Title:

Measurement of the zygomatic bone and pilot hole technique for safer installation of zygomaticus implants.

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Abstract:

The zygomaticus implant (Brånemark system, Nobel Biocare, Gotebörg, Sweden) was developed for patients with severe bone resorption of the posterior maxilla, which may eliminate or minimize the need for bone grafting. Although the zygomaticus implant has had a remarkable success rate in a difficult patient population, the method requires an advanced surgical technique and carries increased risk of complications, such as the perforation of the orbital floor or infratemporal fossa. Although it is important to have a detailed understanding of the anatomy of the zygomatic bone when performing the installation, there have been few anatomic studies on the zygomatic bone for installation of zygomaticus implants. In this study, we measured the height and thickness of the zygomatic bone for the installation. The thickness at a 90-degree angle point, where the upper margin of the zygomatic arch and the temporal margin of the frontal process of the zygomatic bone intersect and where the apex of the implant penetrates, according to the original method, was 1.8 ± 0.4 mm, which gradually increased inferiorly and anteriorly. In conclusion, the penetration point of the apex of the zygomaticus implant should be located more inferoanterior to the 90-degree angle point, as the thickness of the 90-degree angle point is thinner than the diameter of the implant. Based on these results, we have proposed a newer and safer installation method for the zygomaticus implant using a drill guide, which can be easily made.

Key words: maxillary sinus, sinus floor augmentation, zygomatic bone, zygomaticus implant

In the molar region of the maxilla, certain length dental implants often cannot be installed due to severe alveolar bone resorption and the presence of the maxillary sinus. Although onlay or inlay bone grafts are normally used in these cases, there is usually a low rate of success of the implants in the bone graft area (Kahnberg et al. 2001; Raghoebar et al. 2001; Lekholm et al. 1999; Clayman. 2006). Lekholm et al. (1999) reported on the success rates of implants placed in autogenous bone grafts performed by five separate techniques: local onlay graft full onlay graft maxillary inlay graft (sinus floor augmentation), combined onlay/inlay graft and Le Fort I osteotomies. A total of 781 Brånemark implants were inserted, and the majority of patients were treated with simultaneous bone grafting. The overall implant survival rate was approximate 80% after three years. Onlays, inlays and LeFort I osteotomies showed almost identical success rates (76 - 84%), whereas the onlay/inlay technique resulted in less favorable outcomes (60%). In addition, these bone-grafting techniques often require the harvesting of bone from the iliac bone, which causes severe mental and physical strain for the patient.

The zygomaticus implant (Brånemark system, Nobel Biocare, Goteborg, Sweden) was developed for patients with severe bone resorption of the posterior maxilla, which can eliminate or minimize the need for bone grafting and can support an implant-anchored fixed prosthesis (Jensen et al. 1996; Stella & Warner 2000; Higuchi 2000; Bedrossian & Stumpel 2001; Stevenson & Austin 2000). The overall success rate for the zygomaticus implant is 97.9%, which included a total of 1541 implants placed over a three-year-time span (Goiato et al. 2014). Regarding the management of similar patient populations, the aforementioned success rate supersedes any previously published success rates of implants in grafted bone with severely resorbed maxillae (Kahnberg et al. 2001; Raghoebar et al. 2001; Lekholm et al. 1999; Stella & Warner 2000; Clayman 2006). When compared with bone grafts, zygomaticus implants have the advantage of a reduced total treatment time, as bone grafts require an extended healing time, especially with the two-stage procedure, in which the bone grafting is followed by the placement of the implants (Higuchi 2000; Bedrossian & Stumpel 2001).

Although the success rates of zygomaticus implants are high, treatment requires an advanced surgical technique and carries the risk of severe complications, such as the perforation of the orbital floor or infratemporal fossa. Therefore, it is important for dentists to have a detailed understanding of the anatomy of the zygoma before performing surgery for the installation of zygomaticus implants. Although there have been anatomic studies regarding the linear and angular measurements for the installation of zygomaticus implants (Uchida et al. 2001; Rossi et al. 2008; Corvello et al. 2011), there is a paucity of information regarding the thickness of the zygoma.

