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Tolerance within the sleeve inserts of different surgical guides for guided implant surgery

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Abstract

Objectives: Recently, guided implant surgery has been introduced and several studies verified its accuracy. While those studies reported on the accuracy of the entire procedure, this experiment wanted to evaluate the degree of deviation that can occur during the drilling procedure alone, due to the tolerance of the drill in the sleeve insert.

Material and methods: Drilling was executed in a plexi-glass box with a maximal inclination of the drills within the sleeve insert. Different sleeve inserts, sleeve positions, sleeve heights, sleeve insert heights and diameters were evaluated.

Results: The two tested sleeve inserts gave a maximum deviation in angulation of 5.2° and a maximum horizontal deviation of 1.3 mm at the implant shoulder and 2.4 mm at the apex for a 13 mm implant. These deviations decreased if the distance of the sleeve above the plexi-glass box became smaller and hand hold sleeve inserts gave less deviation than drill hold sleeve inserts. The deviation increased by longer implant length, larger drill key diameter, shorter sleeves and/or drill key heights.

Conclusions: For a minimal deviation during the surgery with a stereolithographic guide, it is very important to use the drill in a centric position, parallel to the cylinder. The use of longer drill keys and sleeves are critical for optimal accuracy.

The introduction of computer-based guided implant surgery has been an important development in implant dentistry. Guided implant surgery makes it possible to transfer the planned three-dimensional position of the implant from the computer to the surgical site. As such the restoration can be fabricated prior to surgery and even placed into the patient's mouth immediately after surgery. Besides an improved prosthetic planning, it also allows a better positioning of the implants towards vital anatomical structures such as the maxillary sinus, the mandibular canal and the mental foramen (BouSerhal et al. 2002). The surgical intervention becomes fast, minimally invasive and more predictable.

Both *ex vivo* (Sarment et al. 2003; Van Assche et al. 2007; Ruppin et al. 2008; Pettersson et al. 2010a) as well as *in vivo* (Steenberghe et al. 2002; Ozan et al. 2009; Pettersson et al. 2010b; Vasak et al. 2011) studies described the accuracy of the transfer from the planning to the surgical field by surgical guides for oral implants. The accuracy of the entire procedure is defined as the deviation between the position of the placed and the planned implant. It is a quantitative evaluation, which calculates the angle between both positions and/or the deviation at the neck and/or the apex of the implant. The measurements are done on fused pre- and postoperative CT images. A recent review (Schneider et al. 2009) reported *ex vivo* a mean deviation of 1 mm at the neck and 1.4 mm at the apex together with a mean angle deviation of 4.9°. *In vivo* a mean deviation of 1.2 mm at the neck and 2 mm at the apex and a mean angle deviation of 5.7° were found. The deviation between the planned and the placed implant is a summation of all individual errors (Widmann & Bale 2006). These errors can be associated with the scanning, processing, surgery and prosthetics (Block & Chandler 2009).

One possible source for error is the deviation during drilling due to the tolerance of the drill in the sleeve insert. This error is till now checked in one *ex-vivo* study only considering the position of the sleeve as influencing factor (Van Assche & Quirynen 2010).

The aim of the current study was to test the impact of different types of sleeve inserts, the sleeve insert height, the sleeve insert diameter and finally the sleeve height on the accuracy.

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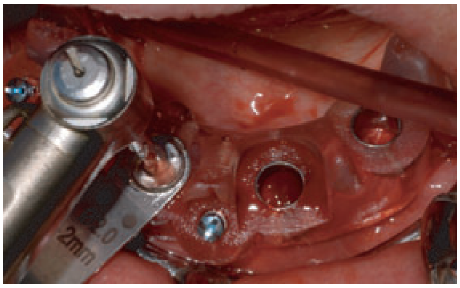

Fig. 1. Clinical situation with stereolithographic guide, sleeve insert and drill.

Material and methods

Stereolithographic surgical guides consist of a sleeve in which a sleeve insert and drill are inserted (Fig. 1). Depending on the system, the sleeve is placed on a specific height above the future implant shoulder (e.g. 9 mm for NobelGuide®; NobelBiocare, Göteborg, Sweden), or the height of the sleeve insert can vary (Facilitate®; AstraTech, Mölndal, Sweden). The following experiments were performed by one clinician (R.K.). In each experiment one drilling procedure per group has been performed (n = 1).

