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C E C S M O R U B R I C

Successes and failures with orthodontic mini-screws: a retrospective clinical study of 95 mini-screw implantations

Arnaud COSTI

CECSMO Memoire directed by Doctor M.-H. DECOSSE

The use of mini-screws has increased broadly over the last ten years. Effectively, these implantable devices, greatly reduced in size and easy to set in place and to remove, have provided orthodontists with a low cost means of reinforcing anchorage for a pre-determined period of time. However, their success rate is far from satisfactory compared to the well-established implants used for tooth replacement or for other sources of skeletal anchorage. In a recent meta-analysis Schätzle[9] reported a failure rate of 16.4% for mini-screws as opposed to 10.5% for palatal implants and only 7.3% for mini-plates.

The Faculty of Dental Surgery, Paris 7, determined, accordingly, that there was need for a retrospective study on the use of mini-screws. Beyond a simple calculation of the failure rate, we felt it was especially important for us to try to gain an understanding of the most dangerous risks so that they could be avoided in the future.

1 – METHODS AND MATERIALS

Between December 2005 and May 2009, 41 patients consulted us at Garancière for prospective orthodontic treatment that would require use of mini-screws.

We included in the study only the 29 patients who had, in fact, benefited from placement of mini-screws and follow-up orthodontic care at the Faculty, 22 women and 7 men from 12 to 61 years of age, with an average age of 40. It is important to note that 13 of them received preliminary periodontal treatment (fig. 1).

Address for correspondence:
A. COSTI,
21, avenue Niel,
75017 Paris.
arnaud.costi@wanadoo.fr

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Figures 1 a to e
Initial intraoral photos of M.T. taken after periodontal prophylaxes. An over-retained upper right temporary canine, distal to the upper right permanent canine had a 3 mm maxillary midline deviation to the left.

In total, we placed 95 AbsoAnchor@ (Dentos@) self-drilling, cylindro-conical, titanium alloy mini-screws were available in a variety of:

- lengths, ranging from 6 to 12 mm. We used the 10 mm mini-screws most frequently, in 70% of the cases;
- diameters, ranging from 1.2 mm to 1.6 mm. We used the 1.3 mm size for 67% of our sample;
- models. We chose the SH, small head mini-screw more often than the CH, circle head.

Intrusion was the type of tooth movement that our orthodontists most frequently decided needed the assistance of mini-screw anchorage. But they decided on the type, number, and placement of the screws in collaboration with the oral surgeon. Primarily they more often elected to use mini-screws in the maxilla than the mandible, buccally than palatally, and in the posterior rather than the anterior. More precisely, mini-screws were placed between the second premolar and the first premolar 40% of the time. In 93% of cases the attached gingiva was respected. (table 1).

Orthodontic treatment was never started before necessary periodontal treatment had been completed.

Fourteen different operators, all of them experienced in implantology, placed the mini-screws. The mini-screw placement protocol began with a chlorhexidrine mouth rinse, injection of local anesthetic, and preliminary

		NUMBER OF SCREWS
INDICATION	**intrusion** uprighting antero-posterior traction	**50 (53%)** 8 (8%) 37 (39%)
ARCH	mandibular **maxillary**	19 (20%) **76 (80%)**
SURFACE	palatal **buccal**	35 (37%) **60 (63%)**
SECTOR	**posterior** anterior	**89 (94%)** 6 (6%)
TYPE OF GINGIVA	**attached** free	**89 (94%)** 7 (7%)

Table I
Indication and site of mini-screw insertion.

drilling of the site with a 0.9 mm bur. In conformity with the manufacturer's recommendations, the operators inserted the mini-screws with the aid of a manual screw driver furnished in the kit (fig. 2 a to c).

After inserting the mini-screws we took periapical radiographs to be sure we had not breached the integrity of any adjacent roots.

The patients were assigned to 14 CECSMO students. Sixty-one mini-screws were inserted and loaded immediately and 41% of them were left in place for more than 6 months.

Operators usually, in 74% of the cases, used a direct connection of screw to appliance rather than an indirect one (fig. 3 a and b).

a b c

Figures 2 a to c
After having removed the upper right temporary cuspid, the student orthodontist had two mini-screws placed for patient M.T., both CH 1.3 x 10 mm between the upper right first and second bicuspids, one buccal and the other palatal. After preparing the sites with a .9 mm bur (a) Dr. Rosec, the oral surgeon, inserted each mini-screw with the aid of a screwdriver until all the threads were buried.

a *b*

Figures 3 a and b

The orthodontist delivered force to patient M.T.'s appliance with elastic chains, changed every two weeks, to retract the upper right cuspid into the space left by the over-retained temporary canine. Re-opening of space for the upper right first molar was accomplished at the same time. (a) Next the patient was asked to supply the force necessary for en masse retraction of the upper incisors (b) by placing elastics between the between the buccal mini-screw and a hook soldered on the arch wire just distal to the upper right lateral incisor.