In this study, we measured the height and thickness of the zygomatic bone and proposed a new and safer installation method. The method used for the zygomaticus implant consisted of the pilot hole technique using a drill guide; this can be easily performed without the use of a computer-aided surgical navigation system.

Materials and Methods

CADAVERS

Thirteen Japanese cadavers were used for practical anatomic training at University of Tokushima. The body heights of the cadavers ranged from 148 to 179 cm (159.4 ± 9.2 cm) and the ages ranged from 62 to 88 years (79.9 ± 8.3 years). According to their medical histories, they had not had any diseases involving the zygoma, maxilla or maxillary sinus, and they did not show any facial asymmetries. Their sinus membranes were all shown to be healthy when the maxillary sinus was exposed. In each specimen, the maxilla and zygoma were taken out, and the surrounding soft tissue was removed from the bone. Seven of the 26 specimens were excluded, as they had maxillary molars. Nineteen specimens without molar teeth were evaluated by the following measurement system.

LANDMARKS AND MEASUREMENTS

From the lateral view, the point of intersection (the so-called 90-degree angle point) between the upper margin of the zygomatic arch and the temporal margin of the frontal process of the zygomatic bone was designated as point A (Fig. 1). A perpendicular line to the upper margin of the zygomatic arch was drawn from point A. The intersection point between the perpendicular line and the lower margin of the zygomatic arch was designated as point B. Segment A-B was divided into four parts, which were designated, starting from the superior-most aspect, as points A1, A2 and A3. The middle point on the line extending from the upper margin of the frontal process of the zygomatic bone, between the orbital margin and the temporal margin of the frontal process of the zygomatic bone, was designated as C1. The perpendicular line to the upper margin of the zygomatic arch was drawn from point C1, and the intersection point between the perpendicular line and the lower margin of the zygomatic arch was designated as point C5. Segment C1-C5 was divided into four parts, which were designated, starting from the superior-most aspect, as points C2, C3 and C4. The thickness of each point (A, A1, A2, A3, C1, C2, C3 and C4) was measured five times using calipers (Mitsutoyo, Kanagawa, Japan). The starting point for the installation of a zygomaticus implant was in the second premolar region of the maxillary alveolar process, in a slightly palatal position (Higuchi 2000; Uchida et al. 2001). Because the specimens had no molar teeth, the position of the second premolar was estimated from the infraorbital foramen, according to Uchida's method (2001). The starting point for the installation of the zygomaticus implant was shifted 3 mm toward the palatal side from the second premolar. As a reference for the length of the possible zygomaticus implant, the distances from the starting point to each point on the outer surface of the zygomatic bone were also measured.

For the statistical analysis, Student's t-test was performed to identify measurement differences between males and females using the "Stat View 5.0" program (Abacuus Concepts Inc., Berkeley, CA, USA). For the correlation analysis, the Pearson's correlation coefficient was calculated using the same program; the correlation was tested by applying the Fisher test. The critical p value was set at 0.05.

Results

The height and thickness of the zygomatic bone at each point are summarized in Table 1.

The thickness at point A (corresponding to the 90-degree angle point) was 1.8

± 0.4 mm. The thickness gradually increased from point A to A2 and from point C1 to C3. The thicknesses at points A, A1, A2 and A3 were thinner than the corresponding anterior points C1, C2, C3 and C4, respectively. In other words, the more inferoanterior portion was thicker than point A. Although no significant differences in the height of the zygomatic bones between males and females were observed, the zygomatic bones in the females (at all points, except point A) were significantly thinner than in the males.

Table 2 summarizes the distances from the starting point to each point on the outer surface of the zygomatic bone. For all specimens, the mean distances ranged from 42.4 to 55.5 mm. There were no significant differences in the distances from the starting points to their respective corresponding points between males and females.

The thickness of the zygomatic bone at some of the measured points (A, A1, A3, C3 and C4) correlated to the body height (Table 1). However, there was no correlation found between the body height and the height of the zygomatic bone. In addition, the distance from the starting point to each point on the outer surface of the zygomatic bone did not correlate to body height.