Sleeve insert type

In the first experiment the accuracy of hand hold sleeve inserts (drill key) or drill hold sleeve inserts (guide sleeve) was tested (Fig. 2a). Sleeves of 4 mm were stepwise mounted on top of a plexi-glass box, the latter representing the bone (Fig. 2b). The distances between the apex of the sleeve and the box were 3, 5, 7 and 9 mm respectively. For this experiment the SurgiGuide universal® system (Materialize, Leuven, Belgium) was used as a hand hold sleeve insert, and the Expertease® system (Dentsply Friadent, Mannheim, Germany) for the drill hold sleeve insert; each system with its respective inserts and drills. For each system two drill diameters were used: for SurgiGuide universal® 1.95 and 3.15 mm and for Expertease® 2.0 and 2.9 mm. The plexi-glass box was properly fixed in a bench vice. Cavities (representing osteotomy sites) of 8 and 13 mm were prepared by inclining the drill maximal to the left and to the right (Fig. 2c).

Sleeve insert height

For this experiment hand hold sleeve inserts from the Facilitate® system with a height of 5 and 8 mm were used, which were, respectively, 1 and 4 mm above the sleeve (thus same distance away from bone, Fig. 3). Drills of Facilitate® with diameters of 2.0 and 3.2 mm, respectively, were used.

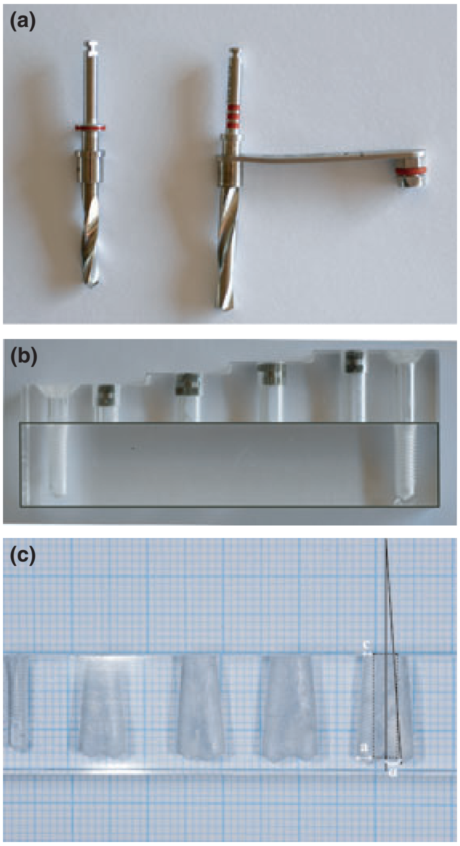

Fig. 2. (a) At left the drill hold sleeve insert and at right the hand hold sleeve insert attached to the drill. (b) Box representing surgical guide (from left to right) with sleeves at a distance of 3, 5, 7 and 9 mm from a plexi-glass box representing the bone (box surrounded by black line). At left and right two screw holes are visible to attach the surgical guide to the bone. (c) Plexi-glass box after preparation of osteotomies with maximal inclination of the drill within the sleeve insert to the left and right placed on millimetre paper (dotted line represents the theoretically ideal osteotomy). Measured distances and angle from theoretically ideal osteotomy, mean of mesial and distal measurements; c, coronal deviation from ideal osteotomy; a, apical deviation from ideal osteotomy; α, deviation in angulation from ideal osteotomy.

Sleeve insert diameter

For this test, two different hand hold sleeve inserts from the SurgiGuide universal® system were used with an internal diameter of, respectively, 3.2 and 3.3 mm for a 3.15 mm drill from the same system. The position of the sleeves of 4 mm was similar as in the first experiment (Fig. 2b).

Sleeve height

Sleeves of, respectively, 3, 5, 7 and 9 mm in height were used in this test (Fig. 4). The coronal parts of the sleeves were 11 mm away from the bone. The hand hold sleeve insert height was 9 mm, of which 1 mm was above the sleeve. This sleeve insert was made for this experiment and was not commercially available. Two drill diameters were used 2.0 and 3.0 mm.

Data collection

After the preparation of the osteotomies, the plexi-glass box was placed on top of scale paper for calibration. A digital image was made with a Nikon® D80 (Shinjuku, Tokyo, Japan) digital camera. The image was imported in Gimp 2.6® (http://www.gimp.org) software to measure the horizontal deviation at the neck and apex and the deviation in angulation of the osteotomy in comparison with the theoretically ideal osteotomy, see Fig. 2c. These measurements were done for the right and left extreme deviated osteotomies and the mean was calculated. The deviations at the neck and the apex were measured as pixel values after having determined the centre points at the preparation entrance and apex, and these values were then converted into mm using a reference level (scale paper [calibrated in millimetres] behind the plexi-glass box). As already mentioned only one drilling procedure for each condition has been performed. Therefore, only descriptive data are reported.

