Original Article

Impact of Insertion Depth and Predrilling Diameter on Primary Stability of Orthodontic Mini-implants

Benedict Wilmes[a]; Dieter Drescher[b]

ABSTRACT

Objective: To test the hypothesis that the impact of the insertion depth and predrilling diameter have no effect on the primary stability of mini-implants.

Materials and Methods: Twelve ilium bone segments of pigs were embedded in resin. After implant site preparation with different predrilling diameters (1.0, 1.1, 1.2, and 1.3 mm), Dual Top Screws 1.6 × 10 mm (Jeil, Korea) were inserted with three different insertion depths (7.5, 8.5, and 9.5 mm). The insertion torque was recorded to assess primary stability. In each bone, five Dual Top Screws were used as a reference to compensate for the differences of local bone quality.

Results: Both insertion depth and predrilling diameter influenced the measured insertion torques distinctively: the mean insertion torque for the insertion depth of 7.5 mm was 51.62 Nmm (±25.22); for insertion depth of 8.5 mm, 65.53 Nmm (±29.99); and for the insertion depth of 9.5 mm, 94.38 Nmm (±27.61). The mean insertion torque employing the predrill 1.0 mm was 83.50 Nmm (±33.56); for predrill 1.1 mm, 77.50 Nmm (±27.54); for the predrill 1.2 mm, 61.70 Nmm (±28.46); and for the predrill 1.3 mm, 53.10 (±32.18). All differences were highly statistically significant ($P < .001$).

Conclusions: The hypothesis is rejected. Higher insertion depths result in higher insertion torques and thus primary stability. Larger predrilling diameters result in lower insertion torques. (*Angle Orthod.* 2009;79:609–614.)

KEY WORDS: Insertion depth; Predrilling diameter; Mini-implant; Insertion torque; Primary stability; Anchorage

INTRODUCTION

Skeletal anchorage and orthodontic mini-implants especially have attracted great attention in recent years because of their versatility, minimal surgical invasiveness, and low cost.[1–7] However, failure rates of approximately 10%–30% as described in the literature are still not satisfactory.[8–11]

A sufficient primary stability measured by insertion torque seems to play a major role for the treatment time survival rate.[5,12,13] This is also proven in dental implantology.[14–16] Implant stability immediately after insertion is called primary stability (press fit). The relevant factors having an impact on primary stability of mini-implants are as follows:

- implant design,[17–21]
- bone quality (ie, thickness of cortical bone),[13,18]
- implant site preparation (no predrilling vs predrilling depth and diameter),[18,22] and
- insertion angle.[23]

On the other hand, the length of the mini-implant as well as the predrilling depth in spongious bone do not have significant effects on insertion torques.[18]

For mini-implants with a diameter of 1.6 mm, an insertion torque of 5 Ncm to 10 Ncm (50 Nmm to 100 Nmm) seems to be favorable to minimize the risk of failure.[12,13] Higher values may result in higher failure rates because of a distinctive bone compression with microdamages[24] or may even cause mini-implant fracture.[18] To summarize, it seems very important (1) to know the factors affecting the insertion torque/primary stability exactly and (2) to adapt the clinical procedure with the goal of achieving an insertion torque in the

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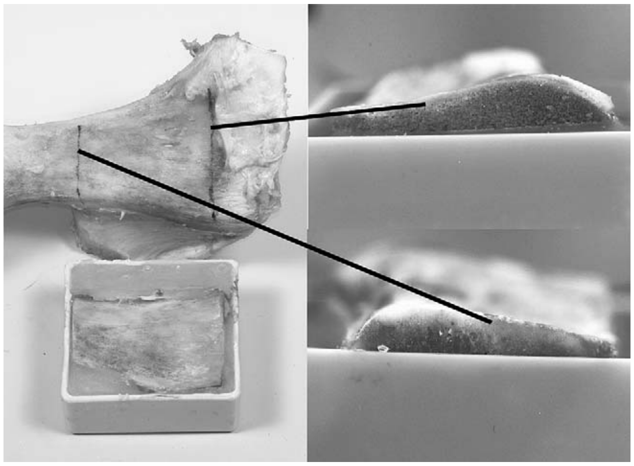

Figure 1. Ilium segment of a pig. The compacta thicknesses of the bone segments ranged from 0.5 mm toward the iliosacral joint up to 3.0 mm toward the hip joint.

recommended range. Besides the above-mentioned factors, the effect of the insertion depth of a mini-implant on insertion torque has not yet been investigated.