Discussion

According to the procedures for zygomaticus implant placement by Nobel Biocare AB, a twist drill with a 2.9-mm diameter should be slowly advanced in order to penetrate the alveolar crest, the maxillary sinus and the zygomatic bone from the oral cavity. The drill should penetrate the 90-degree angle point between the zygomatic arch and the temporal margin of the frontal process of the zygomatic bone. However, the present study clearly demonstrates that the thickness of the 90-degree angle point is less than 2.8 mm, which is the diameter of the apex of the zygomaticus implant. This means that the apex of the zygomaticus implant would be exposed from the inner side or both (inner and outer) sides of the temporal process of the zygomatic bone even if the orientation of the twist drill was perfect. The inner space of the zygomaticus bone, the infratemporal fossa, contains many important anatomical structures, such as the temporalis muscle, the maxillary artery and its branches and the pterygoid plexus. Although, to date, no severe complications of the zygomaticus implant have been reported, we believe that this method would have an increased possibility of severe complications than that of an ordinary dental implant procedure.

Frodel et al. (1993) reported that the bone surrounding an osseointegrated implant should contain at least a 1-mm thickness. In other words, the thickness of the zygomatic bone around the apical portion of the implant should be at least 4.8 mm. Moreover, because the diameter of the implant gradually increases, eventually reaching 4.0 mm (4.3 mm from the apex), the thickness of the zygomatic bone should be more than 6.3 mm. An oral and maxillofacial surgeon should also note that the threads of the implant may be exposed, particularly on the inside, from the zygomatic bone in females.

There is a decreased risk of perforation on the outer side of the zygomatic bone when compared with the risk of a perforation on the inner side; this is likely because soft tissue is detached from the bone and is protected by a retractor during the installation. Considering the thickness of the zygomatic bone at the 90-degree angle and the risk of a perforation of the zygomatic bone, we recommend that the zygomaticus implant should penetrate the outer side of the zygomatic bone at an inferoanterior position to the 90-degree angle point, which corresponds to point C1 or C2. This is particularly important in females and short people, as the thickness of the female's zygomatic bone is significantly thinner than in males; in addition, the thickness of the zygomatic bone correlates to body heights.

The installation method, where the twist drill is aimed at the 90-degree angle point from the alveolar process, advanced and exactly penetrating this point, is difficult secondary to the narrow surgical field. This is very difficult in practice and may cause complications in the zygomaticus implant. Using a round but to make a mark on the outer side of the zygomatic bone with a small hole inferoanterior to the 90-degree angle point followed by advancement of the twist drill toward the hole using the drill guide may help lead the tip of the drill to the hole. This is much easier and more precise than directly aiming at the 90-degree angle point from the alveolar process, as the hole is much easier to see than the 90-degree angle point. The pilot hole technique, using the drill guide described above, could reduce the risk of complications for the installation of the zygomaticus implant.

1) DRILL GUIDE

Our drill guide resembles the original drill guard supplied by Nobel Biocare and consists of two parts: a drill guard and a drill direction indicator (Fig. 2). The tip of the drill direction indicator indicates the direction of the drill guard. Because the drill guard has a 3.0-mm diameter, the twist drill, with a 2.9-mm diameter, can reach the tip of the drill direction indicator thorough the drill guard with little play. The drill direction indicator also has a curve, which aids in avoiding the frontal process of the maxilla when using the tip to reach the hole.

2) PILOT HOLE TECHNIQUE

To determine the pathology in the maxillary sinus and to evaluate the zygomatic bone volume and the topography of the anterior wall of the temporal fossa (and the presence of concavities), an examination by computed tomography (CT) is recommended before the installation of the zygomaticus implant. A photocurable plastic skull model produced from the CT scan can be useful for a simulation of the installation of the zygomaticus implant, the determination of the point on the zygomatic bone where the apex of the implant would penetrate and the selection of the length of the implant (Fig. 3).

Under general anesthesia, a LeFort I vestibular, or crestal, incision from one maxillary tuberosity to the contralateral tuberosity is made (Higuchi 2000; Stella & Warner 2000; Stevenson & Austin 2000). With a periosteal elevator, a traditional LeFort I exposure is made, extending around the base of the piriform rim, up to the inferior aspect of the infraorbital nerves. The exposure is in a posterior-superior direction to the lateral surface of the zygomatic bone up to the 90-degree angle point, according to the recommendation for the zygomaticus implant placement by Nobel Biocare. A bony window on the lateral wall of the maxillary sinus, or a bony slot using the sinus slot technique (Stella & Warner 2000), is made, and the sinus membrane is lifted away from the area where the zygomaticus implant will pass through the sinus.

