Original Article

Effect of the length of orthodontic mini-screw implants on their long-term stability: *A prospective study*

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ABSTRACT

Objective: To analyze the influence of the length of temporary intraoral skeletal anchorage devices (TISAD/TAD) on their long-term stability in the mandible in a homogenous group of patients.

Materials and Methods: A group of generally healthy patients of the same gender (female) and with a statistically insignificant age difference (20–29 years) highly homogenous with respect to known factors affecting the success rate of TISAD/TAD was evaluated. One type of TISAD/TAD was applied (6- or 8-mm long). Each patient received both 6- and 8-mm-long TISAD/TAD in randomly selected mandibular quadrants: left or right. The long-term success rate of TISAD/TAD was analyzed.

Results: The 8-mm orthodontic mini-screw implants were significantly more stable than the 6-mm ones in the analyzed group.

Conclusion: The length of the TISAD/TAD may be one of the factors that can affect the long-term success rate in the mandibles of 20- to 29-year-old women. (*Angle Orthod.* 2015;85:33–38.)

KEY WORDS: Mini-screw implants; TISAD/TAD; Anchorage; Long-term stability

INTRODUCTION

Anchorage control is one of the key issues to be taken into account when planning orthodontic treatment. Expectations are not always met, despite the applied different anchorage reinforcement protocols. Most of conventional anchorage devices require either the patients' compliance or they load patients' teeth, thus leading to their uncontrolled, mostly undesired movement.[1–5]

Temporary intraoral skeletal anchorage devices (TISAD/TAD) have many advantages, such as low price, ease of insertion and removal, and rare complications related to their application, but most of all they ensure excellent biomechanics of tooth movement and anchorage control, even in uncooperative patients.[5–7]

The premature loss of a mini-screw implant is considered a failure that prevents the achievement of treatment goals. Thus, it is fully justified that numerous studies focus on the analysis of factors influencing TISAD/TAD stability during orthodontic treatment. The analysis of the reported results has revealed that those factors may be the patient's oral hygiene, coexisting diseases, smoking, the condition of mucosal membranes, the surgical protocol (including mini-screw implant location), the method of loading (time, force, and its direction), and the type of TISAD/TAD.[8–14] Unfortunately, it is quite likely that multifactorial analysis of TISAD/TAD stability may lead to bias; therefore, forming a homogenous group of patients is mandatory for reliable results and conclusions.

The review of the available literature proves that most authors disagree as to whether a higher percentage of failures concern the mandible or the maxilla; controversy also applies to the minimum time that should elapse between TISAD/TAD insertion and loading as well as to TISAD/TAD size vs their stability. However, the precise analysis of TISAD/TAD failures is hindered by the fact that long-term TISAD/TAD

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survival may depend on many factors, including those not fully definable (eg, competency of the clinician in the surgical procedures).

Moreover, comparing the information available in the literature, one cannot obtain a definite answer to the question about the impact of the length of the mini-screw implants on the success rate. Some authors of in vivo studies[7–16] deny this relationship, while others confirm it.[9,17,18] Also, the results of in vitro studies are not conclusive. Some clinicians[19–21] found a positive correlation between the length of the mini-screw implants and the maximum possible loading, which can be identified with the primary stability. However, others[22] claim that the use TISAD/TAD that are too long may cause micro injuries to the bones, and they also emphasize the possibility of more frequent and more serious complications caused by the larger mini-screw implants.[23,24] In turn, Wilmes et al.[25] have shown that the shape of the TISAD/TAD has a great impact on the success rate achieved, but they believe that the diameter and geometry of the longitudinal cross-section rather than the length determine the results.

Therefore, the aim of this prospective study was to analyze the influence of one factor only—the length of TISAD/TAD—on the long-term stability of TISAD/TAD in the mandible and in a homogenous group of patients to minimize the fortuity of the results.

MATERIALS AND METHODS

This study was approved by the Ethical Review Committee of Wroclaw Medical University (No. 293/2007). The study included a group of generally healthy patients of the same gender (female) and age (20–29 years), who reported toothbrushing three times per day (after each meal) and no symptoms of any oral disease. Since it is known that a patient's right- or left-handedness may affect the long-term result,[14] this aspect was also taken into account. All of the left-handed patients were rejected from the study group.

According to the Segner and Hasund individual analysis of lateral cephalograms, all patients presented a Class I skeletal pattern with the hyperdivergent (in the range of 1 standard deviation) angle between the maxillary and mandibular planes. Only patients with planned extraction of the lower first or second premolar were included in the study group.

