Evaluation of the blood and nerve supply patterns in the molar region of the maxillary sinus in Japanese cadavers

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Summary: The maxillary sinus (MS) in the maxilla bone is located near the orbit, the nasal cavity and the oral cavity; however, the positioning of the constituent bones is complex. The posterior superior alveolar branches of the maxillary artery and nerve are distributed in the lateral wall of the MS. The courses of these blood vessels and nerves are restricted by the morphology of the craniofacial bones, and the landmarks used in dental implant treatment of these courses mainly run along the lateral wall of the MS. In this study, 19 human cadavers with 34 sides of Japanese origin (ranging in age from 59–94 years, mean 77.7 ± 9.8 years) were prepared for measurement of the MS, the superior alveolar artery and the infraorbital artery using cone beam computed tomography (CBCT). The posterior superior alveolar artery (PSAA) of the lateral wall of the MS can be classified into one of three groups based on the supply pattern. In the greatest number of cadavers, the PSAA ran mainly to the lateral surface of the zone between the superior border of the alveolar foramen and the inferior border of the MS (53.0%, 18/34). In others, the PSAA ran to the zone between the infraorbital foramen and the superior border of the alveolar foramen (17.6%, 6/34); in a third group, the PSAA ran to the zone between the inferior border of the MS and the greater palatine foramen (23.5%, 8/34). The lest of two sides are spread out in this area (5.9%, 2/34).

CBCT is the most accurate tool to evaluate important anatomical parameters, such as the distance of the blood supply, for the implant of grafts in the floor of the MS during surgical procedures.

Introduction

The size of the MS has been reported directly from the examination of cadavers, the radiography of living patients (Jun, 2005; Wolf et al., 1993; Shah et al., 2003; Kim et al., 1999; Scuderi et al., 1993; Park et al., 2000; Moon et al., 1998; Koo et al., 1993; Kawarai et al., 1999; Jun et al., 2003) and in studies of changes in its volume during aging (Ariji et al., 1994). Many studies have also reported the effect of tooth loss on the size of the maxillary sinus (Saglam, 2002). In one study, the apices of the teeth and surrounding structures were analyzed by computed tomography (CT) (Eberhardt et al., 1992). There is the variation in the size of the MS as a function of age and the presence of teeth in detail using CT (Ariji et al., 1994). In a separate study, CT was used to obtain overlapping 1.2-mm axial images that were taken at 1-mm intervals, and the axial images were reconstructed into cross-sections (Mardinger et al., 2007). A cone beam CT (CBCT) system can be used to obtain high-resolution (voxel size 0.1 mm) images of the MS and to perform volumetric analysis (Howe, 2009). Stratemann et al. reported that CBCT systems provide highly accurate data compared with physical measurements (Stratemann et al., 2008).

The anterior superior alveolar, middle superior and posterior superior alveolar arteries supply blood to the lateral wall of the MS. However, previous reports that were based on the examination of cadavers indicated only the presence of the supply from the posterior superior alveolar artery (PSAA) in this region of the MS. Traxler et al. (1999) reported that the arterial supply of
the maxilla originated from the PSSA and the infraorbital artery, with an intraosseous anastomosis between these two vessels. They described the pattern of blood vessel branching and anastomosis in the lateral wall of the MS. However, there are few reports employing CBCT to describe the supply of the PSAA to the MS.

Moreover, the CBCT analysis of the normal structure of the maxilla and the course of the PSAA also provides useful information for surgical procedures involving dental implant surgery in the alveolar process of the maxilla. Our study was focused on measurement of the maxilla and description of the vascular network of the sinus membrane using cadaver dissection and CBCT analysis.

Materials and Methods

Maxillae were examined from 19 human cadavers, aged 59–94 years (mean, 77.7 ± 9.8 years; male, 80.0 ± 10.7 years; female, 75.1 ± 8.5 years). We eliminated four sides that had remarkable external injury and artifact with metal materials.

Cone beam CT (CBCT) images

Images of 19 maxillae (34 sides) were acquired using CBCT (Alioth: ASAHI Roentgen Industry, Kyoto, Japan). The cone beam scans were operated around the maxilla bone with a tube potential of 80 kV, a tube current of 4 mA, and high-resolution cylindrical areas 51 × 51 mm in size were acquired (voxel size 0.1 mm). The Frankfurt horizontal (FH) plane of each maxilla was placed parallel to the floor. The region of interest (ROI) was set as the anterior region of the maxilla to place the incisive canal at the center of the ROI. The images were reconstructed from the CBCT data using proprietary Asahi Vision image reconstruction software (Asahi Roentgen Industry Co., Ltd).

Five measurement points in the maxilla were taken from the radiograph for location of the blood supply. The locations of the four measurement points were determined from CBCT images of the maxilla. Measurement A is the height from the greater palatine foramen inferior-posterior border to the superior border of the MS; measurement B is the height from the greater palatine foramen point to the most superior border of the infraorbital foramen; measurement C is the height from the greater palatine foramen point to the most superior border of the alveolar foramen; and measurement D is the height from the greater palatine foramen to the top of the inferior border of the MS. Measurement E gives the size of the greater palatine foramen. We defined five lines to delineate three areas of the lateral surface of the maxilla, each running parallel to the Frankfurt horizontal plane: the SBMS line (passing through point A), the SBIF line (passing through point B), the SBAF line (passing through point C), the IBMS line (passing through point D), and the GPF line (passing through point E).

