that could be randomized clinical trials, or prospective and retrospective clinical studies.

Exclusion criteria included: 1. articles on standard dental implants, 2. animal studies, 3. *in vitro* studies, 4. case reports and case series, and 5. literature reviews.

The articles were selected after first reading their titles and abstracts. All of the articles that appeared to meet the inclusion criteria on the basis of the abstract were read, and further selections were made.

These articles were independently selected by three reviewers (EL, MD, and DD). Any disagreements were resolved by discussion until consensus was achieved.

The null hypothesis was that TAD success rates are independent to the factors listed in Figure 1, and *P* values of less than 0.05 were chosen to indicate statistical significance. Review Manager (RevMan) software (version 5.2, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012) was used to construct a forest plot for each factor considered at least by five studies, weighting implant failure rates, reported as odds ratios, under the random effects model. The same software was used to calculate the I^2 index, which is an indicator of studies heterogeneity, and to construct a funnel plot, which was used to detect publication bias. I^2 has a range of 0–100 per cent: an I^2 value near 0 per cent indicates that almost all the observed variance is spurious, whereas an I^2 value near 100 per cent means that most of the observed variance is real.

Results

The electronic search provided 244 abstracts that addressed mini-screws and mini-implants used as anchorage. After screening, 35 of these abstracts were excluded because they described maxillofacial procedures. Another 10 abstracts that were literature reviews were also discarded. The remaining 199 articles, for which the abstracts seemed to be relevant, were read in full. After applying the selection criteria, 26 articles were considered suitable for the study. These articles contained specific references to the factors that could influence the success or failure of the mini-screws or mini-implants. The sequence of the application of exclusion criteria is shown in Supplementary Figure 1, available online.

Patient-related factors:	Implant-related factors:	Management-related factors:
- age,	- type of TAD,	- time of loading,
- sex,	- length of TAD,	- type of movement,
- type of malocclusion,	- diameter of TAD.	- clinician.
- thickness and kind of mucosa,		
- features of the bone,		
- thickness of the cortical bone,		
- location in the bone,		
- side of the placement,		
- location in relation to roots,		
- soft tissues inflammation,		
- hygienic care,		
- smoking habit.		

Figure 1 Summary of factors associated with temporary anchorage devices failure or success.

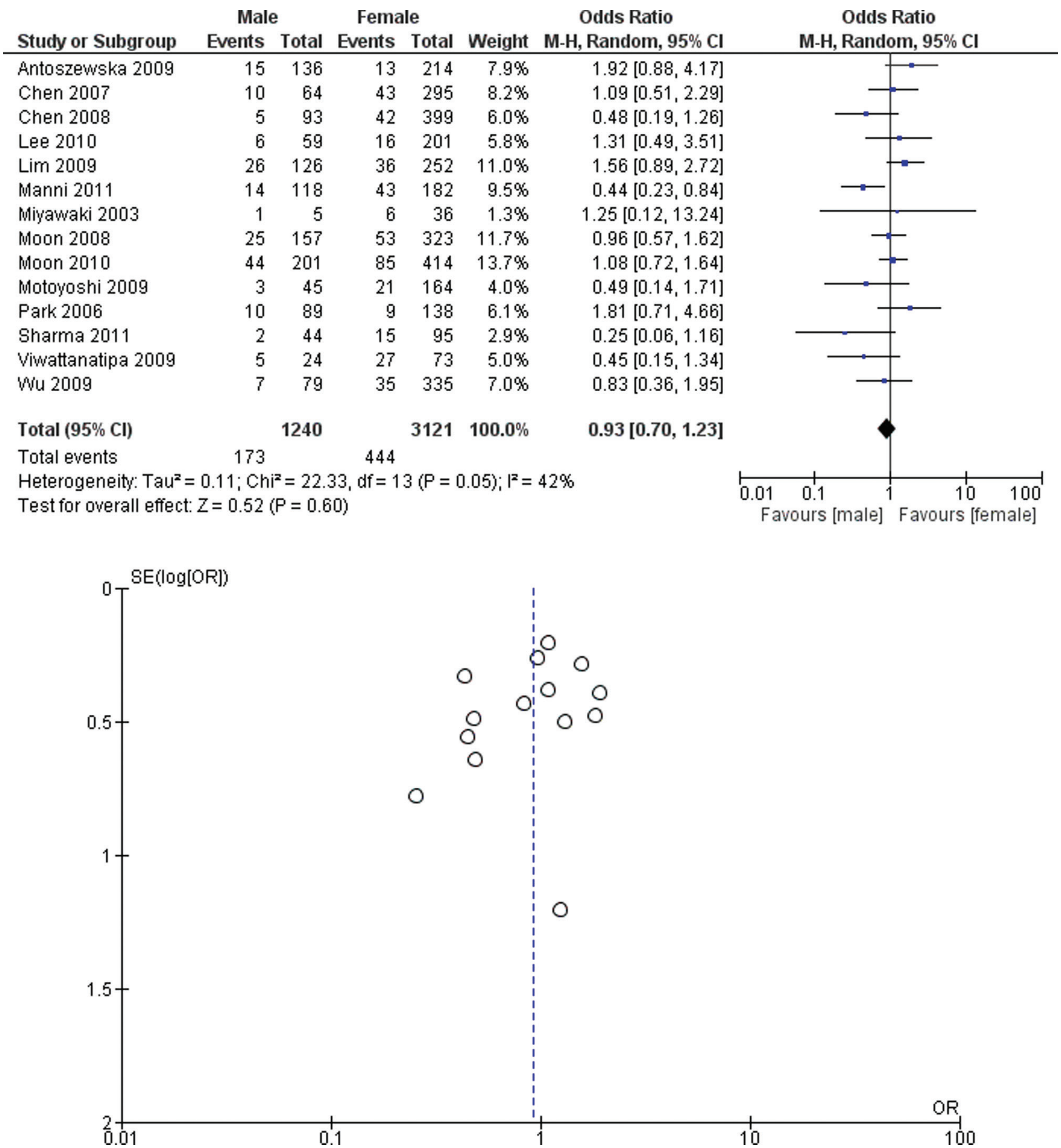
The first search of the reviewed articles aimed to highlight all of the factors that were considered to have an effect on TAD success or failure. We divided those factors in to three main groups:

