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Vascularization of the Facial Bones by Facial Artery: Implications for Full Face Allotransplantation.

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Products used in this study:

Lead oxide powder (Science Stuff, Austin, TX)

Powdered gelatin (Aldon Corp., Avon, NY)

Abstract

Background-Maxillary artery is recognized as the main vascular supply of the facial bones; nonetheless clinical evidence supports a co-dominant role for the facial artery. This study explores the extent of the facial skeleton within a facial allograft that can be harvested based on the facial artery.

Methods-Twenty-three cadaver heads were used in this study. In 12 heads, the right facial, superficial temporal and maxillary arteries were injected. In 1 head, facial artery angiography was performed. Ten facial allografts containing the mandible, naso-orbito-maxillo-zygomatic complex and tongue were raised. The soft tissues were dissected to show the arterial anastomotic connections and thereafter removed. Radiograms and CT scans were performed.

Results-Constant anastomosis between the facial, inferior alveolar and infraorbital arteries at the mental and infraorbital foramina were found. Facial artery vascularized the homolateral mandibular symphysis, body and ramus. The condylar and coronoid processes were vascularized in 67% of the allografts. The homolateral maxilla was contrasted in all allografts with the exception of the alveolar and palatine processes which contained the contrast in 83% of specimens. The maxillary process of the zygomatic bone was perfused in all allografts, followed by the body, frontal (83%) and temporal processes (67%). The nasal lateral wall and septum were vascularized in 83% of the allografts. The medial and lateral orbital walls and the orbital floor were stained in all specimens. The zygomatic process of the temporal bone was the least perfused bone.

Conclusions-A composite allograft containing 90-95% of the facial bones can be based on bilateral facial arteries.

Introduction

In the past 8 years, a total of 27 facial allotransplants have been performed worldwide[1]. With increased confidence in the favorable outcome of the procedure[2, 3], there has been a consistent progress towards more complex allografts including all facial soft tissues and increasing amounts of the craniofacial skeleton. To ensure the viability of all components in these composite allografts, the selection of the vascular inflow is of utmost importance[4].

Maxillary artery has been traditionally considered the main blood supply of the maxilla and mandible[5]. The role of this artery for inclusion of the maxilla in facial allotransplantation was supported in an anatomical study by Yazici et al.[6] who presented a maxillary allograft based on the maxillary artery. The authors demonstrated that the branches necessary for nutrition of the bone originated from the pterygopalatine portion of the artery.

Banks et al. [7] studied the circulatory patterns of the composite midface allografts and concluded that inclusion of the maxilla demands bilateral vascular pedicles based on the maxillary arteries. However, the deep course of the maxillary artery, in the infratemporal and pterygopalatine fossae, makes this vessel difficult to dissect and prone to injury during the osteotomies required to harvest a composite maxillo-mandibular complex in facial transplantation[4, 8]. Therefore, most of the osteomyocutaneous facial allografts were based on the facial artery[9]. The clinical experience with these allografts supported the possible co-dominant role of the facial artery in providing a physiological perfusion to the bone component of the flap[8, 10].

The aim of the present study was to assess the role of the facial artery in the vascularization of the facial bones and to determine the extent of the facial skeleton that could be safely harvested based on the facial artery as the main arterial supply.

Materials and Methods

A total of twenty-three fresh cadaver heads were studied.

Selective artery injections

Twelve cadaver heads were drained of blood and flushed with normal saline. The external carotid artery was isolated through an 8 cm longitudinal incision along the anterior border of the sternocleidomastoid muscle. The superior thyroid, ascending pharyngeal and lingual arteries were ligated.

The right facial artery (6 heads), superficial temporal (3 heads) and maxillary arteries (3 heads) were isolated and cannulated after ligating the external carotid artery distally. Lead oxide gel was prepared adding one hundred milliliters of warmed normal saline (70ºC) to 3 g of powdered gelatin (Aldon Corp., Avon, NY), and 65 g of lead oxide powder (Science Stuff, Austin, TX). Each vessel was injected with 60 ml of lead oxide gel using a 60 ml syringe and injecting in a pulsatile fashion. The bodies were refrigerated at 4ºC for 24 hours[11].

Full Facial Allograft Harvest

Ten facial allografts containing the mandible, naso-orbito-maxillo-zygomatic complex and tongue were raised based on the facial artery (6) and maxillary artery (4).

Facial Artery based Allografts

The external carotid artery was isolated as above. Hypoglossal nerve was exposed and transected. The digastrics muscle was divided at the level of the intermediate tendon exposing the facial artery. The external carotid artery was ligated distal to the origin of the facial artery. The contralateral side was prepared in the same manner; however the facial artery was ligated. Thereafter, a coronal incision was performed and the dissection continued in a subperiosteal fashion, over the frontal bone until the orbital rim was encountered. The supraorbital and suprathroclear pedicles were dissected and divided. Laterally, the dissection was continued under the deep temporal fascia up to the zygomatic arch. The temporalis muscle was removed from the temporal fossa. The coronal incision was extended along the posterior auricular groove to include the ears in the flap. Caudally, the skin incision was performed 2 cm inferior to the jaw line and crossed over the midline to the controlateral side.

On both sides, conjunctival incisions were performed at the tarsal margins of the upper and lower palpebral fornix to include the eyelids within the flap.