Each patient had a four page information booklet containing on the:

- First page a short medical history of the patient reporting age, sex, previous medical and dental histories, state of oral hygiene, facial type, local constraints, and any painful sites;
- Second page an account of the surgical situation: type of pre-surgical preparation; information on the implant site, its locale, its osseous density, and the quality and quantity of surrounding soft tissue; the surgical protocol; and any noted defects;
- Third page an assessment by the orthodontist covering indications for treatment, the bio-mechanical appliance and force applications being considered, and data on treatment timing, anticipated duration, possible problems and complications;
- Fourth page devoted to the mini-screws stipulating their shape and dimensions.

All this data was keyed into a digital table with the Microsoft Office Excel@ 2007 program with which we could calculate the overall failure rate. Then we made a univariate analysis of variance of the potential causes of failure in this study. This was done with the aid of the R Development Core Team@ 2009 program composed by Doctor Charpentier, a dentist and statistician at the Pitié-Salpêtrière Hospital in Paris.

2 – RESULTS

2 – 1 – Calculating the failure rate

Of the 95 mini-screws that we put in place, 23 were lost, which constitutes a failure rate of 24.2%. The causes of failure were:

- 3 fractures;
- 7 loss of stability, 5 immediately and 2 later;
- 13 losses of stability associated with inflammation of surrounding

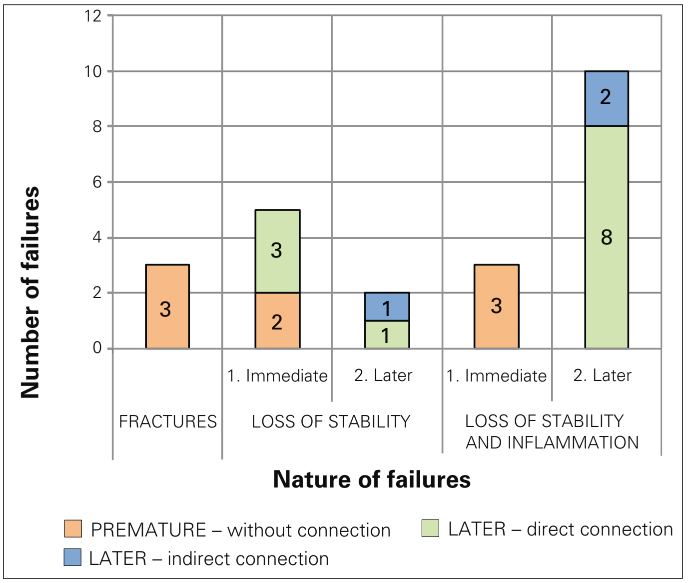

Figure 4
Distribution of failures in relation to their nature and the type of connection.

soft tissues, 3 immediately and 10 later.

It is interesting to note that:

– 8 screws were lost prematurely, that is before any force was applied to them,
– 15 screws began to loosen later when they were subjected to orthodontic traction, 3 were connected indirectly, 12 were connected directly (fig. 4).

This failure rate of 24.2% is about 1.5 times higher than the 16.4% figure that Schätzle[9] reported in his meta-analysis and is situated beyond the upper limit of the 95% confidence level (95% CI: 13, 4–20.1%).

2 – 2 – Univariate analysis of variance

An examination of the data suggests that the factor ''patient'' is important in view of the unequal distribution of screws between patients.

A comparison between the functions of distribution of the number of screws with the number of failures provides another illustration of this inequality: the four patients with the most failures accounted for 52% although they had received only 22% of the screws.

And the small size of the sample and the poor distribution of some of the factors being studied, notably the factors clustered around ''patient'', make this intervening variable one of confusion.

The comparisons that we are about to make will accordingly be presented in a mixed model format, the only aleatory factor being an intercept on ''patient.''

In decreasing order of significance, where $p < .01$, we have retained the following variables: number of screws in the system considered, angle of screwing in relation to the long axis of the tooth to which it was connected in an application of force, duration of its being employed, and type of connection (tab. 2).

It flows from this analysis that the risk of failure would increase when:

- The number of screws in the system diminishes: the risk is maximum for the first screws not put to work; then the risk diminishes for the systems of 1, 2, 3, 4, and, finally, 5 screws where the failure rate is nil;
- The screw is inserted at 90^0 or more with respect to long axis of the tooth rather than 40-45^0;
- The duration of the orthodontic employment is short: failures primarily occurred primarily before force was applied to the screw or during the first three months of its employment;
- The type of connection applied little force to the screw: failures occurred most often before any orthodontic force was applied, and more for indirect connections than for direct.