1. Patient-related factors
2. Implant-related factors
3. Management-related factors

Each group could be further divided into subsections, as shown in Figure 1.

The summary of all of the factors analysed in each study is shown in Supplementary Table 1, available online.

Forest and funnel plots of TADs failures rates are reported in Figures 2–6, and from Supplementary Figures 2A, 2B, 3, and 4, available online, together with I^2, Tau^2, and chi^2 values.



Study or Subgroup	Male Events	Male Total	Female Events	Female Total	Weight	Odds Ratio M-H, Random, 95% CI
Antoszewska 2009	15	136	13	214	7.9%	1.92 [0.88, 4.17]
Chen 2007	10	64	43	295	8.2%	1.09 [0.51, 2.29]
Chen 2008	5	93	42	399	6.0%	0.48 [0.19, 1.26]
Lee 2010	6	59	16	201	5.8%	1.31 [0.49, 3.51]
Lim 2009	26	126	36	252	11.0%	1.56 [0.89, 2.72]
Manni 2011	14	118	43	182	9.5%	0.44 [0.23, 0.84]
Miyawaki 2003	1	5	6	36	1.3%	1.25 [0.12, 13.24]
Moon 2008	25	157	53	323	11.7%	0.96 [0.57, 1.62]
Moon 2010	44	201	85	414	13.7%	1.08 [0.72, 1.64]
Motoyoshi 2009	3	45	21	164	4.0%	0.49 [0.14, 1.71]
Park 2006	10	89	9	138	6.1%	1.81 [0.71, 4.66]
Sharma 2011	2	44	15	95	2.9%	0.25 [0.06, 1.16]
Viwattanatipa 2009	5	24	27	73	5.0%	0.45 [0.15, 1.34]
Wu 2009	7	79	35	335	7.0%	0.83 [0.36, 1.95]
Total (95% CI)		**1240**		**3121**	**100.0%**	**0.93 [0.70, 1.23]**
Total events	173		444			

Heterogeneity: $Tau^2 = 0.11$; $Chi^2 = 22.33$, df = 13 (P = 0.05); $I^2 = 42\%$
Test for overall effect: Z = 0.52 (P = 0.60)

Figure 2 Forest and funnel plots of studies comparing the influence of patient's gender on temporary anchorage devices failure rate.