A modified Le Fort III osteotomy was made with an oscillating saw. The osteotomy was carried down the lateral orbital wall from the zygomatico-frontal suture to the inferior orbital fissure, across the floor of the orbit to the medial orbital wall extending behind the nasolacrimal fossa, and finally across the fronto-nasal junction. Most of the orbital floor was preserved. The zygomatic arch was cut at its base. Next, the muscles of mastication were released and removed to allow for complete disarticulation of the mandible. The origin of the pterygoid plates from the basicranium was fractured with an osteotome. The soft tissue dissection was completed above the hyoid bone (Figures 1-2).

The right facial artery was flushed with normal saline and injected with 60 ml of lead oxide gel. The flap was preserved at 4°C for 24 hours.

Maxillary Artery based Allografts

In four heads, the allograft was based on the maxillary artery. After exposure of the external carotid artery, the superior thyroid, ascending pharyngeal, lingual, facial and superficial temporal arteries were ligated. The rest of the procedure was similar to that described above. After the dissection and the osteotomies were completed, the allografts were inspected to assess the integrity of the maxillary artery.

Angiography of the Facial Artery

In one head, 60 milliliters of lead oxide gel were injected in the facial artery while the angiogram (Artis Zeego, Siemens Digital Angiography, Erlangen, Germany) was being recorded.

Soft Tissue Dissection

The soft tissues were dissected in all heads that received selective artery injection (13) and the facial allografts (10), to show the anastomotic connections between the terminal branches of the facial, superficial temporal and maxillary arteries.

Radiograms and Computed Tomography

At the end of dissection, all soft tissues, with the exception of gingival and mucosal layers of the maxillary sinus, palate and nasal cavities, were removed (Figure 3). Traditional radiograms were used to screen the mandible and the midfacial complex for the presence of the contrast. Thereafter in all specimens, CT scans (GE 64 slice

Lightspeed VCT, General Electric Company, Waukesha, WI) of the mandible and the naso-orbito-maxillo-zygomatic complex were performed (slice thickness 0.6 mm). Three-dimensional images and videos were reconstructed by GE Advantage workstation 4.2 software (General Electric Company, Waukesha, WI).

The CT scan images were used to investigate the presence of contrast in the different segments of the facial bones and in the following arteries: inferior alveolar, superior alveolar, infraorbital, major palatine, sphenopalatine (posterior septal branches, postero-lateral nasal branches) and anterior ethmoidal (anterior septal branches, antero-lateral nasal branches).

Results

Maxillary Artery Based Allografts

The origin of the inferior alveolar artery and the main trunk of the maxillary artery located within the infratemporal fossa were preserved. However, the terminal bifurcation in infraorbital and sphenopalatine arteries was damaged bilaterally in 3 allografts. All of the branches to the cranial base were severed.

Soft Tissue Dissection

Constant anastomotic connections were apparent between the terminal branches of the facial artery and inferior alveolar artery (Figures 4-5), and between the facial artery and infraorbital artery (Figure 6). These communications were at the level of the mental foramen (1-2 anastomotic branches, 0.2-1 mm in size) and at the level of the infraorbital foramen (2-3, 0.2-1 mm). The anastomotic branches communicating with the inferior alveolar artery originated from the facial artery just prior to its bifurcation into superior and inferior labial arteries or from the inferior labial artery. The branches communicating with the infraorbital artery arose from the superior labial artery, angular or lateral nasal arteries. All anastomotic branches followed the terminal divisions of the mental nerve and infraorbital nerve.

Periosteal branches originating from the facial artery were constantly present and were supplying the anterior cortex of the mandibular symphysis, body, angle and ramus, and the anterior cortex of body of the maxilla and nasal bones (Figure 7).

Consistent anastomoses were observed between the transverse facial artery and branches of the facial and infraorbital arteries.

The facial artery supplied branches to the buccal mucosa and the deep fat pad.

Radiograms and Computed Tomography Scans

In the following description, "head" indicates where only a selective injection of one of the 3 arteries was performed as opposed to "allograft" where the injection was performed after the flap was raised. Perfusion data are summarized in Tables 1 and 2.

Mandible

Facial artery vascularized the homolateral symphysis, alveolar process, body and ramus in all heads and allografts. The homolateral condyle was vascularized in 57% of the heads and 67% of the allografts. The homolateral coronoid process was perfused in 43% of the heads and 67% of the allografts. Contrast was present at the mental foramen, in the inferior alveolar artery and in the branches ending in the central foramina and central canals of the teeth as well as in the periodontal dentogingival plexus (Figure 8-9) (See

Videos, Supplemental Digital Content 1 and 2, which show the presence of contrast in both inferior alveolar arteries, INSERT LINK 1 HERE; INSERT LINK 2 HERE).

Facial artery vascularized the contralateral symphysis (100%), body, ramus and alveolar process (71%) of the heads. In the allografts, the contrast was present in 100% of the symphysis and mandibular bodies and 83% of the rami and alveolar processes. The condylar and coronoid processes of the contralateral side were the least perfused.

The maxillary artery did not perfuse the contralateral mandible.

Maxilla

The contrast was present in all components of the maxilla in more than 71% of the heads and allografts and in the mucosa of the maxillary sinus (100%) (Figures 10-11).