The aim of the present study was to analyze the impact of the insertion depth on the insertion torque and hence primary stability of mini-implants. Second, the coeffect of the predrilling diameter was to be evaluated.

MATERIALS AND METHODS

The ilium of country pigs was chosen as the bone model. The compacta thickness of the bone segments ranged from 0.5 mm to 1.0 mm on the side toward the iliosacral joint and from 2.0 mm to 3.0 mm toward the hip joint. These values are comparable with compacta thicknesses encountered in the human maxilla and mandible (Figure 1). Twelve bone segments were embedded in resin (Probase, Ivoclar Vivadent, Schaan, Liechtenstein), and curing was performed under water cooling to avoid bone overheating by polymerization energy.

The predrillings were performed in the direction of the planned mini-implant insertion by a bench drilling machine (Opti B 14 T, Rexon, Germany) at 915 rpm. The following drills were used: Tomas Drill (Dentaurum, Ispringen, Germany) with diameters of 1.1 mm and 1.2 mm and drills from the Dual Top system (Jeil Medical Corporation, Seoul, Korea) with diameters of 1.0 mm and 1.3 mm. The predrilling depths were adjusted to 3 mm.

The employed mini-implant was the Dual Top Screw (Jeil, Korea), 1.6 × 10 mm (Figure 2). Prior to the measurement, the implants were manually inserted using a handheld screwdriver (Jeil, Korea) until the distance between the bone and mini-implant collar

Figure 2. Tested mini-implant type: Dual Top Screw 1.6 × 10 mm (Jeil, Korea).

reached 0.7 mm, 1.7 mm, or 2.7 mm (Figures 3 and 4). Every combination of insertion depth and predrilling diameter was repeated 25 times. In each bone segment, five Dual Top Screws (1.6 × 8 mm) were used as reference to establish compatibility between the bone segments (Figure 5).

Afterward, final screwing by another 0.2 mm up to the definite insertion depth (Figure 6) was performed by the Robotic Measurement System. The central component of the measuring system is a precision robot RX60 (StäubliTec-Systems GmbH, Bayreuth, Germany), which was equipped with a precision potentiometer (WHALE 300, Contelec, Biel/Bienne, Switzerland) functioning as an angle sensor as well as a torque sensor (8625-5001, Burster Präzisionsmesstechnik GmbH, Gernsbach, Germany). The moment sensor was coupled with the mini-implant using the driver shaft of the Dual Top System. The analog signals delivered by the sensors were digitized by the multichannel measuring device Spider 8 (Hottinger Baldwin Messtechnik GmbH, Darmstadt, Germany) and were stored in a personal computer. The software of the measuring system was programmed in such a way that the robot arm performed a rotation of 80° within 2 seconds (Figure 6).

All maximum insertion torques were transferred to a

Figure 3. Manual insertion using a handheld screwdriver (Jeil, Korea) up to different distances between bone and collar (in this case, 0.7 mm).

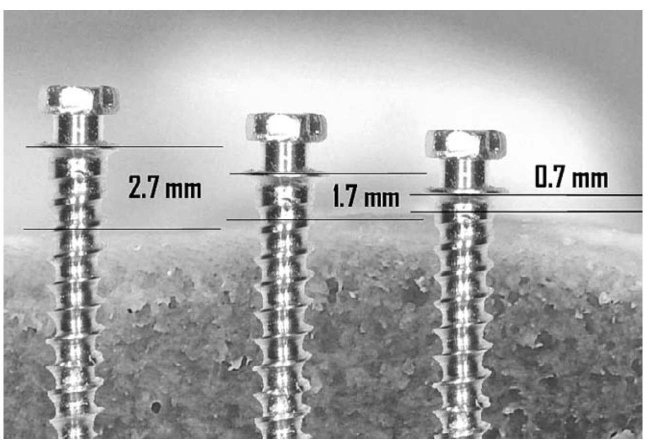

Figure 4. Different insertion depths before torque evaluation (7.3, 8.3, 9.3 mm) measured by the respective different distances between bone and collar (2.7, 1.7, 0.7 mm).