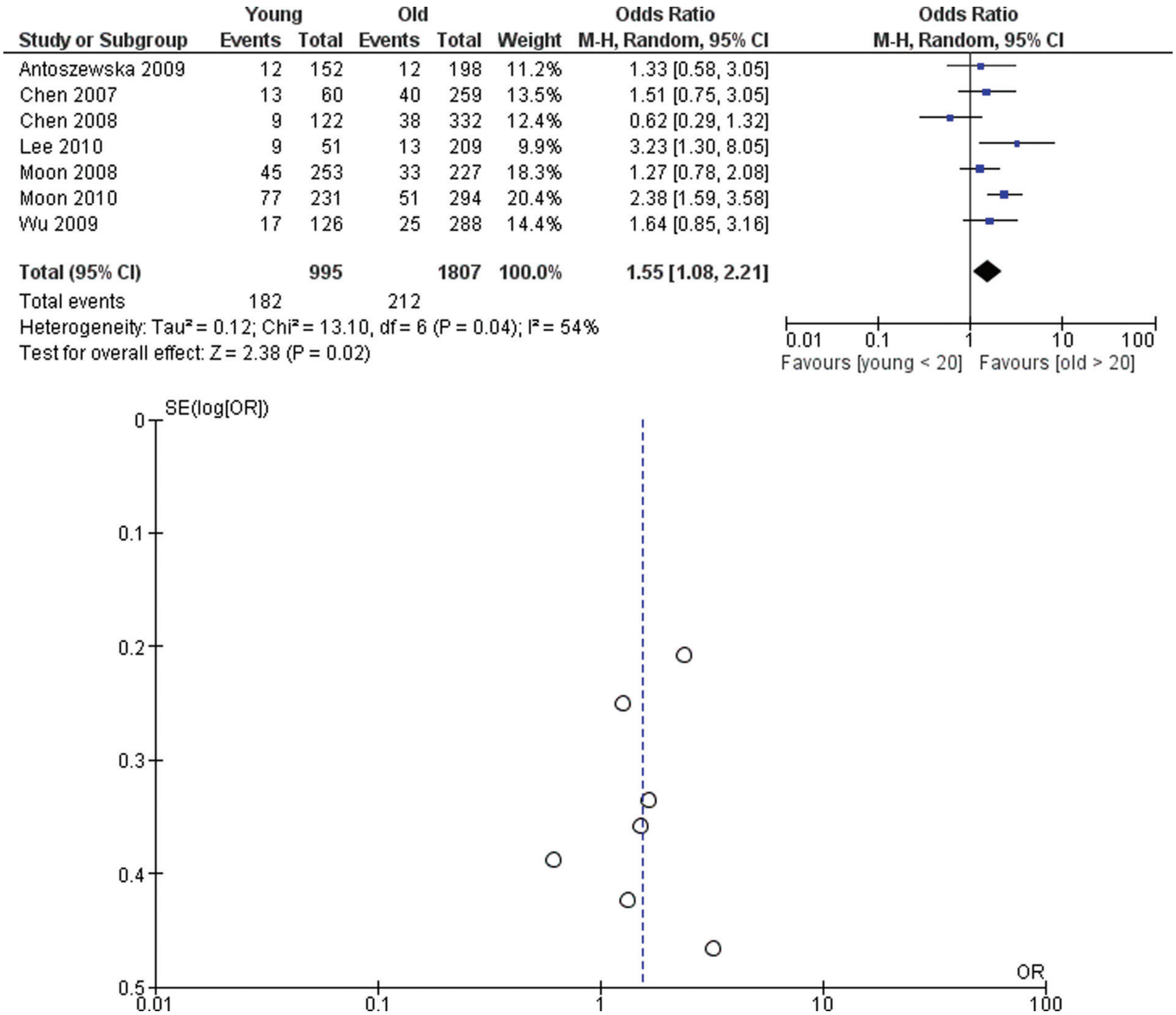


Figure 3 Forest and funnel plots of studies comparing the influence of patient's age (younger or older than 20 years of age) on temporary anchorage devices failure rate.

Discussion

A systematic review with a strict protocol and an accurate search strategy was performed to provide data about success and failure rates of TADs. The primary aim of this review was to gather information about the factors that influence failure and success rates.

The articles were selected according to specific inclusion and exclusion criteria to ensure appropriate selection of the literature. After evaluating all of the articles published about TADs and after the application of the inclusion criteria, 26 articles were considered to be suitable for review.

Data analysis

An evaluation of the methodological soundness of each article was performed, even if it was not used as a criterion for the inclusion of the studies in the review.

For each study, four variables were considered: definition of success, configuration of the study, description of the analysis, and clinical explanation of the results. Each variable was valued with 1 point if the descriptor was complete, with 0.5 points if the descriptor was partially fulfilled, and with 0 points if the request was not fulfilled or not mentioned. As the aim of our review was to evaluate factors that affected the success and failure rate of TADs, the fulfillment of these four criteria is in reference to this factor (Juni *et al*., 2001; Higgins and Green, 2008; Reynders *et al*., 2009).

The total score of the studies was calculated, and the articles were classified as being high quality (H) if the overall score was 3 or more points, medium quality (M) if the score was between 2 and 3 points, and low quality (L) if the score was below 2 points (Table 1).

Success rate

The average success rate was greater than 80 per cent in all of the studies.