The contralateral maxilla was well perfused in the allografts based on facial artery (>83%). In the injected heads, the zygomatic and the frontal processes of the maxilla represented areas of weakness with contrast being detected in 28% and 57% of the cases respectively (See Videos, Supplemental Digital Content 3 and 4, which show the presence of contrast in both infraorbital and palatine arteries, INSERT LINK 3 HERE; INSERT LINK 4 HERE).

The maxillary artery contributed to the vascularization of the contralateral palatine process. The orbital process and the body of maxilla were less perfused when compared to the facial artery.

Zygomatic Bone

The body (57%), the frontal and temporal processes (43%) of the zygomatic bone were the least vascularized parts in the injected heads. The allografts contained the contrast in at least 71% of the specimens (Figure 12).

The facial artery perfused the contralateral zygomatic bone well (>83% of the allografts). The maxillary artery did not contribute to the vascularization of the contralateral zygomatic bone.

Palatine bones and nose

The palatine bones and all components of the nasal cavity were well perfused (>71%). (Figure 11).

The contralateral palatine and nasal bones contained the contrast in at least 83% of the allografts. The perfusion was less in the injected heads (71% of the palatine bones and 57% of the septa and lateral nasal walls).

The contribution of the maxillary artery to the contralateral nose was slightly better than the facial artery in the palatine and septal components (100%) and slightly worse in the lateral components (67%).

Orbit

The orbital floor contained the contrast in 100% of the injected heads and allografts. In the allografts, the medial and lateral walls of the orbit contained the contrast in all cases (Figure 12), while in the injected heads the vascularization decreased to 57%.

Facial artery vascularized the contralateral orbital walls and floor in the allografts. In the injected heads, the contralateral orbital floor contained the contrast in 71% of the cases, while the lateral and medial orbital walls were less perfused (14% and 28%). Maxillary artery perfused 67% of the contralateral orbital floors, while the lateral and medial orbital walls did not contain the contrast.

Zygomatic Process of the Temporal Bone

The zygomatic process of the temporal bone presented the lowest perfusion values: 43% of the injected heads and 50% of the allografts were stained.

Contralaterally, the facial artery contributed to the vascularization of the zygomatic process of the temporal bone in 50% of the allografts. This contribution was less in the injected heads (14%).

The maxillary artery did not perfuse the contralateral zygomatic process of the temporal bone.

Presence of the Contrast in the Intraosseus Arteries

Following injection of the lead oxide gel in the facial artery, the main homolateral arteries were stained in more than 83% of the allografts (Table 3). The injected heads presented a similar pattern of perfusion with exception of the posterior septal branches of the sphenopalatine artery. Contralaterally, the staining was consistently less and paralleled the observed perfusion of the bones.

Angiography of the Facial Artery

Angiography of the facial artery revealed retrograde flow of the contrast, through the infraorbito-facial anastomosis, in the infraorbital artery and the maxillary artery. Within the inferior alveolar artery, the contrast became evident at the junction of the mandibular body and ramus, flowing retrogradely in the direction of the condyle (see Video, Supplemental Digital Content 5, which demonstrates the retrograde flow in the infraorbital and inferior alveolar arteries, INSERT LINK 5 HERE).

Discussion

Vascularized composite allotransplantation has revolutionized the field of facial reconstructive surgery. In the 8 years following the first face transplantation, the number and the complexity of the facial allografts has increased, with greater amounts of facial skeleton being included in the allograft[1].

The success of the composite facial allografts demands full understanding of the perfusion of both the facial soft tissues and craniofacial skeleton to ensure the viability and return of function. Specifically, optimal vascularization is necessary to guarantee the return of sensation and contractile properties in the transferred muscles[3, 13], diminish bone resorption, prevent loss of teeth and avoid the creation of pockets of marginal viability which can well predispose to lethal infections. Finally, ideal vascularization is of extreme importance to counteract some of the potential complications of the systemic immunosuppressive treatment such as avascular necrosis and infection.

The pre-clinical studies based on animal models and cadaver dissection had indicated the maxillary artery as the main blood supply of the maxilla and mandible[5, 13]. Yazici et al.[6]

presented a model of vascularized maxilla based on the demonstration that the whole maxilla could be perfused by the main branches of the pterygopalatine tract of the maxillary artery. These observations were sustained by a detailed cadaveric study by the Maryland group, which showed hypovascularity of the upper maxilla and zygoma by selective injections of the superficial temporal and facial arteries. They determined that preservation of the maxillary artery was necessary for survival of the bone component of the midfacial allografts[7]. These findings were not confirmed by the progressively increasing clinical experience in facial allotransplantation, which proved that parts of the mandible, maxilla and zygoma could be safely included in the allografts based on the facial artery[4, 9, 14, 15].