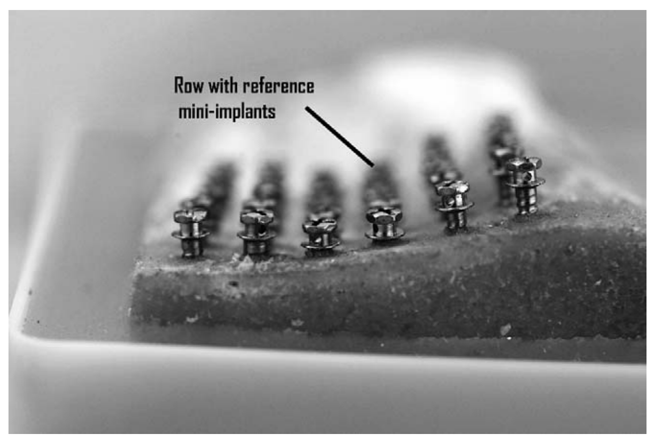

Figure 5. Bone segment with different distances from bone to collar (from left to right: 1.7, 1.7, 0.7, 0.7, 1.7, and 2.7 mm). In one row, five Dual Top Screws (1.6 × 8 mm) were used as a reference to establish comparability between the bone segments.

pivot table (Excel 2003, Microsoft) and categorized depending on the parameter insertion depth and predrilling diameter. The significance of the mean value differences was evaluated by Kruskal-Wallis tests (SPSS 15.0, Chicago, Ill). The maximum error was limited to $P < .05$.

RESULTS

The insertion depth influenced the measured insertion torques distinctively: the mean insertion torque for the insertion depth of 7.5 mm was 51.62 Nmm (±25.22); for insertion depth of 8.5 mm, 65.53 Nmm (±29.99); and for the insertion depth of 9.5 mm, 94.38 Nmm (±27.61). The differences were highly statistically significant ($P < .001$; Table 1; Figure 7). In particular, the final part of the insertion (insertion depth of 8.5 mm to 9.5 mm) results in a massive increase in insertion torque.

The predrilling diameter also had a major impact on

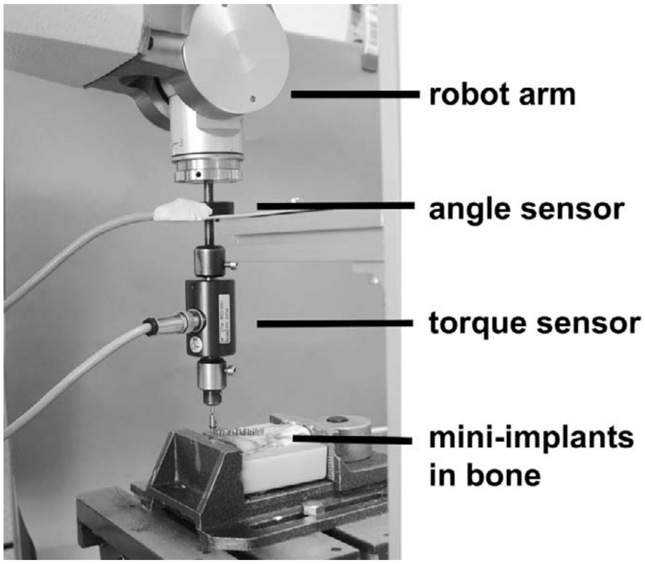

Figure 6. Construction of the measurement system, comprising a precision potentiometer functioning as an angle sensor, a torque sensor, and the driver shaft.

the measured insertion torques: the mean insertion torque employing the predrill of 1.0 mm was 83.50 Nmm (±33.56); for predrill of 1.1 mm, 77.50 Nmm (±27.54); for the predrill of 1.2 mm, 61.70 Nmm (±28.46); and for the predrill of 1.3 mm, 53.10 Nmm (±32.18). The differences were highly statistically significant ($P < .001$; Table 1; Figure 8). Figure 9 displays each combination of insertion depth and predrilling diameter and the area of the recommended placement torque[12] for mini-implants with a diameter of 1.6 mm.

DISCUSSION

The measured insertion torques in this study using an animal bone model were similar to values derived from other studies[12,13] and to our clinical measurements (unpublished data). Higher insertion depths resulted in higher insertion torques/primary stabilities. Larger predrilling diameters resulted in lower insertion torques.