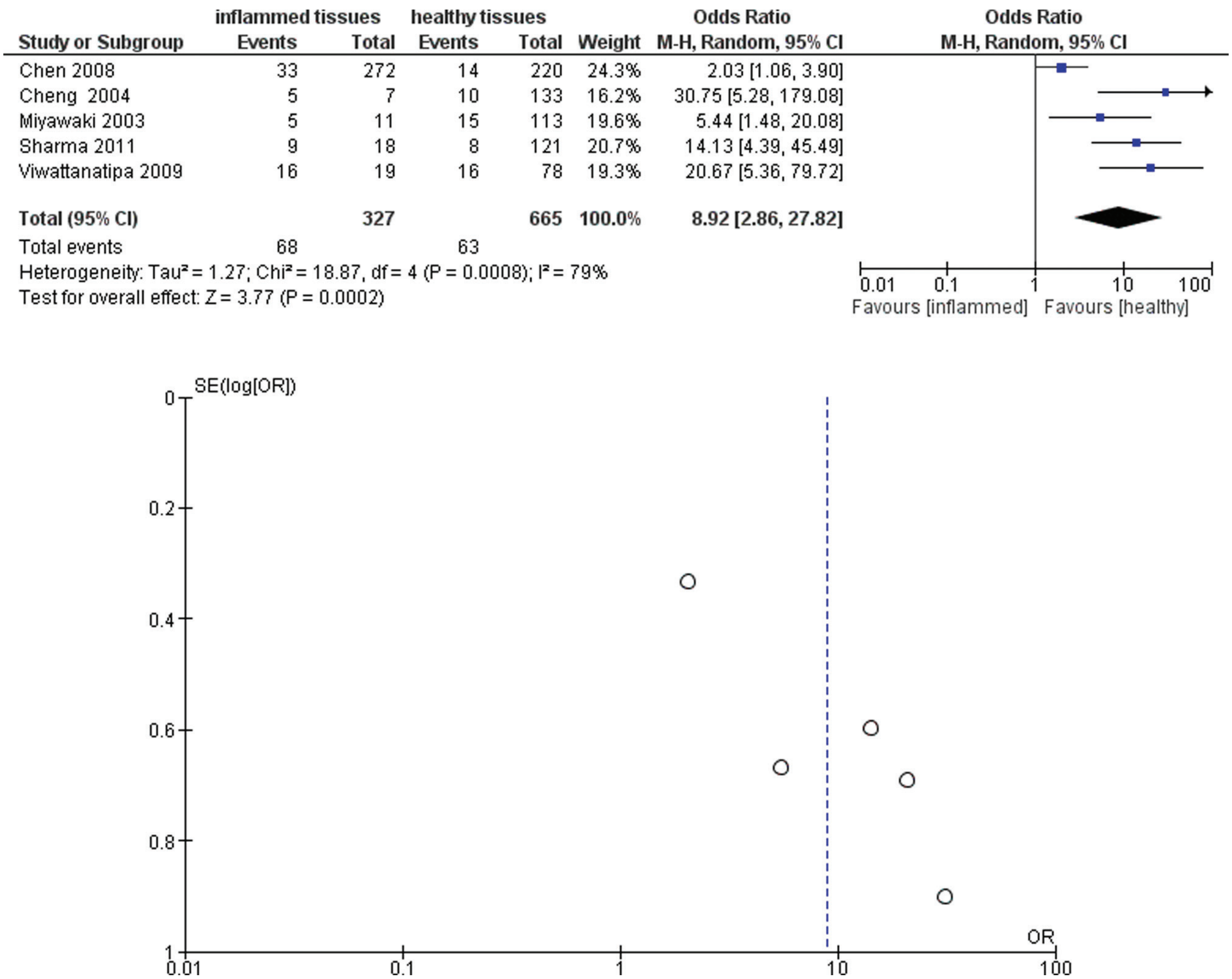


Figure 4 Forest and funnel plots of studies comparing the influence of healthy versus inflamed soft tissues on temporary anchorage devices failure rate.

In the articles that included analyses of different types of TADs, the individual success rate is specified for every type of TAD: some of the factors that influenced success rates were common to several articles, but other factors were only evaluated by a single work (Table 2).

Patient-related factors

Figure 2 shows that there is no difference ($P = 0.60$) in TAD failure rate between males and females. Funnel plot symmetry suggests a low risk of publication bias presence.

Figure 3 suggests that age could be considered a factor that influences the success of TADs, which is lower ($P = 0.02$) in patients under the age of 20 years, even if funnel plot asymmetry notice the possible presence of publication bias. An explanation for this finding could be due to the stability of TADs, which need mechanical retention. Bone density and the thickness of cortical bone play major roles in mechanical retention; thus, it stands to reason that for older patients, retention should be better because bone density is higher, which results in fewer failures. Besides Schätzle *et al*. (2009) in their review suggest that in adolescent patients the use of compliance-dependent appliances could be preferred to the use of TADs allowing for growth modification of patients that TADs cannot influence.

Supplementary Figure 2A, available online, seems to suggest that there is no difference ($P = 0.41$) in TAD failure rate placed in keratinized versus non-keratinized tissues. Actually when removing the study by Sharma *et al*. (2011), which is the only one that found higher success rate in presence of non-keratinized tissues, forest plot analysis supports the presence of a significantly ($P = 0.007$) higher success rates when TADs are placed in attached gingival tissues. Limited number of available studies and funnel plot asymmetry suggest to avoid speculative assumptions regarding this prognostic factor.

Figure 4 reports a significant ($P < 0.005$) higher success rate when the soft tissue around TADs is not inflamed: peri-implant inflammation, due to poor hygienic care, is a factor that leads to implant failure. Nevertheless, even in the absence of keratinized mucosa, health of the tissues around

Table 1 Quality assessment of included studies.

Authors	Definition of success	Configuration of the study	Description of the analysis	Explanation of results	Type of study	Total evaluation
Antoszewska *et al.*, 2009	0	1	0.5	0.5	R****	M**
Bayat and Bauss 2010	0	0.5	0.5	1	ND******	M**
Berens *et al.*, 2006	0	0.5	0.5	0	ND******	L***
Chen *et al.*, 2006a,b	0	1	1	1	R****	H*
Chen *et al.*, 2007	1	0.5	0.5	0.5	R****	H*
Chen *et al.*, 2008	1	1	0.5	1	R****	H*
Cheng *et al.*, 2004	1	1	0.5	1	P*****	H*
Jung *et al.*, 2012	1	1	0.5	0.5	R****	H*
Kim *et al.*, 2010	0	0.5	0.5	1	P*****	M**
Kuroda *et al.*, 2007	0	0.5	0.5	1	ND******	M**
Lee *et al.*, 2010	0	0.5	0	0.5	P*****	L***
Lim *et al.*, 2009	0	1	0.5	0.5	R****	M**
Luzi *et al.*, 2007	1	1	0.5	0.5	P*****	H*
Mannchen and Schatzle 2008	1	1	0.5	0.5	P*****	H*
Manni *et al.*, 2011	1	1	1	1	R****	H*
Miyawaki *et al.*, 2003	1	0.5	1	1	R****	H*
Moon *et al.*, 2008	1	0.5	0.5	1	R****	H*
Moon *et al.*, 2010	0	1	0	1	R****	M**
Motoyoshi *et al.*, 2009a,b	0	0.5	0	0.5	ND******	L***
Motoyoshi *et al.*, 2010	0	0.5	0.5	1	ND******	M**
Park *et al.*, 2006	1	0.5	0.5	1	R****	H*
Sharma *et al.*, 2011	1	1	0.5	1	P*****	H*
Takaki *et al.*, 2010	0	1	1	1	R****	H*
Viwattanatipa *et al.*, 2009	0	0.5	1	0.5	ND******	M**
Wiechmann *et al.*, 2007	1	0.5	0.5	1	P*****	H*
Wu *et al.*, 2009	1	0	0	1	ND******	M**