The present study confirmed that the facial artery alone can sustain the perfusion of 90-95% of the lower two thirds of the facial skeleton. Contrary to the belief that the contribution of the facial artery to the vascularization of the facial bones was mainly periosteal[4], the angiography of the facial artery showed that revascularization is principally endosteal and occurs through reversal of the flow in the inferior alveolar and the infraorbital artery. Hellem and Ostrup[13] showed that in presence of blocked circulation in the inferior alveolar artery, the facial artery was the source of the retrograde perfusion of the mandible through symphyseal and periosteo-medullary anastomosis. We demonstrated that there is a rich anastomotic system between the facial artery and the maxillary artery through discrete-sized connections. The presence of these anastomoses, especially at the mental and infraorbital foramina, mandates the preservation of these anatomical landmarks during the planning and execution of the osteotomies to allow the maximal vascularity of the bones. The periosteal contribution of the facial artery to the blood supply of the facial bones was confirmed; however this role seems minor and probably cannot independently sustain the perfusion of the contralateral cortex as well as the teeth[15]. In the present study, following injection of lead oxide gel into the facial artery, the central canal branches, and the periodontal dentogengival plexus of the teeth, were contrasted; therefore, the physiologic vascularization of the teeth could be restored. Our conclusions are also supported by the presence of viable teeth in patients undergoing segmental mandible resection or surgical interruption of the inferior alveolar artery[16].These considerations, together with evidence from the clinical experience, should address the concerns of the viability of the teeth following allograft transfer.

The only bone segments which were not consistently vascularized by the facial artery were the mandibular condyle and coronoid process, the frontal and temporal processes of the zygomatic bone and the zygomatic process of the temporal bone. Although the presence of the contrast in these segments was observed in more than 50% of the specimens, caution and clinical judgment in a case to case basis should be used when including these components in the allograft. We observed that the perfusion of the facial skeleton in the allografts was better than in the selectively injected heads in the majority of the specimens, which seems to indicate that the perfusion of the bone segments improves when the distribution territory of the facial artery is smaller. Interestingly, the contribution of the facial artery to the controlateral facial bones was greater than the maxillary artery. Therefore in the event of unilateral arterial thrombosis, an allograft based on bilateral facial arteries has a greater chance of survival than an allograft based on bilateral maxillary arteries.

Conclusions

This study confirms that the facial artery can consistently support the perfusion of a composite allograft containing all the facial bones with exclusion of the mandibular condyle, coronoid process, temporal process of the zygomatic bone and zygomatic process of temporal bone. The physiologic perfusion of the teeth and deep mucosal elements of the nasal cavity and maxillary sinus is maintained.

The selection of the main arterial supply of the allograft should be made according to the location and the extent of the soft tissue defect relative to the skeletal defect, considering each side separately. Facial artery can supply both soft tissues and skeletal elements if the anastomotic connections at the level of mental and infraorbital foramina are preserved. If these connections cannot be included in the allograft or if harvest of the condylar and coronoid processes of the mandible is anticipated, the maxillary artery should be dissected as part of the vascular pedicle.

The Authors believe that bilateral vascular anastomoses should be performed, as the contribution of the facial artery seems less significant to the contralateral facial skeleton. Furthermore, bilateral anastomoses may prevent disastrous consequences of vascular thrombosis resulting from a unilateral vascular repair.

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References

1. Siemionow, M.,Z., Bassiri Gharb, B., Rampazzo, A. Successes and lessons learned after more than a decade of upper extremity and face transplantation. *curr opin organ transplant* December: In Press, 2013.

2. Gharb, B. B., Rampazzo, A., Altuntas, S. H., et al. Effectiveness of topical immunosuppressants in prevention and treatment of rejection in face allotransplantation. *Transplantation* 95: 1197, 2013.

3. Siemionow, M., Gharb, B. B., Rampazzo, A. Pathways of sensory recovery after face transplantation. *Plast. Reconstr. Surg.* 127: 1875, 2011.

4. Pomahac, B., Lengele, B., Ridgway, E. B., et al. Vascular considerations in composite midfacial allotransplantation. *Plast. Reconstr. Surg.* 125: 517, 2010.

5. Otake, I., Kageyama, I., Mataga, I. Clinical anatomy of the maxillary artery. *Okajimas Folia Anat. Jpn.* 87: 155, 2011.

6. Yazici, I., Cavusoglu, T., Comert, A., et al. Maxilla allograft for transplantation: An anatomical study. *Ann. Plast. Surg.* 61: 105, 2008.

7. Banks, N. D., Hui-Chou, H. G., Tripathi, S., et al. An anatomical study of external carotid artery vascular territories in face and midface flaps for transplantation. *Plast. Reconstr. Surg.* 123: 1677, 2009.

8. Alam, D. S., Papay, F., Djohan, R., et al. The technical and anatomical aspects of the world's first near-total human face and maxilla transplant. *Arch. Facial Plast. Surg.* 11: 369, 2009.

9. Siemionow, M., Ozturk, C. An update on facial transplantation cases performed between 2005 and 2010. *Plast. Reconstr. Surg.* 128: 707e, 2011.

10. Dorafshar, A. H., Bojovic, B., Christy, M. R., et al. Total face, double jaw, and tongue transplantation: An evolutionary concept. *Plast. Reconstr. Surg.* 131: 241, 2013.

11. Tregaskiss, A. P., Goodwin, A. N., Acland, R. D. The cutaneous arteries of the anterior abdominal wall: A three-dimensional study. *Plast. Reconstr. Surg.* 120: 442, 2007.

12. Siemionow, M., Gharb, B. B., Rampazzo, A. The face as a sensory organ. *Plast. Reconstr. Surg.* 127: 652, 2011.

13. Hellem, S., Ostrup, L. T. Normal and retrograde blood supply to the body of the mandible in the dog. II. the role played by periosteo-medullary and symphyseal anastomoses. *Int. J. Oral Surg.* 10: 31, 1981.