Morphology of the oral mucosa (ie, frenula) in the area of implantation was also considered: only patients without frenula potentially loading the TISAD/TAD head while chewing or facial movement were considered.

To provide the highest homogeneity of the study material, the optical bone density (OPD) was evaluated in each individual, applying Østravik's protocol.[26,27]

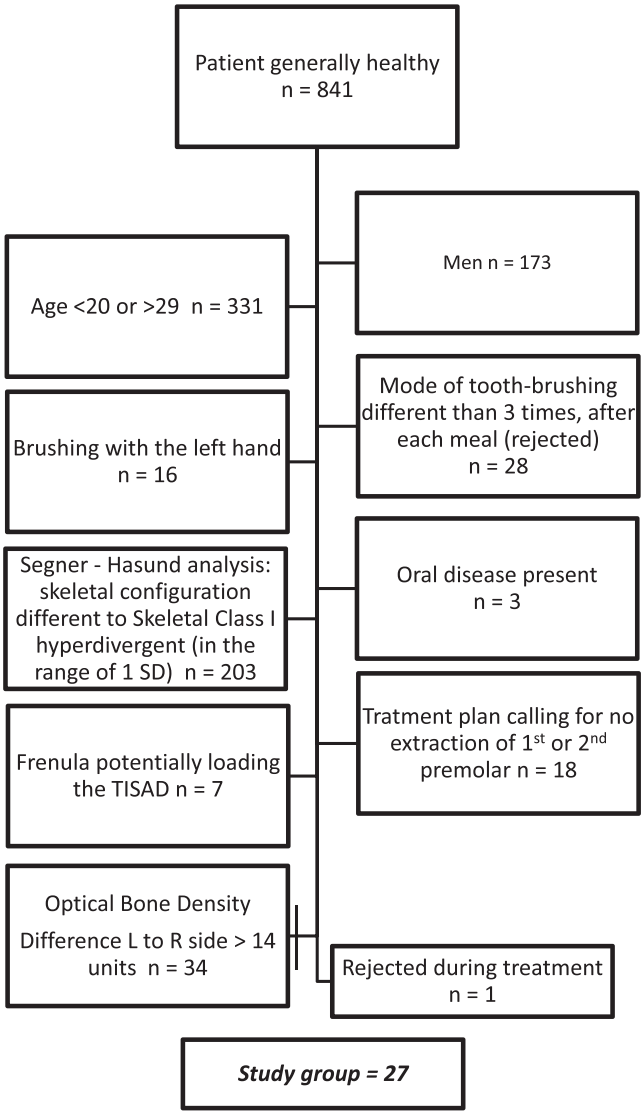

Figure 1. The CONSORT flow diagram of the study.

For this purpose, the points lying at a distance of 4.6 and 8 mm from the alveolar ridge, in the mid-space between the roots of the first and second molars on either side of the mandible, were established. Subsequently, Gendex software measured the OPD at the defined points, providing the results in unnamed units corresponding to the gray-scale images reflecting the grade of radiation weakening while passing the investigated structures. This measurement allowed comparison of the bone density in both mandibular quadrants, thus determining the OPD discrepancy between right and left sides in every patient. Only the individuals with differences not exceeding 14 units (statistically insignificant; Student *t*-test: $P = .084$) were included in the study (Figure 1).

To obtain the same force characteristics, the maximum anchorage was introduced only in extraction

Figure 2. Apical radiograms showing the relationship of the adjacent roots and the temporary intraoral skeletal anchorage devices.

cases (first or second premolar), for the purpose of the group retraction of the lower incisors and canines.

One type of TISAD/TAD was applied: OrthoEasy Pin (Forestadent, Phorzheim, Germany), 6- or 8-mm long. Each patient received both the 6- and 8-mm-long TISAD/TAD, in randomly selected mandibular quadrants (left or right); thus, the same number of a given TISAD/TAD length was collected in consecutive patients. All mini-screw implants were screwed by the same orthodontist and always according to the same Wroclaw protocol:

- Working on both sides of a dental unit
- Mandatory stab incision and predrilling mode
- Placing the TISAD/TAD perpendicularly to the alveolar bone, which was allowed since the TISAD/TAD were located 3 mm beneath the mucogingival junction, and therefore the roots were not jeopardized
- Placing the TISAD/TAD between the first and second molars
- Loading mini-screw implants after 2 weeks with a 13-mm NiTi spring (Dentos, Daegu, South Korea) with 100–150 g of force

After placement, all TISAD/TAD were evaluated considering the root proximity by taking periapical radiograms (Figure 2). If there was no contact or overlapping of the roots adjacent to TISAD/TAD, the case was included in the study. Only TISAD/TAD with no initial mobility or perfect initial stability were included. Since the study was designed in the split-mouth mode, two study groups were eventually obtained (Table 1).