Results

Sleeve insert type

The apical and coronal deviation increased for both sleeve inserts if the distance from the sleeve towards the bone (box in plexi-glass) became larger. This was also observed when increasing the osteotomy depth from 8 to 13 mm. For the drill hold sleeve inserts the deviations were considerably higher than for the hand hold sleeve inserts, especially for the 2 mm drill. The angulation (α) between the ideal and the extreme deviated osteotomy increased for both sleeve insert types with increasing distance from the sleeve to the bone. The drill hold sleeve insert had a mean α of 5° (range: 4.9–5.2) for a drill diameter of 2.9 mm and osteotomy depth of 13 mm, whereas the hand hold sleeve insert had a mean α of 4.5° (range: 3.9–5.2) for a drill diameter of 3.15 mm and osteotomy depth of 13 mm (Table 1).

Sleeve insert height

Lower apical and coronal deviations as well as angulations were observed if the sleeve insert became longer (Table 2).

Sleeve insert diameter

An increase of 0.1 mm in sleeve insert diameter (3.2 mm vs. 3.3 mm) gave only slightly higher apical and coronal deviations, as well as minimal changes in angulation for the

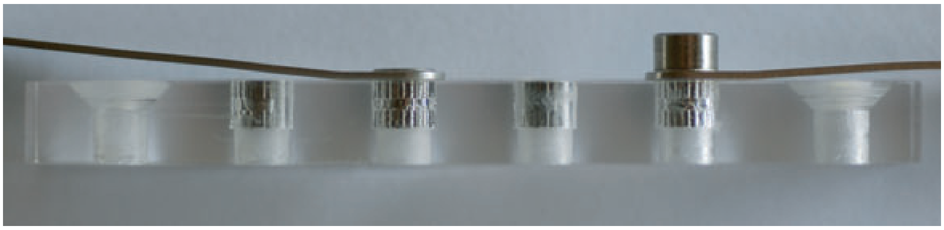

Fig. 3. Surgical guide with sleeves 3 mm from bone. At left 5 mm and at right 8 mm hand hold sleeve insert (drill key).

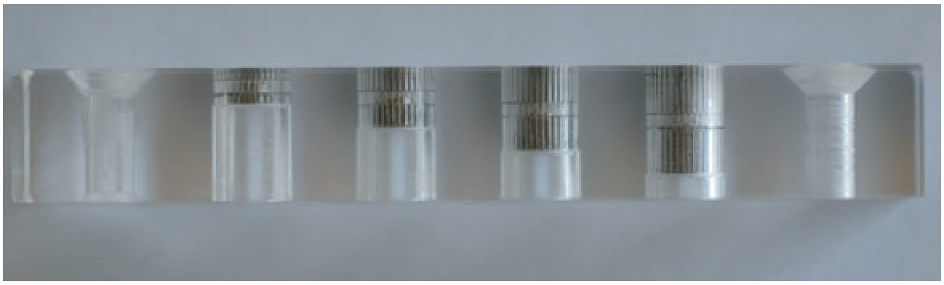

Fig. 4. Surgical guide (from left to right) with different sleeve heights of 3, 5, 7 and 9 mm respectively.

Table 1. **Measurements of uni-lateral deviation towards the ideal position for osteotomies of 8 and 13 mm for two different sleeve inserts (*n* = 1)**

Distance sleeve-bone ⇒ Osteotomy depth and ∅ drill(mm) ⇓	3			5			7			9*		
	c	a	α	c	a	α	c	a	α	c	a	α
Drill hold sleeve insert												
8/2.0	0.6	1.1	2.7	1.0	1.4	3.7	1.1	2.0	6.9	1.5	2.3	7.0
13/2.0	0.7	1.2	2.8	1.0	2.1	5.6	1.2	2.5	6.7			
8/2.9	0.8	1.5	3.9	1.0	1.6	4.1	1.2	1.8	4.4	1.5	2.0	4.5
13/2.9	0.9	2.0	4.9	1.1	2.2	5.0	1.2	2.4	5.2			
Hand hold sleeve insert												
8/1.95	0.4	0.5	1.5	0.6	0.9	2.5	0.8	1.1	2.3	0.9	1.4	3.0
13/1.95	0.5	0.7	1.7	0.6	0.9	2.4	0.9	1.2	2.6	0.9	1.6	3.5
8/3.15	0.6	0.9	1.2	0.8	1.3	3.3	1.1	1.9	4.7	1.4	1.9	3.2
13/3.15	0.7	1.7	3.9	0.8	1.7	4.5	1.1	2.2	5.2	1.3	2.2	5.1