14. Bojovic, B., Dorafshar, A. H., Brown, E. N., et al. Total face, double jaw, and tongue transplant research procurement: An educational model. *Plast. Reconstr. Surg.* 130: 824, 2012.

15. Meningaud, J. P., Hivelin, M., Benjoar, M. D., et al. The procurement of allotransplants for ballistic trauma: A preclinical study and a report of two clinical cases. *Plast. Reconstr. Surg.* 127: 1892, 2011.

16. Casey, D. M., Aguirre, A. Dental blood supply in the segmentally resected mandible. *J. Endod.* 25: 629, 1999.

Figures' and Tables' Legend

Figure 1- A Full facial allograft containing mandible and naso-orbito-maxillo-zygomatic complex is shown. The injection cannula is inserted in the right facial artery.

Figures 2- The deep aspect of the full facial allograft: choanae, soft palate and base of the tongue are visible. Background is placed under the right facial artery.

Figure 3- Naso-orbito-maxillo-zygomatic complex (frontal and superior aspect) harvested through the modified Le Fort III osteotomy and the mandible after removal of the soft tissues are shown.

Figure 4- Following injection of the lead oxide in the facial artery, an anastomotic connection with the inferior alveolar artery is evidenced at the level of the mental foramen. This artery runs along a branch of the mental nerve. Posteriorly, 2 branches of the facial artery supplying the parasymphyseal periostium are visible.

Figure 5- Facial artery is shown bifurcating into superior and inferior labial arteries. The anastomotic connection with the inferior alveolar artery at the mental foramen and a periosteal branch arise just before the bifurcation.

Figure 6- Multiple anastomotic connections are seen between the angular artery and the terminal branches of the infraorbital artery, running along the infraorbital nerve branches.

Figure 7- Both anastomotic connections between the facial artery and inferior alveolar and infraorbital arteries and some of the periosteal branches to the mandible and maxilla are dissected.

Figure 8- CT scan of the mandible after injection of the lead oxide gel in the right facial artery confirms the presence of contrast at the level of condyle, coronoid process, ramus, angle (within the inferior alveolar canal), mental foramen and symphysis (*From top left*

to bottom right). Central canal arteries to the teeth and branches to the periodontal dentogingival plexus contained the contrast.

Figure 9- Tridimensional CT images show the presence of contrast in both inferior alveolar arteries (on the right), and in both infraorbital arteries and posterior superior alveolar arteries (on the left). Note the rich vascularization of the nasal septum, turbinates and palate and the different distribution of the contrast in the right and left sides.

Figure 10- The descending palatine artery is seen in the pterygopalatine canal, emerging from the greater palatine foramen and coursing forward in a groove on the medial side of the alveolar border of the hard palate to the incisive canal. The contrast material is present also in the palatine mucosa.

Figure 11- *Top row*: lead oxide gel is present in the posterior, central and anterior aspects of the septum and incisive foramen. *Bottom row*: the contrast is shown in the mucosal lining of the turbinates, nasal septum and palatal gingiva as well as in the palate and nasal bones.

Figure 12- The contrast is present in the infraorbital artery. The lateral orbital wall, the body of zygomatic bone and the zygomatic process of the temporal bone contain the contrast in this specimen.

Table Legends

Table 1- The presence of the contrast in the different **homolateral** bone segments was expressed as the percentage of the specimens which contained the contrast over the total number of injected specimens.

Table 2- The presence of the contrast in the different **contralateral** bone segments was expressed as the percentage of the specimens which contained the contrast over the total number of the injected specimens.

Table 3-The presence of the contrast in the different intraosseous arteries was expressed as the percentage of the specimens which contained the contrast over the total number of the injected specimens. P, process; H, Homolateral; C, Contralateral.

Supplemental Digital Content Legend

Video Graphic 1. See video, Supplemental Digital Content 1, which shows the presence of contrast in both inferior alveolar arteries. The contrast is present in both homolateral and contralateral inferior alveolar arteries. The right mandible contains more contrast than the left side. INSERT LINK HERE.

Video Graphic 2. See video, Supplemental Digital Content 2, which shows the presence of contrast in both inferior alveolar arteries. The contrast is present in both homolateral and contralateral inferior alveolar arteries. The right mandible contains more contrast than the left side. INSERT LINK HERE.

Video Graphic 3. See Video, Supplemental Digital Content 3, which shows the presence of contrast in both infraorbital and palatine arteries. The contrast is present in both homolateral and contralateral infraorbital and palatine arteries, as well as in the mucosal lining of the nose and the walls of the maxillary sinus, body of the zygomatic bone and zygomatic process of the temporal bone. The right side contains more contrast than the left side. INSERT LINK HERE