First, a small bony hole, using a round bur, is made as a landmark point on the zygomatic bone, which is located inferoanterior to the 90-degree angle point (where the apex of the implant will penetrate) (Fig. 3). The tip of the drill direction indicator is hooked onto the hole. Next, the tip of the drill guard is placed on the starting point of the zygomaticus implant on the maxillary alveolar crest (usually at a position in the second premolar region and in a slightly palatal position). The length between the tip of the drill direction indicator and that of the drill guard can be adjusted and fixed by a lateral screw (Figs. 4 and 5). In other words, the portion from the alveolar crest to the lateral surface on the zygomatic bone where the zygomaticus implant will be placed is nipped by the drill guard and the drill direction indicator. Drilling, using a twist drill with a 2.9-mm diameter, is then performed through the drill guide (Fig. 6). It is important that the drill penetrates the posterior-superior roof of the maxillary sinus very slowly, as the direction of the drill is oblique to the plane of the roof and is apt to change internally and anteriorly. The rest of the procedure is identical to the procedure recommended by Nobel Biocare.

The pilot hole technique, using the drill guide, is considered to provide a much safer and more exact installation of the zygomaticus implant. In addition, the drill guide can also be useful when an ordinary installation is performed. One disadvantage of this technique is that the starting point on the alveolar crest is located slightly palatally, as the penetration point of the apex of the implant is lower and is inclined to move laterally. In this case, the sinus slot technique could provide a solution (Stella & Warner 2000).

In conclusion, the penetration point of the apex of the zygomaticus implant should be located inferoanterior to the 90-degree angle point because the thickness of the 90-degree angle point is thinner than the diameter of the implant. The pilot hole technique, using the drill guide, could provide a much safer and more precise installation of the zygomaticus implant. The drill guide may also be useful when performing an ordinary installation.

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Legends

Fig. 1 Landmarks and measurements of the zygomatic bone.

From the lateral view, the intersection point (so called 90-degree angle point) between the upper margin of the zygomatic arch and the temporal margin of the frontal process of the zygomatic bone was designated as point A. The perpendicular line to the upper margin of the zygomatic arch was lowered from point A. The intersection point between the perpendicular line and the lower margin of the zygomatic arch was designated as point B. Segment A-B was divided into four parts, which were designated as points A1, A2 and A3 from the upper side, respectively. On the extension line of the upper margin of the frontal process of the zygomatic bone, the middle point between the orbital margin and the temporal margin of the frontal process of the zygomatic bone was designated as C1. The perpendicular line to the upper margin of the zygomatic arch was lowered from point C1 and the intersection point between the perpendicular line and the lower margin of the zygomatic arch was designated as point C5. Segment C1-C5 was divided into four parts, which were designated as points C2, C3 and C4 from the upper side, respectively. The thickness of each point (A, A1, A2, A3, C1, C2, C3 and C4) was measured.

Fig. 2 The drill guide consists of two parts, the drill guard (G) and the drill direction indicator (I). The tip of the drill direction indicator is consistent with the direction of the drill guard. The twist drill, with a 2.9-mm diameter, can reach the tip of the drill direction indicator thorough the drill guard, with little play because the drill guard has a 3.0-mm diameter. The drill direction indicator also has a curve, which can avoid the frontal process of the maxilla for the tip to reach the hole. The length between the tip of the drill direction indicator and that of the drill guard can be adjusted and fixed by a lateral screw (S).

Fig. 3 Simulation of the pilot hole technique using a photocurable plastic skull model produced from the CT. A small bony hole as a landmark point on the zygomatic bone, which is located lower and anterior to the 90-degree angle point, and where the apex of the zygomaticus implant will penetrate, is made with a round bur.

Fig. 4 Simulation of the pilot hole technique using a photocurable plastic skull model. The tip of the drill direction indicator is hooked onto the hole. The tip of the drill guard is put onto the starting point of the zygomaticus implant on the maxillary alveolar crest (usually at a position in the second premolar region and in a slightly palatal position). The length between the tip of the drill direction indicator and that of the drill guard can be adjusted and fixed by a lateral screw.