Mini-implant failure rates described in the literature still seem to be unsatisfactory. One important goal at the time of insertion is to achieve a proper insertion torque/primary stability of the mini-implant. For mini-implants with a diameter of 1.6 mm, an insertion torque of 5 Ncm to 10 Ncm (50 Nmm to 100 Nmm) is favorable to minimize the risk of a failure.[12,13] Higher

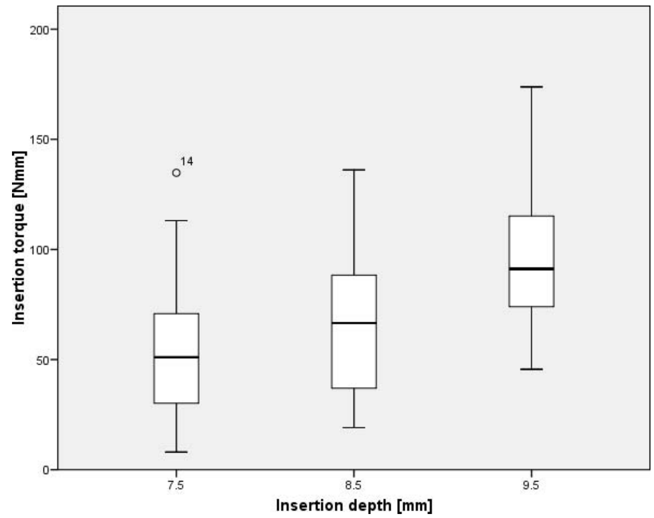

Figure 7. Insertion torques depending on the different insertion depth. The differences were highly statistically significant ($P < .001$).

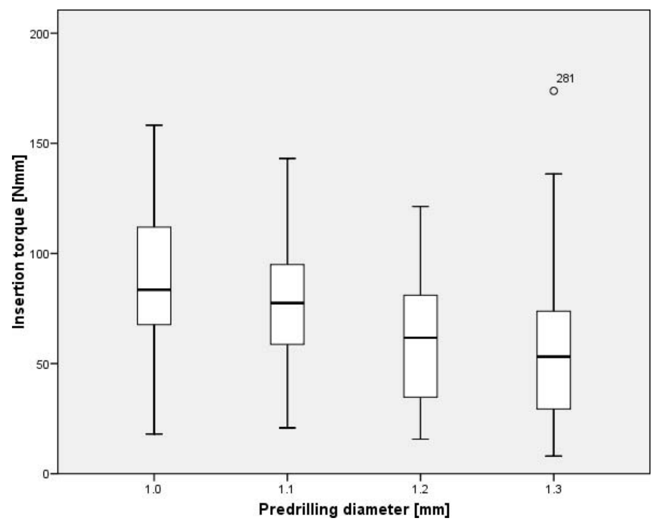

Figure 8. Insertion torques depending on the different predrilling diameters. The differences were highly statistically significant ($P < .001$).

Table 1. Insertion Torques Depending on Insertion Depths and Pre-drilling Diameters

	Insertion Depth, Nmm			
	7.5	8.5	9.5	All Insertion Depths
Predrilling diameter, mm				
1.0	70.80 (±28.38)	86.20 (±24.62)	116.60 (±26.24)	83.50 (±33.56)
1.1	58.40 (±22.97)	72.50 (±23.58)	93.90 (±24.39)	77.50 (±27.54)
1.2	39.10 (±18.35)	37.00 (±30.66)	83.50 (±19.58)	61.70 (±28.46)
1.3	29.80 (±19.07)	43.30 (±28.90)	79.60 (±28.37)	53.10 (±32.18)
All diameters	51.62 (±25.22)	65.53 (±29.99)	94.38 (±27.61)	

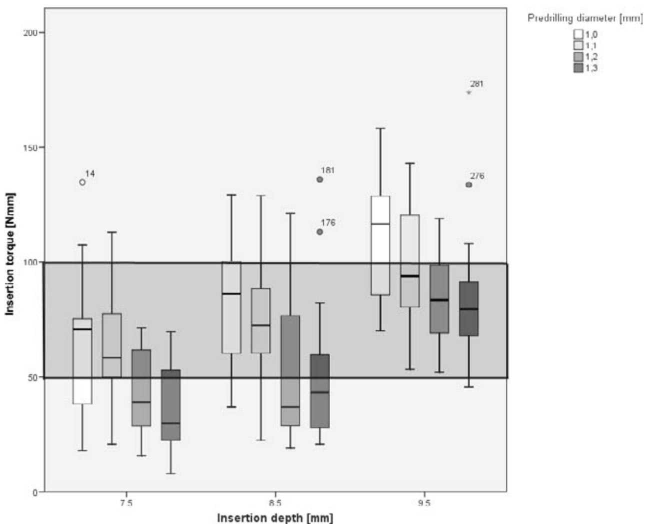

Figure 9. Insertion torques depending on insertion depth and predrilling diameter. The area of the recommended placement torque (50 Nmm to 100 Nmm) for mini-implants with a diameter of 1.6 mm is marked.

values may result in higher failure rates due to a distinctive bone compression with microdamages[24] or even to mini-implant fracture at torque moments above 200 Nmm.[18] As a consequence, it seems important to adapt the clinical procedure to the local circumstances (bone quality, thickness of the gingiva, available space) and the insertion procedure (transgingival vs submucosal insertion).