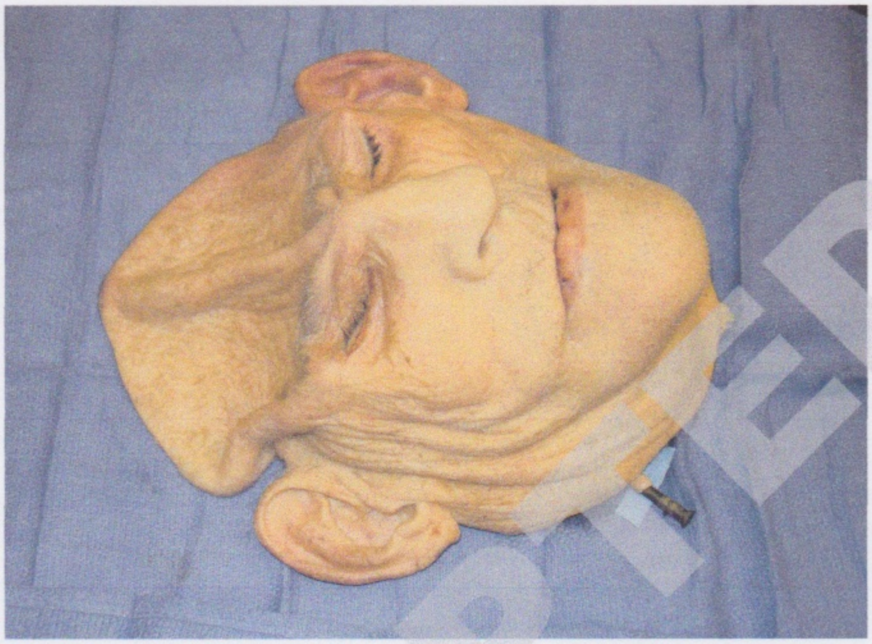
Video Graphic 4. See Video, Supplemental Digital Content 4, which shows the presence of contrast in both infraorbital and palatine arteries. The contrast is present in both homolateral and contralateral infraorbital and palatine arteries, as well as in the mucosal lining of the nose and the walls of the maxillary sinus, body of the zygomatic bone and zygomatic process of the temporal bone. The right side contains more contrast than the left side. INSERT LINK HERE.

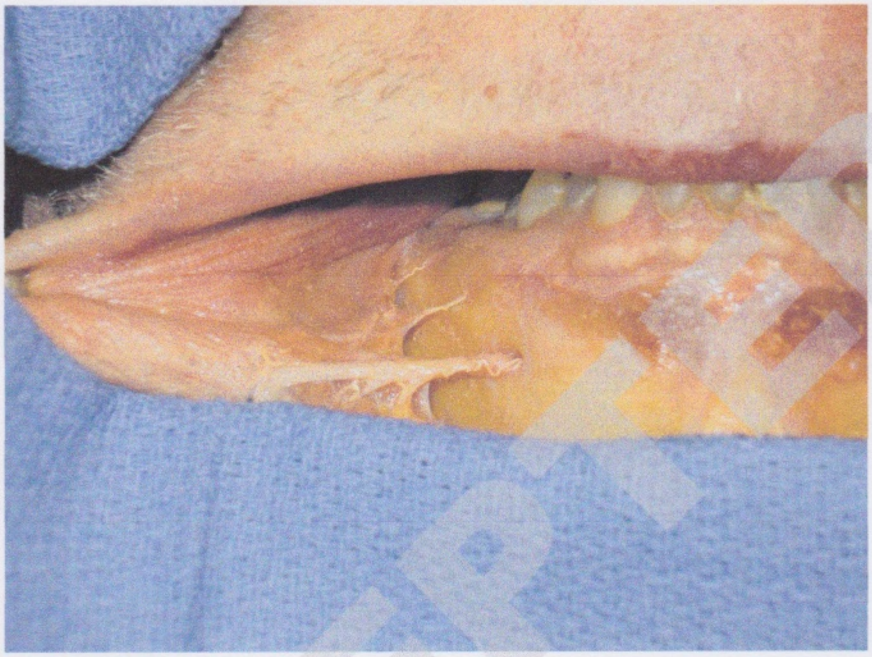
Video Graphic 5. See Video, Supplemental Digital Content 5, which demonstrates the retrograde flow in the infraorbital and inferior alveolar arteries**.** Angiography of the facial artery reveals retrograde flow of the contrast, through the infraorbito-facial anastomosis, in the infraorbital and the maxillary artery. Within the inferior alveolar artery the contrast becomes evident at the junction of mandibular body and ramus and flows retrogradely in the direction of the condyle. INSERT LINK HERE.