Fig. 5 Surgical view of the pilot hole technique. The tip of the drill direction indicator is hooked onto the hole. The portion from the alveolar crest to the hole on the zygomatic bone where the zygomaticus implant will be placed is nipped by the drill guard and the drill direction indicator. The curve of the drill direction indicator avoids the frontal process of the maxilla for the tip of the indicator to reach the hole.

Fig. 6 Simulation of the pilot hole technique using a photocurable plastic skull model. The drilling of the twist drill with a 2.9-mm diameter is being performed through the drill guide. At this time, it is important that the drill penetrates the posterior-superior roof of the maxillary sinus very slowly because the direction of the drill should be oblique to the plane of the roof and is apt to be changed internally and anteriorly. The drill guide can lead the tip of the drill to the hole.

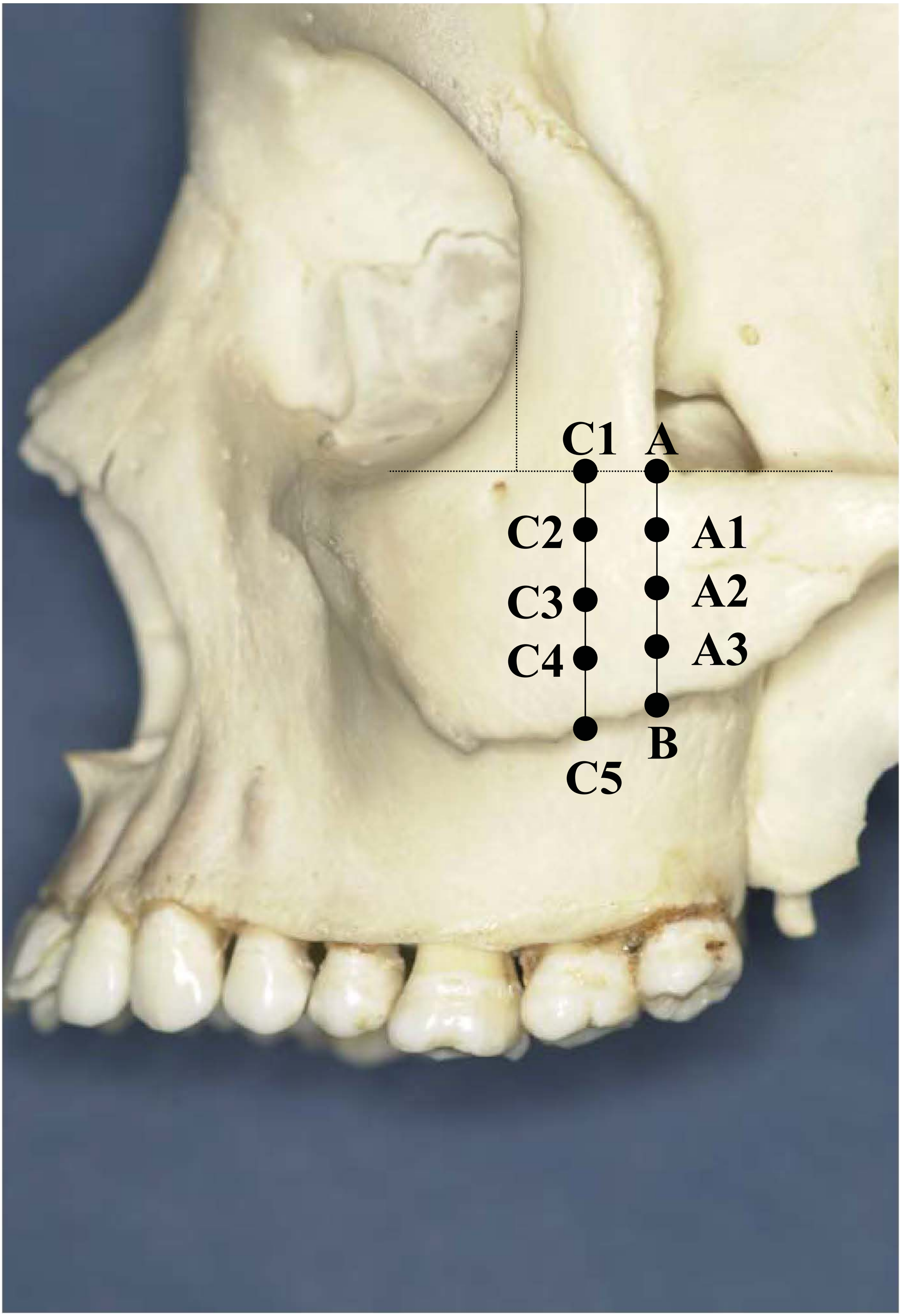

Fig. 1

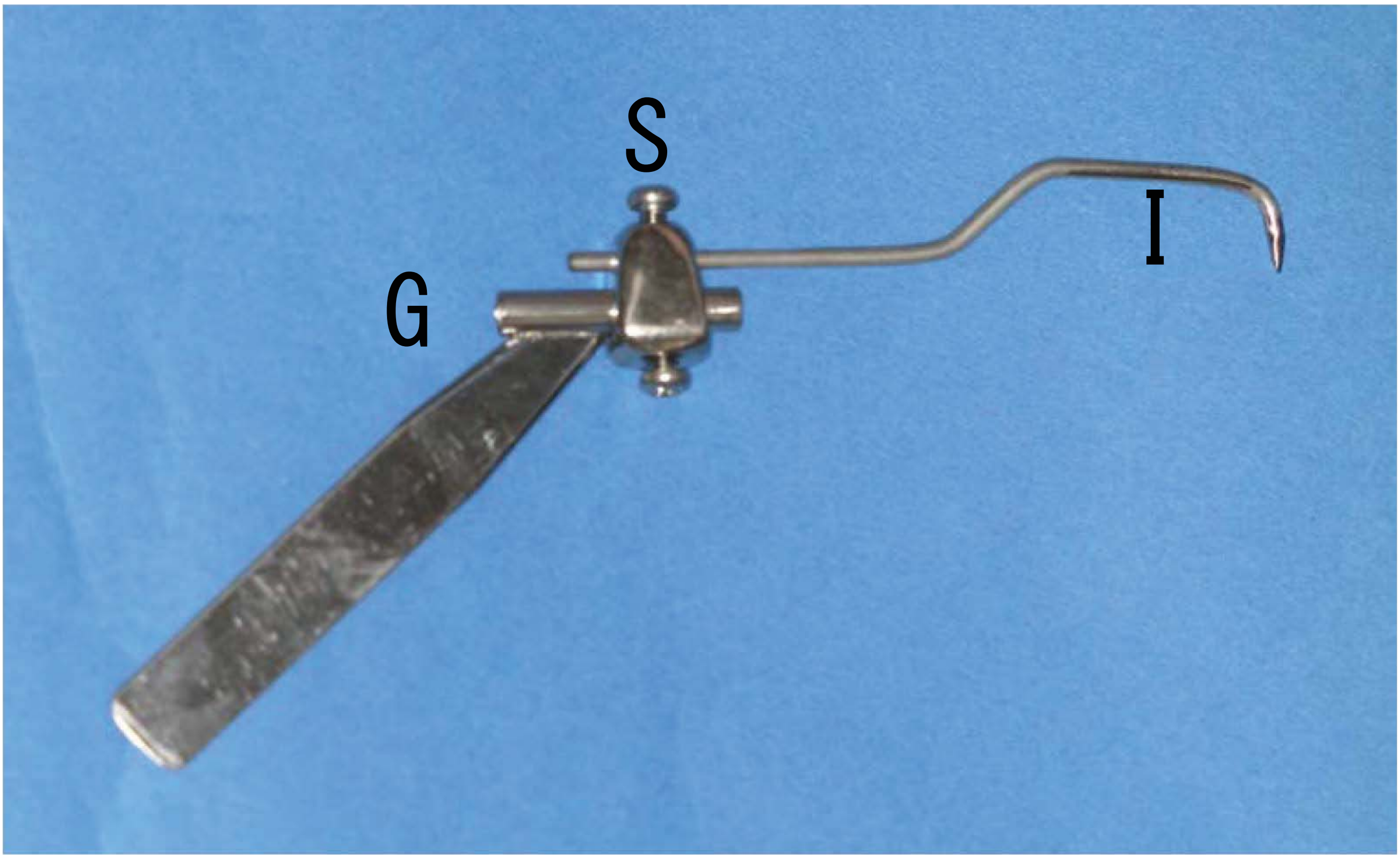

Fig. 2

Fig. 3

Fig. 4

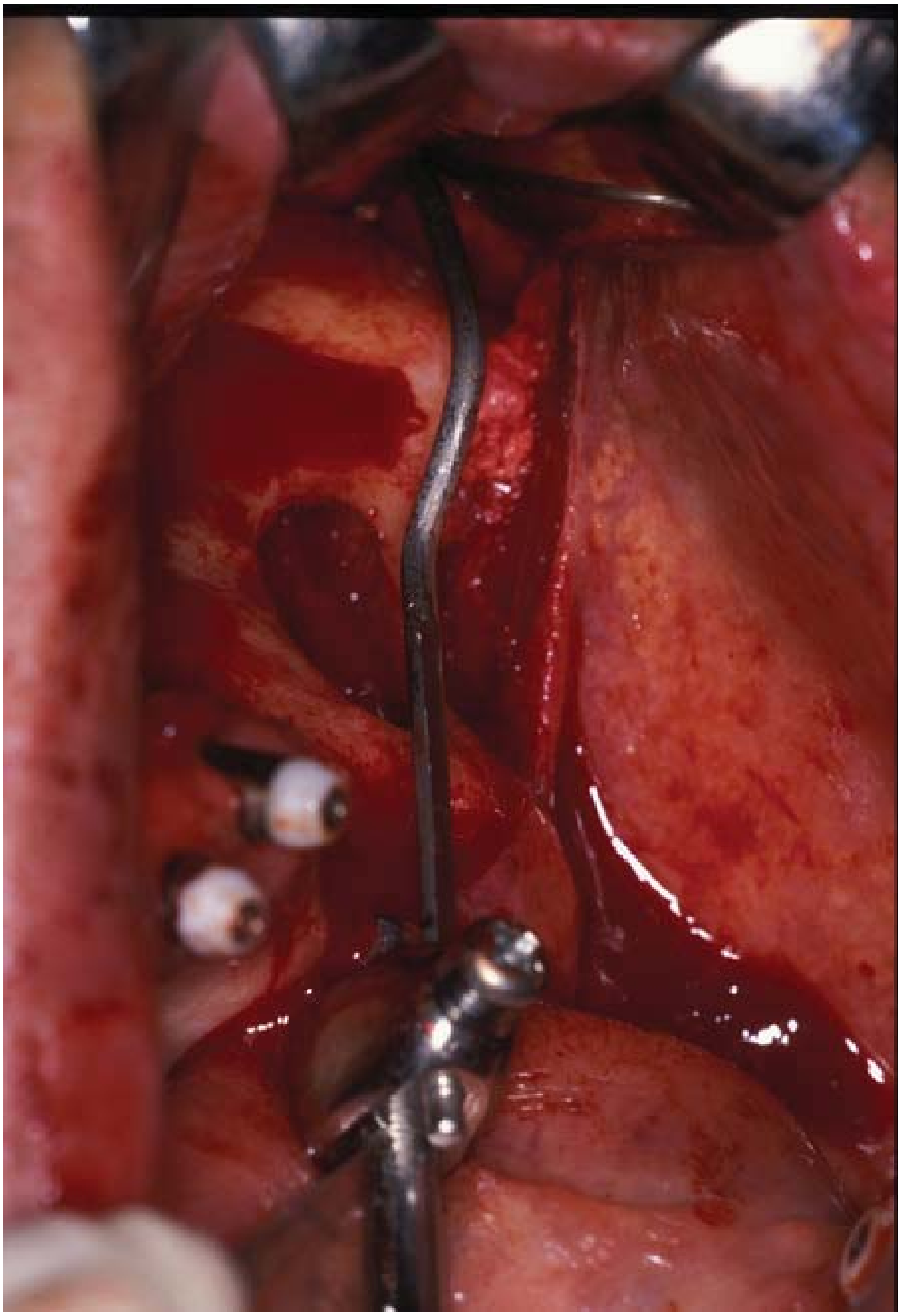

Fig. 5

Fig. 6