Besides variables that are given, such as the local bone quality, there are variables clinicians could change to achieve a proper primary stability:

1. The diameter of the mini-implant has a major effect on the insertion torque[17,18,20,23] but is limited to the available space.[25]
2. Derived from this study, the insertion depth has an impact that should not be underestimated. As a consequence, mini-implants should be inserted as deeply as possible to achieve a proper insertion torque. To achieve this in the case of transgingival insertion, a site with a thin attached gingiva (1 mm to 1.5 mm) is generally recommended. This can be measured easily prior to insertion of the mini-implant (Figure 10). In addition, a high insertion depth is recommended not only to achieve proper stability but also to avoid large tipping moments, which may also lead to an implant failure due to high stresses in the cortical bone.[26]
3. This study also demonstrated the effect of the predrilling diameter: As anticipated, the larger the diameter of the predrill, the smaller the insertion torque. If the mini-implant is inserted only 7.5 mm, use of large predrilling diameters (1.2 mm and 1.3 mm) resulted in insertion torques below the 50-Nmm threshold (Figure 9). As a consequence, in locations with a thick gingiva (eg, palate or maxillary tuberosity), the use of small predrill diameters or even no predrilling seems favorable. On the other hand, at sites with high bone quality and very thin gingiva, or if the mini-implant is to be inserted submucosally, predrilling with a larger diameter is recommended to avoid to excessive insertion torques. This seems to be valid for self-drilling mini-implants (like in this study, which employed Dual Top Screw), as well.

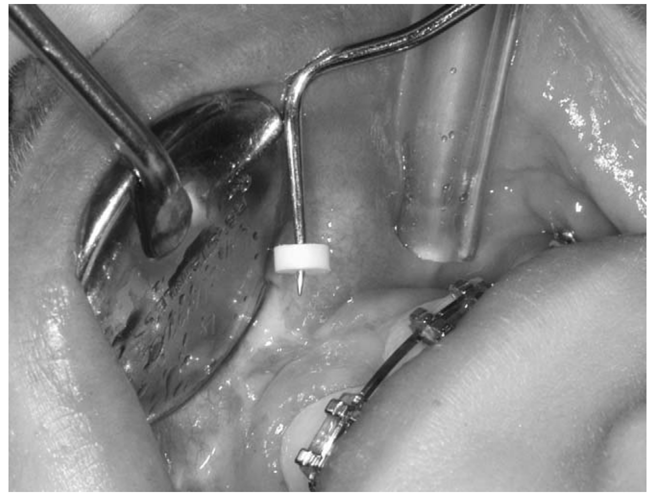

Figure 10. Measurement of gingiva thickness by a dental probe and a rubber stop from endodontics.

Whether the maximum insertion torque (MIT) is appropriate for implant stability evaluation is controversially discussed in dental implantology. According to our findings, MIT measurement is a reliable method to assess primary stability, at least for orthodontic mini-implants. We found a high correlation between maximum insertion and removal torque, Periotest, lateral loading capacity, and ISQ values delivered by Osstell Mentor.[27]

Besides insufficient insertion torque and primary stability, other factors are currently regarded as possible reasons for implant loss:

1. application of excessive forces acting on the mini-implant[26,28];
2. a large lever arm (thick gingiva)[26,28];
3. peri-implantitis, when inserted in the mucosa[9]; and
4. bone damage at insertion (bone compression/bone overheating). This phenomenon is known from dental implantology[29] and could be a reason for the implant loss of mini-implants at very high insertion torques in the mandible.

CONCLUSIONS

- Higher insertion depths result in higher insertion torques/primary stabilities. Larger predrilling diameters result in lower insertion torques/primary stabilities.

- A measurement of gingiva thickness prior to mini-implant insertion is recommended. Mini-implants should generally be inserted at a site with a thin gingiva to achieve a proper primary stability and to avoid large tipping moments.
- If a mini-implant has to be inserted in a site with a thick gingiva, a predrill with a small diameter or no predrilling is recommended. If a mini-implant is to be inserted at a site with a very thin gingiva or submucosally, a predrilling with a larger diameter is recommended to avoid excessive insertion torques.

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