*High quality.
**Medium quality.
***Low quality.
****Retrospective study.
*****Prospective study.
******Not declared.

the implants can be maintained, provided that oral hygiene is correctly performed (Francetti *et al.*, 1997). Better hygiene is often achieved on the left side of the mouth in right-handed patients, who constitute most of the population (Tezel *et al.*, 2001). Park *et al.* (2006) stated that TADs placed in the left side of the mouth exhibited higher success rates than those placed on the right side.

Figure 5 shows a significantly ($P < 0.005$) higher success rate when TADs are inserted in the maxilla, in comparison with the mandible. Funnel plot symmetry suggests a low risk of publication bias.

We were not able to perform a meta-analysis, as fewer than five studies were available for the following 'patient-related factors': smoking, anatomical site (maxilla versus mandible), and proximity of TADs to adjacent roots.

Smoking was associated with an increased risk of complications, as it causes mucositis, peri-implantitis, and implant loss. Bayat and Bauss (2010) found that heavy smokers exhibited higher failure rates in orthodontic mini-screws than non-smokers or light smokers.

Bone drilling is a commonly used step before the insertion of dental implants and of mini-implant TADs. The drilling process generates heat that impairs the turnover activity of bone tissue by causing hyperemia, necrosis, fibrosis, osteocytic degeneration, and increased osteoclastic activity. Bone temperature must be below 47°C during drilling to avoid thermal osteonecrosis.

Friction of the drill may result in generation of heat in dense and thick cortical bone. The cortical bone of the mandible is thicker than the maxillary bone; thus, drilling may result in overheating the mandible and this risk appears higher for the lower jaw than for the maxilla. This, however, would only apply for buccal insertion of TADs in the maxilla and does not explain the high success rate of TADs in the palate.

The placement of TADs in interradicular sites is often necessary for specific anchorage requirements. Safe insertion of TADs in interradicular sites can be performed on the buccal side with adequate bone-implant contact anywhere within the zones of attached gingiva, up to 6 mm apical to the alveolar crest thus allowing for enough interradicular space (Lim *et al.*, 2007). Kim *et al.* (2010) revealed that root proximity itself is not a major risk factor for mini-implant failure. Root contact does not necessarily cause implant failure because the other implant surfaces in contact with the bone can ensure stability, especially if the implant-root contact area is stable during treatment. On the other hand,

Table 2 Analysis of the outcomes of the studies. TAD, temporary anchorage device.

Author	Time of success measurement	Success rate	Definition of success	Definition of failure
Antoszewska *et al*., 2009	19.2 ± 2.3 months	93.43%	Stability of TAD during treatment	
Bayat and Bauss 2010	More than 4 months	82.8%		Loosening, peri-implant inflammation
Berens *et al*., 2006	Average: 235 days			Mini-screws loosening
Chen *et al*., 2006a,b	ND*	Mini-plates 4.7%, mini-screws 4.7–24.6%		Loose TAD, infected TAD, pain
Chen *et al*., 2007	ND*	90.4%		Loss of stability of TAD, soft tissue inflammation, pain
Chen *et al*., 2008	Mean follow-up 20 months	84.7%	Completion of orthodontic treatment, no inflammation	
Cheng *et al*., 2004	Completion of treatment, or last follow-up, or time of failure	89%	Capability of sustaining the function of orthodontic anchorage, in absence of inflammation and clinically detectable mobility	
Jung *et al*., 2012	ND*	95.4%	Completion of active orthodontic treatment	Mobility of implant
Kim *et al*., 2010	ARTT**	96%		
Kuroda *et al*., 2007	ND*	Min = 81.1%, max = 88.6%		
Lee *et al*., 2010	Average: 88 weeks			
Lim *et al*., 2009	ND*	83.6%	Primary stability of implant	
Luzi *et al*., 2007	More than 120 days	84.3%	No implant mobility	Implant lost
Mannchen and Schatzle 2008	ARTT**	94%	Osteointegration	
Manni *et al*., 2011	346 days	81%		Loosening of mini-screw, inflammation
Miyawaki *et al*., 2003	1 year or until completion of the orthodontic treatment	Mini-plates 96.4%; mini-screw 0% (1 mm)–83.9% (1.5 mm)–85% (2.3 mm)	1 year or until completion of the orthodontic treatment	
Moon *et al*., 2008	After 8 months	83.8%	Any mobility after the first 8 months of orthodontic force application	Disdlogement of OMI (ortho-donticminiscrew implants) within 8 months
Moon *et al*., 2010	ND*	79%	Orthodontic force could be applied for at least 10 months without pain or clinically detectable mobility, or its pur-pose was accomplished	
Motoyoshi *et al*., 2009a,b	ND*	86.5 < % < 93.3 Average 88.3		
Motoyoshi *et al*., 2010	ND*	90.5%		Mobility, loosening of mini-implant
Park *et al*., 2006	From 5 to 8 months	91.6%	Stability till the end of treatment	Loosening implant
Sharma *et al*., 2011	ND*	87.8%	No inflammation of the soft tissues surrounding the microimplant, no clinically detectable mobility, and anchorage function sustained until the end of the purpose for which the implant was used	Spontaneous loss, severe clinical mobility of the microimplant requiring replacement, or infected, painful, pathologic changes in the surrounding soft tissues
Takaki *et al*., 2010	ND*	90%		Implant mobility, implant loss
Viwattanatipa *et al*., 2009	ARTT** 6 months 12 months	85% at 6 months 57% at 12 months		Remarkable mobility, dis-lodgemet, infection
Wiechmann *et al*., 2007	Completion of treatment, or last follow-up, or time of failure	86.8%	Capability of sustaining the anchorage funtion throughout the treatment, absence of inflammation and of clinically detectable mobility	
Wu *et al*., 2009	More than 6 months	90%		Loosening or fracturing within 6 months