Table 1. Arrangement of the Study Material[a]

Group	TISAD Length (mm)	Number of TISAD (n)
A	8	27
B	6	27

[a] TISAD indicates temporary intraoral skeletal anchorage devices.

Figure 3. The loaded temporary intraoral skeletal anchorage devices.

All patients were instructed to maintain a perfect oral hygiene regimen and to use gel with chlorhexidine (Elugel) (Pierre Fabre Medicament Polska Ltd, Warsaw, Poland) around TISAD/TAD for the first 4 weeks after operation. All individuals were asked to avoid any recurrent hit against TISAD/TAD and any hard contact with the toothbrush body.

The TISAD/TAD were loaded with the force acting parallel to the occlusal plane: NiTi springs were expanded between the TISAD/TAD, and bull loops, 8-mm long, were bent on both sides of the archwire, between the canines and the lateral incisors (Figure 3). The average observation period lasted 9–12 months. The collected data were analyzed statistically with the McNemara test and using Statistica software version 8.0.

RESULTS

If slight mobility appeared but the TISAD/TAD could still be used as the direct anchorage reinforcement, it was still considered a success. In other words, only TISAD/TAD with greater mobility that could no longer serve as anchorage reinforcement or that were removed by the action of the NiTi spring were indicated as ''lost.'' Because all cases of lost TISAD/TAD also presented with peri-implantitis, the authors could not determine whether the inflammation was the cause or the effect of the mini-screw implant mobility. Therefore, the data concerning mucosa inflammation are not presented.

In total, 40 of 54 TISAD/TAD were able to achieve the treatment goals. The detailed results are shown in Table 2. In group A, 22 (81.5%) mini-screw implants presented long-term stability, while in group B, only 18 (66%) TISAD/TAD were stable throughout the treatment. This difference was statistically significant ($P = .0311$). The total success rate for all inserted mini-screw implants was 74%. In one case (patient 4), TISAD/TAD of both lengths failed.

Table 2. TISAD Stability and Failure Distribution[a]

	Group A (TISAD = 8 mm)		Group B (TISAD = 6 mm)	
Patient No.	Failure (Weeks After Insertion)	Stable	Failure (Weeks After Insertion)	Stable
1	* (4)			*
2				*
3		*		*
4	* (10)		* (8)	
5		*		*
6		*		*
7		*	* (7)	
8	* (9)			*
9		*	* (6)	
10		*		*
11		*		*
12		*	* (4)	
13		*		*
14		*	* (5)	
15		*		*
16		*		*
17		*	* (7)	
18		*		*
19		*		*
20		*		*
21		*	* (5)	
22	* (6)			*
23		*		*
24	* (8)			*
25		*	* (6)	
26		*		*
27		*	* (4)	
Total, n (%)	5 (18.5)	22 (81.5)	9 (33)	18 (66)

$P = .0311$.

[a] TISAD indicates temporary intraoral skeletal anchorage devices.

* = yes.

DISCUSSION

It is quite likely that orthodontic mini-screw implants may not obtain long-term stability because of many factors. These factors may be assigned to different groups: patient related (systemic diseases, smoking, habits, hygiene, the level of immunity, etc), orthodontist related (treatment methodology, experience), and TISAD/TAD related (size, surface coating, and shape).[8–14] The clinical trials, which have been designed to improve the rate of TISAD/TAD stability until the therapeutic goal is obtained (also known as the success rate), require distinguishing factors that have the greatest and most decisive influence on maintaining mini-screw implants in the oral cavity.

One method of study design might be to establish a group with a large sample size that provides many different variables and to further analyze the impact of the variables on TISAD/TAD stability.[9,10] Another approach is to analyze only one variable, on the assumption that the influence of other factors on the results is eliminated to the maximum.[28] The possibility of a mutual cross-interaction between individual variables is a disadvantage of the first method, as is the need to increase the size of the study group to ensure statistical reliability. The strategy of analyzing only one variable also has a weak point: selection of a study group of patients, in whom the effects of all known factors are eliminated—except for the effect undergoing planned analysis—is technically very difficult. However, this difficulty may be overcome if a certain degree of homogeneity (deciding on the significance results) is strictly obeyed. Thus, the inclusive criteria were carefully determined and applied in the presented material. On the other hand, high homogeneity has a kind of quid pro quo limitation: it reduces the external validity of the obtained results, making them likely to match only the individuals strictly corresponding to the characteristics of the study group. Nonetheless, high homogeneity allows control of variables and facilitates the determination of the objective of further research. Therefore, it seems to be a good option for the purpose of clinical trial.