Of the 13 mini-screws that were not put to work, 8 had already failed and couldn't be used for that reason. This comes to a failure rate of 8/13 or 62%. This high but logical proportion of failures occurred with a few parameters that we deemed interesting: the number of screws in an active force system was zero, the duration of their employment was zero, and they were never connected.

VARIABLE	LEVEL	SUCCESS	FAILURE	SHARE OF FAILURE PER LEVEL
Number of screws in the force system	**0** **1** **2** 3 4 5	**5** **8** **14** 13 31 5	**8** **2** **4** 2 4 0	**62%** **18%** **20%** 11% 10% 0%
Angle of screwing with respect to the long axis of tooth	40–45° **90°**	58 **14**	10 **3**	15% **48%**
Duration of employment (month)	**0** **< 3** 3 to 6 > 6	**5** **18** 14 35	**8** **8** 3 4	**62%** **31%** 18% 10%
Connection	**0** **indirect** direct	**5** **9** 58	**8** **3** 12	**62%** **25%** 17%

Table 2
Success and failures of the variable.

An analysis of these parameters would make more sense if we limited it to the sub-group of screws effectively employed. It would, accordingly, be interesting to complete our calculations by a statistical analysis of this sub-group.

3 – DISCUSSION

3 – 1 – Critical analysis of the results

With the univariate analysis we were able to establish a relationship of the fairly high failure rate of 24.2% and certain variables.

First, it seems that the more screws there are in a given orthodontic set-up the fewer failures there will be. It would also appear that when the intensity of the force is spread over a large number of screws it imparts a weaker destabilizing action on each of them. Chen[2] had already formulated this hypothesis in one of his articles. And quite recently Kim[4] confirmed this idea by showing in his multivariate clinical study that splinting screws together was the only factor capable of expressing a positive influence on the success rate of screws placed in the palate.

The second parameter that comes into focus from our study is the angle of the screwing with respect to the long axis of the tooth. An angulation of 40-50° would be preferable, for example, than one equal to or greater than 90°, a better primary stability supporting these results.

In effect, when the gingiva is not attached at a high point, an insertion of a screw at a 90° angle in the keratinized gingival suggests that it is close to the inter-dental papilla where the lesser amount of bone is of poorer quality than it is a deeper level. And if, to compensate for this, the screw is aimed at the base of the buccal sulcus it risks being destabilized by the muscular activity of the cheeks and lips.

Pickard[8] also asserts that screws angulated at 45° to the direction of the orthodontic traction rather than 90° or in ''tent stake'' fashion have greater stability. He explains this phenomenon by its more equal sharing of constraints with the bone surrounding the implanted screw. Wilmes[12] reports that animal studies have shown that an insertion angle of 60–70° is ideal but that this angulation has to be reduced when the screw is placed near roots of teeth. It is true that if the angulation is too acute, the operator might slip in inserting the screw, as Park[7] has observed. In addition, the uppermost thread or threads may not be set in cortical bone.

We also found that our mini-screw failures occurred essentially in the first few months after their insertion, 8 right after surgery, 8 in the first 3 months of their being put to use, which represents 2/3 of the failures (16 of 23). From this it seems clear that operators should delay treatment until after a ''natural selection'' of screws has taken place during the first few months after they have been placed.

Paradoxically, the mini-screws that we connected directly to appliances failed slightly less frequently. 17.1%

of the time, than mini-screws that we connected indirectly to appliances, whose failure rate was 25%. This is the reverse of most reports in the literature[1], where indirect connections have been associated with slight amounts of anchorage loss. It is possible that operators have connected slightly mobile mini-screws indirectly as a precautionary measure that failed to accomplish its purpose in some cases.

Summing up, we found that the univariate analysis merely indicated paths worthy of future investigation. In order to prove the accuracy of our observations and the hypotheses they suggested it will be necessary to set up as many prospective studies as there are variables to test and to do this with a scrupulously identical protocol for all the different groups. Moreover, we have to take certain particularities specific to this study into consideration.

3 – 2 – Particularities of this study

As with any retrospective study, we have to ask ourselves what level of proof our results have achieved.

The first possible bias to consider is the recruitment and follow-up of patients, most of whom had consulted the Periodontology Service seeking correction of migrations of teeth that resulted from loss of other dental units as well as generalized weakening of periodontal support. This sample of patients is special because they were at greater than average of suffering inflammation or infection around the implant sites. So the results we obtained cannot necessarily be extrapolated to a larger population.

Furthermore, there were almost as many practitioners, 14 orthodontists and 14 oral surgeons, as there were patients, which it makes it questionable that the protocol can be replicated or is, in fact, reliable; especially since none of the professional participants in the study had really had any previous experience in the field. And, as we know, there is for every surgical procedure, as is true for any endeavor, a learning curve of apprenticeship[4].