*Not described.
**Anchorage for required treatment time.

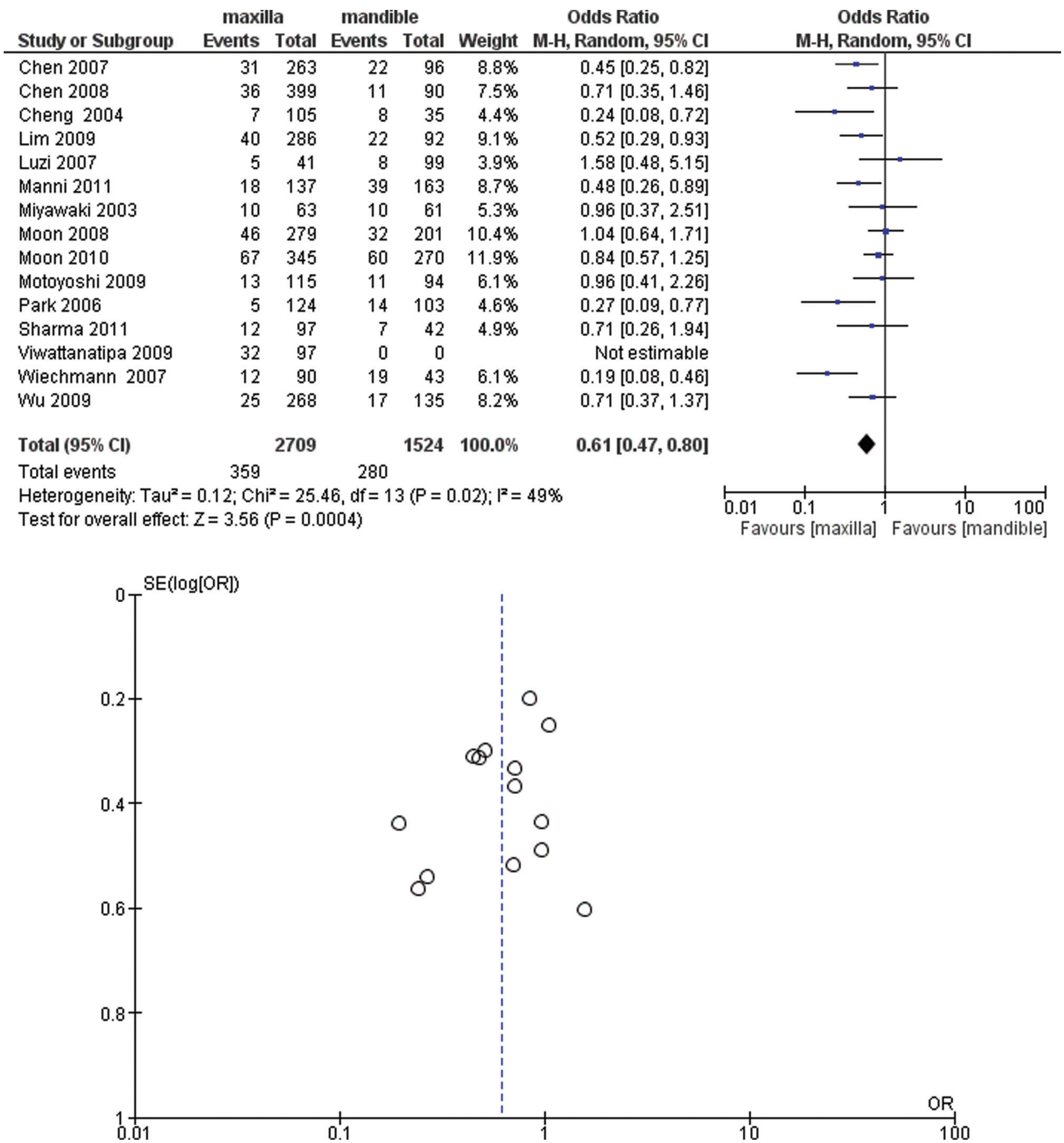


Figure 5 Forest and funnel plots of studies comparing the influence of the insertion site on temporary anchorage devices failure rate.

mini-implants contacting adjacent roots on more than one side exhibited more failures, which were most likely caused by decreased bone-to-implant contact.