Ethics

Cadavers were obtained by consensual donation according to the guidelines provided by the Law Concerning Body Donation for the Law Concerning Cadaver Dissection and Preservation (LCCDP).

Results

Measurements of the lateral surface of the MS

CBCT images of 34 sides were used to obtain the measurements of the MS in this study. The mean with standard deviation of the distance from the GPF to IBMS, GPF-SBIF, GPF-SBIF and GPF-SBMS are 3.03 ± 1.81, 8.83 ± 1.53, 13.45 ± 2.05 and 23.08 ± 1.63 mm. No significant differences with respect to cadaver age or
sex were observed.

During the dissection of cadavers, the PSAA and the posterior superior alveolar nerve (PSAN) were clearly identified on the lateral wall of the MS (Fig. 1a). The PSAA of the lateral wall of the MS from the first premolar to the most superior border of the alveolar foramen was classified according to the supply pattern and placed into one of three groups. In Pattern 1, the PSAA ascended to the zone between the SBIF line and the SBAF line (17.6% of specimens, 6/34); in Pattern 2, the PSAA descended to the zone between the IBMS line and the SBAF line (53.0% of specimens, 18/34); and in Pattern 3, the PSAA extended to the zone between the IBMS line and the GPF line (23.5% of specimens, 8/34). The lest

Fig. 2. The three patterns of blood vessel supply and CBCT images in the posterior lateral wall of the maxillary sinus
(A) The PSAA ran to the zone between the SBIF line and the SBAF line (Pattern 1 see Fig. 1).
(B) CBCT image of Fig. 2A.
(C) The PSAA ran to the zone between the IBMS line and the SBAF line (Pattern 2).
(D) CBCT image of Fig. 2C.
(E) The PSAA ran to the zone between the IBMS line and the GPF line (Pattern 3).
(F) CBCT image of Fig. 2E.
of two sides are spread out in this area (5.9%, 2/34) and which could not be classified into one of the three pattern groups. The PSAA never ran to the zone between the SBMS line and the SBIF line.

Discussion

In general, CT equipment is expensive and delivers a relatively high radiation dose to the patient. In contrast, CBCT employs lower levels of radiation and provides three-dimensional information (Garg, 2007; Monsour and Dudhia, 2008). Therefore, CBCT can provide useful information about MS morphology. Such information can contribute to the knowledge of the effects of vasodilation on surgical implant of grafts in the floor of the MS, effects that are not well understood at present because of the complex and anastomosis-containing branching of the PSAA in the lateral wall of the MS (Solar et al., 1999; Traxler et al., 1999; Mardinger et al., 2007; Ella et al., 2008). Our CBCT system provided high-resolution images (voxel size 0.1 mm) for three-dimensional reconstruction of the structure of the inside of the MS. Specifically, we were able to locate the landmark of the superior border of the alveolar foramen in the course of the PSAA using CBCT. From this site, the PSAA runs to the anterior region of the lateral wall of the MS. Traditional radiographic information is not adequate for describing the course of this artery in cadavers with complex bone structures. When planning for the insertion of dental implants, it is necessary to view the locations of blood vessels and nerves at this site in more detail. CBCT provides the most precise information on the structure and its location in the complex site of the maxilla. In this study, the PSAA mainly ran to the lateral surface of the zone between the superior border of the alveolar foramen and the inferior border of the MS. In this area, Traxler et al. (1999) reported that the arterial supply of the maxilla originated from the PSSA and the infraorbital artery, which formed an intrasosseous anastomosis. They described the pattern of branching of the blood vessels and anastomoses in the lateral wall of the MS. The PSAA and PSAN are the most important blood vessel and nerve, respectively, supplying the mucous membrane of the MS (Murakami et al., 1994). In our study, the PSAA ran along the inner region of the bone of this site, and the PSAA in 21% of specimens ran to the zone between the greater palatine foramen point and the top of the inferior border of the MS, posing a risk of complications during dental implant of grafts in the floor of the MS. During sinus floor elevation for dental implant placement, there is a risk of injuring blood vessels and nerves at this site. Thus, information on the location of the PSAA is necessary to avoid complications. Most high rate of distance of superior border of alveolar foramen is 8.83 mm height from greater palatine foramen in our results. Previous investigators have reported that the anastomosis is located 23–26 mm from the alveolar ridge (Solar et al., 1999) and various distances from the alveolar crest for each region of teeth (5–34 mm) (Mardinger, 2007). These studies’ measurement point is the alveolar process, which shrinks as a result of tooth loss; therefore, we performed each measurement from the greater palatine foramen. CBCT is the most accurate tool to evaluate important anatomical parameters in the molar region, such as distance to the blood supply, for implant of grafts in the floor of the MS.

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