*The drills for the hand hold sleeve insert were not long enough to drill the osteotomy of 13 mm where the sleeve is positioned 9 mm above the plexi-glass box.
∅, diameter; c, coronal deviation in millimetres; a, apical deviation in millimetres; α, angular deviation in degrees.

Table 2. **Measurements of uni-lateral deviation towards the ideal position for osteotomies of 8 and 13 mm for different hand hold sleeve insert heights (drill key heights) (*n* = 1)**

Sleeve insert height ⇒	5			8		
Osteotomy depth and ∅ drill (mm) ⇓	c	a	α	c	a	α
8/2.0	0.7	1.0	3.0	0.3	0.4	1.2
13/2.0	0.7	1.4	3.9	0.5	0.7	1.3
8/3.2	0.7	1.2	3.7	0.6	0.9	2.0
13/3.2	1.0	2.1	4.6	0.8	1.8	4.0

∅, diameter; c, coronal deviation in millimetres; a, apical deviation in millimetres; α, angular deviation in degrees.

sleeves which were placed 3 and 5 mm from the bone. Except for situations where sleeves were placed 7 or 9 mm from the bone there was a clear difference between the different diameters. The better the fit, of course, the smaller the deviation (Table 3).

Sleeve height

Decreasing apical and coronal deviations as well as angulations were observed with increasing sleeve heights. The best observations were made with 7 mm sleeves and higher (Table 4).

Discussion

The introduction of stereolithographic guides improved the accuracy of implant placement in comparison with the conventional surgical guides (Sarment et al. 2003; Vercruyssen et al. 2008), but there are still deviations from the planned ideal position as shown in a recent review (Schneider et al. 2009). One of these errors is the amount of deviation that can already occur during the drilling procedure due to the tolerance of the drill in the sleeve insert. This was already shown in a previous study, where an increase in sleeve height to the bone or in osteotomy length gave larger apical and coronal deviations as well as angulations for hand hold sleeve inserts (Van Assche & Quirynen 2010), which was confirmed in this study. The use of drill hold sleeve inserts, which was not tested in the previous study, gave for all measurements larger deviations than hand hold sleeve inserts. A possible explanation for the latter could be, that it is only attached to the drill which can be less stable than a hand hold sleeve insert which is also stabilized by the hand of the surgeon. The maximum coronal and apical deviations and angulations for both sleeve inserts were slightly higher than the mean deviations in the review of Schneider et al. (2009), but did not reach the maximum deviations as described in the review of Jung et al. (2009). Another observation was an increase in angular deviations for deeper osteotomies. A possible explanation can be the cutting of metal of the sleeve insert by the drill and as a consequence widening of this insert. Attrition of sleeves and drills is a cumulative phenomenon that occurs with every drilling operation. A study of Horwitz et al. (2009) showed that multiple use of drills and sleeves on resin jaw models significantly reduced the system accuracy. To prevent this wear, a guideline for the maximum number of times for using the sleeve insert could be useful, although a precise number of drillings cannot be recommended either from this study or from the study of Horwitz et al. (2009). Another possibility of preventing wear is intra-operative real-time tracking of the surgical instruments. This technology seems to give the same deviations as stereolithographic guides (Ruppin et al. 2008). A last option is to create a device that guides the drills in which wear and heating is not possible.

An increase in sleeve insert height will lower the coronal and apical deviation as well as the angulation, which will improve the accuracy of the implant placement (Van Assche & Quirynen 2010). The use of higher sleeve inserts for a better accuracy is advisable, but not available for every system.