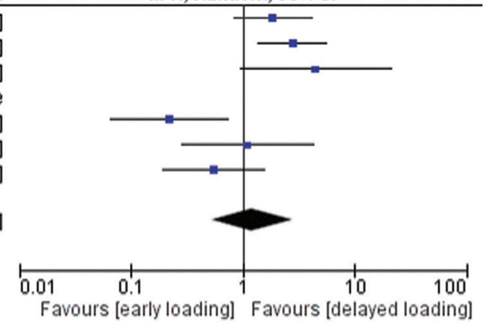
Operators need to remember that contact between root and TAD could potentially damage the root itself, although Janssen *et al*. (2008) demonstrated histologically almost complete repair of the damaged periodontal structure within 12 weeks following the removal of the screw.

Implant-related factors

Supplementary Figure 3, available online, shows that there is no difference (P = 0.09) in TAD failure between mini-screws and mini-implants longer than 8 mm, even if funnel plot asymmetry showed risk of publication bias and visual forest plot analysis possibly suggest a better result for longer TADs.

Study or Subgroup	Early loading Events	Early loading Total	Delayed loading Events	Delayed loading Total	Weight	Odds Ratio M-H, Random, 95% CI
Chen 2007	14	98	13	157	19.3%	1.85 [0.83, 4.11]
Chen 2008	17	93	19	256	20.2%	2.79 [1.38, 5.64]
Jung 2012	9	239	2	230	13.0%	4.46 [0.95, 20.87]
Luzi 2007	13	140	0	0		Not estimable
Manni 2011	3	54	54	256	15.8%	0.22 [0.07, 0.73]
Miyawaki 2003	3	20	14	101	14.5%	1.10 [0.28, 4.23]
Sharma 2011	10	98	7	41	17.2%	0.55 [0.19, 1.57]
Total (95% CI)		**742**		**1041**	**100.0%**	**1.21 [0.53, 2.78]**
Total events	69		109			

Heterogeneity: Tau² = 0.76; Chi² = 19.03, df = 5 (P = 0.002); I² = 74%
Test for overall effect: Z = 0.45 (P = 0.65)



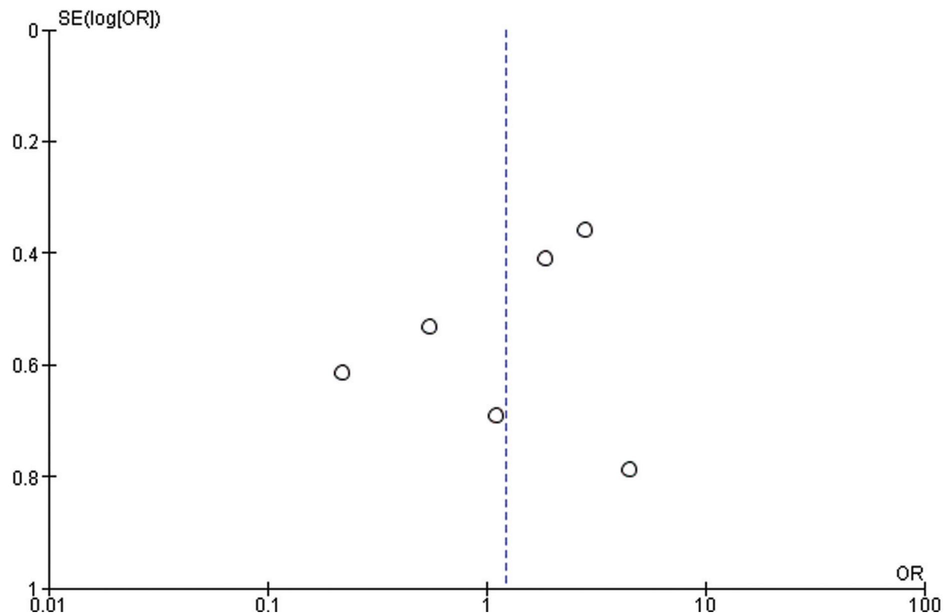


Figure 6 Forest and funnel plots of studies comparing the influence of early (less than 4 weeks) versus delayed (more than 4 weeks) loading on temporary anchorage devices failure rate.

Supplementary Figure 4, available online, shows that there is no difference (P = 0.48) in TAD failure rate for mini-implants with a diameter of more than 1.3 mm. The slight asymmetry of the funnel plot indicates a possible risk of publication bias.

It was inappropriate to undertake a meta-analysis, because of the availability of less than five studies, for the following implant-related factor: thread shape, TAD surface, and use of plates versus mini-implants.