According to the available data, the impact of the orthodontic mini-screw implants' length on their stability was tested in vivo in only a few multivariate analyses. A statistically significant relationship was not shown by Miyawaki et al.,[9] Antoszewska et al.,[7,14] or Park et al.[16] In turn, Chen et al.[13] conducted a thorough analysis of 16 various articles, studying the factors responsible for the success rate of TISAD/TAD. The authors concluded that the minimum length of the TISAD/TAD should be at least 6 mm. If an assumption is made that 6 mm is the minimal length and the longer mini-screw implants give better results, the conclusions drawn by Chen et al.[13] will be consistent with the results of the presented study, in which using 6-mm-long TISAD/TAD was less successful than the application of 8-mm-long TISAD/TAD. However, Chen et al. conclude that further research may show that shorter and smaller TISAD/TAD can be more successful in the toothed area, because ''slimming'' the size poses a lower risk of contact between the mini-screw implants and the dental roots. This view has been confirmed by Kuroda et al.,[15] who demonstrated in the in vivo studies that the close proximity of the dental roots may be one of the main factors responsible for the failure of TISAD/TAD.

On the other hand, the meta-analysis of the factors determining the success rate of TISAD/TAD conducted by Papageorgiou et al.[29] revealed that the length of the mini-screw implant was unimportant. However, according to these authors, both the close proximity to the root and too high torque during the TISAD/TAD insertion may increase the risk of their loss. In our study, the risk of the contact between TISAD/TAD and the roots of the adjacent teeth was reduced, but at the stage of the research methodology by using the original method of insertion, whose effectiveness is 93.46%. Moreover, the radiologic verification carried

out after each TISAD/TAD insertion excluded the patients who were predisposed to the loss at the very beginning. As for mechanical consideration, Wilmes et al.[25] reported that the longer TISAD/TAD may cause higher torque during screwing in, which can lead to the micro-damage of the bone and the consequent loss of the mini-screw implant. Nevertheless, our results prove that, even if such a factor existed, it is irrelevant from a clinical point of view. Perhaps it resulted from the mandatory predrilling during every insertion of the mini-screw implant.

Studies conducted by Kau et al.[30] proved that, on average, 71.2% of the TISAD/TAD thread area contacts with the alveolar bone. It can therefore be assumed that the absolute contact surface in longer mini-screw implants will provide better initial stability. Cha et al.[31] claim that this factor is one of the determinants of the higher success rate. This is consistent with our results; nonetheless, it should be noted that the good initial stability was a sine qua non inclusive criterion for both 6- and 8-mm-long mini-screw implants. Here, we can pose the question as to whether better resistance to the mechanical pressure, which is exerted on TISAD/TAD during the orthodontic treatment, is the major factor responsible for the higher success rate of 8-mm-long mini-screw implants. The positive answer can be supported by the results of the in vitro studies presented by Petrey et al.[19] They reported that the deeper placement of the mini-screw implants in the bone structure, which requires a greater length of TISAD/TAD, provides better resistance to the orthodontic forces. However, the same authors found that from a purely mechanical point of view, even short, 6-mm-long mini-screw implants remain stable, provided that the proper value of orthodontic forces are preserved. In our study, all TISAD/TAD were loaded in the same manner, without exceeding the value defined as the maximum force the orthodontic mini-screw implants may withstand,[32] which allows us to relate the premature TISAD/TAD loss to their length rather than to their loading protocol.

We propose that strictly obeying the rules of the Wroclaw method helped to eliminate a significant number of the recognized factors that are under the control of an operator that might predispose to loss of the mini-screw implants. Moreover, the far-reaching unification of the study group in terms of the host-dependent, well-known factors as well as the random placement of TISAD/TAD of different lengths allow the extensive isolation of a single tested variable affecting the loss or maintenance of TISAD/TAD.

CONCLUSIONS

- Eight-millimeter orthodontic mini-screw implants inserted in the mandibles of 20- to 29-year-old women, loaded 2 weeks after insertion with a continuous force ranging from 100 to 150 g, are significantly more stable than the 6-mm implants.

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