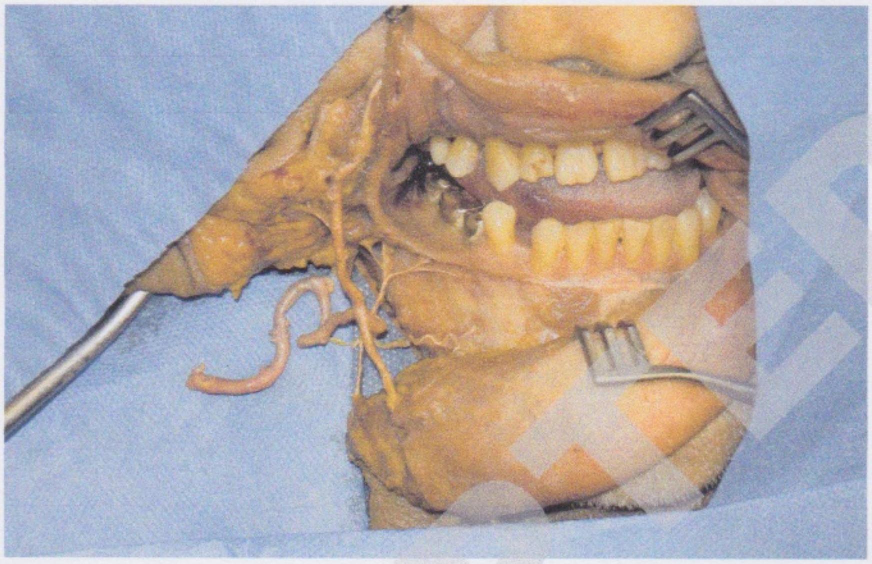
	Mandible						Maxilla						Zygomatic Bone				Palate	Nasal cavity		Orbit			Temporal Bone
Injected Artery	Symphysis	Body	Ramus	Condyle	Coronoid Process	Alveolar Process	Alveolar Process	Zygomatic Process	Frontal Process	Orbital Plate	Palatine Process	Sinus	Frontal Process	Temporal Process	Maxillary Process	Body	Palate	Lateral Wall	Septum	Medial Wall	Floor	Lateral Wall	Zygomatic Process
Maxillary Artery	67.7	67.7	67.7	100	100	67.7	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Superficial Temporal Artery	0	100	100	67.7	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Facial Artery (Head)	100	100	100	57.1	42.9	100	85.7	71.4	71.4	100	100	100	42.9	42.9	85.7	57.1	71.4	85.7	85.7	57.1	100	57.1	42.9
Facial Artery (Allograft)	100	100	100	66.7	66.7	100	71.4	100	100	100	71.4	100	71.4	66.7	100	71.4	71.4	71.4	71.4	100	100	100	50

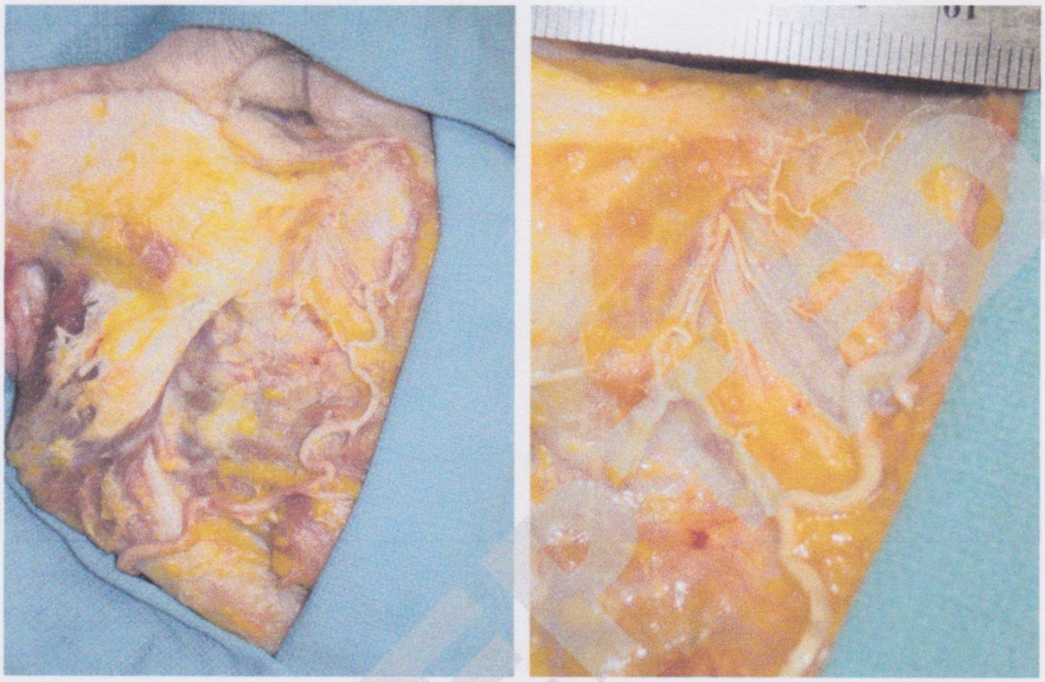
	Mandible						Maxilla						Zygomatic Bone				Palate	Nasal cavity		Orbit			Temporal Bone
Injected Artery	Symphysis	Body	Ramus	Condyle	Coronoid Process	Alveolar Process	Alveolar Process	Zygomatic Process	Frontal Process	Orbital Plate	Palatine Process	Sinus	Frontal Process	Temporal Process	Maxillary Process	Body	Palate	Lateral Wall	septum	Medial Wall	Floor	Lateral Wall	Zygomatic Process
Maxillary Artery	0	0	0	0	0	0	100	0	100	66.7	100	66.7	0	0	0	0	100	66.7	100	0	66.7	0	0
Superficial Temporal Artery	0	0	66.7	0	0	0	0	0	66.7	66.7	66.7	0	66.7	0	0	0	0	0	66.7	66.7	100	66.7	0
Facial Artery (Head)	100	71.4	71.4	0	0	71.4	71.4	28.6	57.1	71.4	71.4	85.7	28.6	14.3	28.6	14.3	71.4	57.1	57.1	28.6	71.4	14.3	14.3
Facial Artery (Allograft)	100	100	83.3	16.7	33.3	83.3	83.3	83.3	100	100	83.3	83.3	83.3	83.3	83.3	83.3	83.3	83.3	83.3	83.3	100	83.3	50