In a prospective study carried out in 2004 at the University of Aarhus in Denmark Melsen[6] obtained a failure rate of 10.5%. Of the 19 failures reported, 16 occurred in the first weeks of the project, all of which the chief investigator attributed to the inexperience of the dentists who placed the mini-screws and especially to the difficulty they encountered in keeping the axis of the screwing-in constant. This study showed that when the screwdriver is held incorrectly, like a pen, the failure rate is greater than when it is grasped with the whole hand, the palm exerting pressure.

In our study we used only screws of the AbsoAnchor@ Dentos@ brand, which many authors, especially those from Asia, have employed with success. But in our study we used only self-setting screws with a diameter of 1.6 mm or less, the majority of which were 1.3 mm in diameter. Our having utilized a pre-insertion drilling or a prepared hole in more than half of the cases certainly avoided the occurrence of additional fractures. But, on the other hand, it may have contributed to a loss of primary stability in some cases where the screw's diameter was 1.6 mm or less, particularly in the maxilla. Moreover, Kim[3] considers that pre-drilling is not only unhelpful, but perhaps harmful for primary stability when the diameter of the screw if 1.6 mm or less, the preparatory bur used always being smaller sized than the mini-screws chosen for their sites[1].

3 – 3 – Some thoughts on the notion of failure

Some authors[11] believe that any screw that becomes mobile must be considered a failure. While it is true that the short term viability of any mobile screw is not promising, if it has fulfilled its role there is no reason that it should be recorded in the category of failures.

The determining factors are the moment when it began to show mobility and the extent to which it is mobile. We must bear in mind that implanted orthodontic mini-screws have a limited *raison d'être* and period of utility: to facilitate the movement of a tooth or groups of teeth by serving as *temporary* anchorage reinforcement and the time required to accomplish that goal (fig 5 a to e).

In other words, the success of orthodontic movement does not necessarily depend on the success of the mini-screw: in our study the failure of one mini-screw was associated with satisfactory displacement of teeth and the failures of 5 mini-screws were associated with partial, but acceptable orthodontic movement.

a b c d e

Figures 5 a to e

Intraoral photos taken at the end of orthodontic treatment by Dr. Rosec, for patient M.T. The maxillary center line has been corrected and spaces have been opened in the upper right and lower left first molar regions in which implants can be placed.

VARIABLE	LEVEL	SUCCESS	FAILURE
TOOTH MOVEMENT	insufficient	**8**	17
	partially satisfactory	**30**	**5**
	satisfactory	34	**1**

Table 3
Success of tooth movement in relation to success of the mini-screws.

This means either that even though these screws were lost prematurely, they played their roles satisfactorily or that recourse to mini-screws was not indispensable in these cases (table 3).

On the other hand, of course, the success of a mini-screw does not necessarily mean that the orthodontic treatment has succeeded: 8 screws deemed to be successful were associated with failure of the orthodontic therapy and 30 with improvements that were only partial. A mini-screw remains nothing more than an aid to therapy like any other aid and it is the orthodontist's responsibility to anticipate and overcome biomechanical difficulties.

In addition, Liou[5] and later Wang[10] have demonstrated that, unlike teeth, mini-screws subjected to orthodontic force can move through bone without becoming mobile. Such displacements, of the head as well as the tip of the screw, can extend to 1.5 mm. To explain this phenomenon these authors have pointed out that the fibro-conjunctive nature of the bone-implant interface allows a certain freedom of movement in the direction of the source of the force application. This means then that mini-screw anchorage is not absolute as was formerly thought.

Finally, the concept of failure is relative: the criteria that authors use to define it differ considerably. For the notion of failure to have clinical significance success rates should be systematically related to the length of utilization: so that we would speak of a survival rate of 6 months, 12 months, and, eventually 18 months.

4 – CONCLUSION

Mini-screws offer orthodontists an appreciable source of temporary supplementary anchorage. However, their failure rate is not negligible.

The retrospective clinical study that we carried out over the last three years at the Faculty of Dental Surgery of Paris 7, compiled a failure rate of 24.2%, which is higher that the 16.4% figure reported in the literature.

The majority of our failures were associated with a loss of primary stability, a third of them occurring before the application of orthodontic force and a second third during the first three months of mechanotherapy.

The univariate analysis we conducted stressed the importance of certain parameters, notably that the more widely force application is distributed to a range of mini-screws the lower the failure rate will be. Moreover, mini-screws inserted perpendicular to bone or in ''tent stake'' fashion have higher than average failure rates.

Certainly the inexperience of the operators in our study accounts for a high proportion of the failure rate because as in any implant technique there is a learning curve.

Consequently, offering students practical training in the placement of mini-screws will contribute greatly to an increase in future success rates.

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