A discrepancy between the drill and sleeve insert is needed to prevent heating and cutting of metal, but it unfortunately creates a

Table 3. **Measurements of uni-lateral deviation towards the ideal position for osteotomies of 8 and 13 mm for sleeve inserts with less or more fitting diameters (*n* = 1)**

Distance sleeve-bone ⇒ Sleeve insert ∅ and osteotomy depth (mm) ⇓	3			5			7			9		
	c	a	α	c	a	α	c	a	α	c	a	α
Sleeve insert ∅												
3.2/8	0.6	0.9	1.2	0.8	1.3	3.3	1.1	1.9	4.7	1.4	1.9	3.2
3.2/13	0.7	1.7	3.9	0.8	1.7	4.5	1.1	2.2	5.2	1.3	2.2	5.1
3.3/8	0.7	1.4	3.8	1.2	1.9	4.8	1.3	1.9	4.4	1.3	2.0	5.1
3.3/13	0.8	1.6	3.5	1.1	2.2	4.9	1.5	2.9	6.3	1.9	3.4	7.0

∅, diameter; c, coronal deviation in millimetres; a, apical deviation in millimetres; α, angular deviation in degrees.

Table 4. **Measurements of uni-lateral deviation towards the ideal position for osteotomies of 8 and 13 mm for different sleeve heights, but the same insert (*n* = 1)**

Sleeve height ⇒ Osteotomy depth and ∅ drill (mm) ⇓	3			5			7			9		
	c	a	α	c	a	α	c	a	α	c	a	α
8/2.0	1.0	1.5	3.8	0.8	1.1	2.9	0.6	0.7	1.1	0.6	0.8	1.4
11/2.0	1.0	1.6	3.6	0.8	1.1	1.8	0.6	0.8	1.8	0.6	0.8	1.3
8/3.0	1.1	1.7	3.2	0.9	1.3	2.4	0.7	1.0	1.4	0.7	1.0	1.5
11/3.0	1.2	2.0	3.2	1.1	1.4	2.0	1.0	1.1	0.9	1.0	1.1	1.1

∅, diameter; c, coronal deviation in millimetres; a, apical deviation in millimetres; α, angular deviation in degrees.

certain tolerance. It was shown that a difference of 0.1 mm in diameter gives minimal changes in deviations for situations where the sleeve is placed 3 or 5 mm from the bone. Some systems have standard distances from the sleeve to the bone, but for other systems this distance can vary. In guides where the sleeve is placed 3 or 5 mm from the bone the use of a wider sleeve insert diameter is advisable to prevent metal particles in the osteotomy and possible necrosis of the bone due to heating. The use of conventional guides or freehand drilling does not have this problem but will give less accuracy (Besimo et al. 2000; Sarment et al. 2003).

Sleeves of 7 and 9 mm gave less deviation compared with shorter sleeves. Nowadays short sleeves up to 5 mm are commonly used, but for a more precise implant placement it can be better to use longer sleeves. Unfortunately not every system has different sleeve heights.

In this study a plexi-glass box was representing the bone. The density of a plexi-glass box is higher than that of bone, and it is more homogeneous. It is shown that deviations seem to be influenced by the local bone quality and quantity (Kalt & Gehrke 2008). In the mandible, the deviation in mesio-distal direction is significantly less than in the maxilla (Vasak et al. 2011). Hence, deviations observed in this study could be smaller than deviations that can be produced in *ex-vivo*, or patient studies, but as the drills were really forced in both directions, it is still believed that data from this study probably are good indications for the extremes. Unless these drawbacks one should realize that the bigger the distance between sleeve and bone, the more deviation one can expect, but the use of stereolithographic guides with hand hold- or drill hold sleeve inserts still give significant improvement over conventional guides (Sarment et al. 2003).

During surgery, a parallel and central positioning of the drill is crucial as illustrated in this and the previous study (Van Assche & Quirynen 2010). Although these extreme inclinations probably occur infrequently, rare situations can provoke them. For example, in the posterior region of the mouth especially in patients with limited mouth opening (Akca et al. 2002; Valente et al. 2009; Vasak et al. 2011). This situation can provoke an extreme inclination of the drill. Some systems use lateral openings in the surgical guide for an easier insertion of the drill and sleeve insert. A dominant cortex or the lamina dura of an extraction socket can force the drill to the way with the least resistance. Self-tapping, sharp implants are recommended for this type of surgery as well as sharp drills. A significant learning effect could also be registered with regard to decrease in deviations (Valente et al. 2009; Vasak et al. 2011).

Conclusion

To have a minimal deviation during the surgery when using a stereolithographic guide, it is very important to use the drill in a centric position, parallel to the cylinder. The use of longer sleeve inserts and sleeves will help to realize this. The clinician is also advised to move the drill several times in and out the guide in order to feel the smoothest drill position.

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