The thread shape was evaluated to analyse the relationships between geometric characteristics and mechanical properties of TADs. It was found that thread shape correlates significantly with maximum insertion torque, as analysed with pull-out tests (Migliorati *et al*., 2012a,b; Migliorati *et al*., 2013): the removal torque of TADs after use is considered an element that is correlated with TAD stability.

Chaddad *et al.* (2008) compared two systems with different surface characteristics: machined pure titanium and a sand-blasted, acid-etched surfaces. They concluded that the differences in the survival rates between the two types were not statistically significant; therefore, the type of surface may not be the primary consideration in choosing TADs. In their study on palatal implants, Jung *et al*. (2012) analysed two types of implants: single-piece implants versus implants with sand-blasted and acid-etched surfaces. They also found that the type of implant had no influence on the implant success rates.

Some articles evaluated different type of TADs, including mini-plates that used multiple screws for anchorage. Mini-plates exhibited a greater stability compared with mini- and micro-screws, but they required flap surgery for insertion and removal, which could cause swelling and discomfort. Chen *et al*. (2008) suggested that mini-plates exhibited a higher success rate if the insertion site was outside the alveolar area and if they were secured with multiple screws. Kuroda *et al*. (2007) used two types of mini-screws that were different in size, in addition to a mini-plate fixed with three small mini-screws. They found no differences in the success rates of the three types of TADs; they affirmed that the type of TAD does not affect the success rate, but they recommended the use of smaller mini-screws when the implant site allows, as these can be inserted without a flap.

Management-related factors

Figure 6 shows that there is no difference ($P = 0.65$) in TAD failure rate between early (less than 4 weeks) and delayed (4 weeks after insertion) orthodontic loading. Funnel plot symmetry indicates a low risk of publication bias presence.

Meta-analysis could not be performed as less than five studies were available that investigated the following 'management-related factors': type of surgery, pre-drilling, operator experience, type of loading, type of connection to the implant, and type of movement.

The type of surgery used for the insertion of the TADs is considered to be important for patient comfort. TADs can be inserted with a flap surgery, in which the mucoperiosteal flap is reflected to expose the cortical bone and then sutured after insertion. On the other hand, flapless surgery can be performed without a mucoperiosteal incision, crafting the screw holes with a round cutter or punch and then pre-drilling the bone. Kuroda *et al*. (2007) considered two different clinicians and the two types of surgical procedures: the success rate of the two groups of mini-screws was very similar, and the different operators did not influence the success rate of mini-screws. Screws inserted without flap surgery were more comfortable for patients.

Cornelis *et al*. (2007) in a review based on animal studies looked at success rate of pre-drilled mini-implants compared with directly inserted screws and the diameter of the pilot hole. In cases were the diameter of the hole was narrower than the diameter of the screw, no failures were reported.

Other studies looked at the success rates of TADs in relation to insertion by different clinicians. Most studies stress the importance of a learning, but some studies conclude that the failure rate is implant specific (Luzi *et al*., 2007; Chen *et al*., 2008; Jung *et al*., 2012) and thereby conclude that different operators do not affect success rates.

The type of movement, the treatment target, and the appliances used for loading may be correlated to success rates. Park *et al*. (2006) analysed the method of force application to screw implants, which were one of the following type: power chain, super-elastic thread, nickel-titanium coil spring, or ligature tie-back. They found no significant correlation between the success rate and the method of force application.

Jung *et al*. (2012) analysed palatal implants for orthodontic treatment and used different connective systems between palatal implants and teeth using orthodontic forces that ranged from 1 to 6 N. Their data showed that the supra-construction design, the direction of loading, and the force applied on the implant had no influence on implant stability.

When the type of movement is considered, various studies agreed that the direction of tooth movement is important in determining the success rate, but the articles were inconsistent in identifying unfavourable direction of load. Kuroda *et al*. (2007) evaluated the type of tooth movement for which the TAD was used. They analysed the success rate of mini-screw implants used for retraction, protraction, and intrusion of teeth. The implant used for intrusion in the posterior maxilla and mandible exhibited significantly lower success than the ones used for other orthodontic indications. This result could be due to the type of bone, the higher risk of peri-implantitis in the maxilla, technical difficulties, and obstacles to oral hygiene in the mandible.

Conclusions

The conclusions of this analysis must be interpreted cautiously because of the disparate nature of the studies reviewed and the heterogeneity of the data: success was not equally defined in the papers scrutinized in this investigation and it would, therefore, be inappropriate to try and give an exact figure for implant stability and success and the factors that may have an impact on the figures. Furthermore, few studies commented if treatment goals could have been achieved without the use of TADs, but using other means of providing orthodontic anchorage instead.

However, some general conclusions can be drawn from the analysis of the data investigated:

1. In the studies analysed, TADs were only one of several anchorage options available: they were utilized mainly because they were a compliance-free method of providing anchorage and were often less bulky than alternative anchorage devices.
2. In all of the studies, the rates of TADs utilization's scopes achievement were greater than 80 per cent.
3. TADs were more successful when inserted in the alveolar bone of the maxilla compared with the alveolar bone of the mandible and when they are used in patients older than 20 years of age.
4. Good oral hygiene around the implant site is very important because it prevents soft tissue inflammation, which is associated with higher TAD failure rates.

Supplementary material

Supplementary material is available at *European Journal of Orthodontics* online.

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