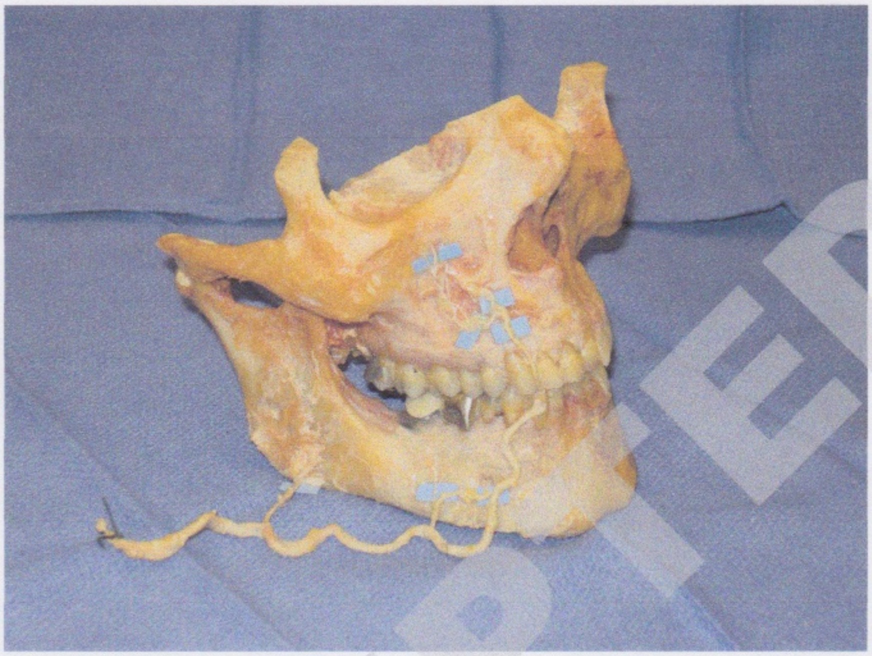
Injected Artery	Inferior Alveolar Artery, H	Inferior Alveolar Artery, C	Superior Alveolar Artery, H	Superior Alveolar Artery, C	Infraorbital Artery, H	Infraorbital Artery, C	Major Palatine Artery, H	Major Palatine Artery, C	Posterior Septal Branches of the Sphenopalatine Artery, H	Posterior Septal Branches of the Sphenopalatine Artery, C	Postero- lateral Nasal Branches of the Sphenopalatine Artery, H	Postero- lateral Nasal Branches of the Sphenopalatine Artery, C	Anterior Septal Branches of the Anterior Ethmoidal Artery, H	Anterior Septal Branches of the Anterior Ethmoidal Artery, C	Anterior Lateral Nasal Branches of the Anterior Ethmoidal Artery, H	Anterior Lateral Nasal Branches of the Anterior Ethmoidal Artery, H
Maxillary Artery	67.7	0.0	100.0	100.0	100.0	67.7	100.0	100.0	100.0	67.7	100.0	100.0	100.0	100.0	100.0	100.0
Superficial Temporal Artery	100.0	0.0	100.0	0.0	100.0	67.7	100.0	67.7	100.0	67.7	100.0	0.0	67.7	67.7	100.0	0.0
Facial Artery (Head)	100.0	71.4	85.7	57.1	100.0	85.7	85.7	71.4	42.9	42.9	85.7	25.7	71.4	57.1	85.7	57.1
Facial Artery (Allograft)	100.0	83.3	83.3	83.3	100.0	100.0	83.3	66.7	83.3	66.7	83.3	66.7	100.0	100.0	100.0	100.0

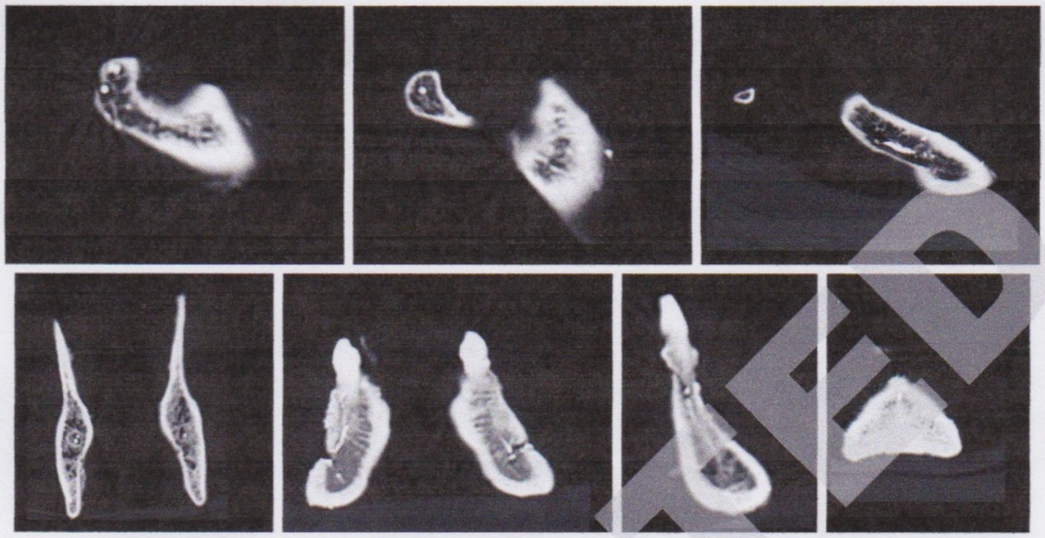


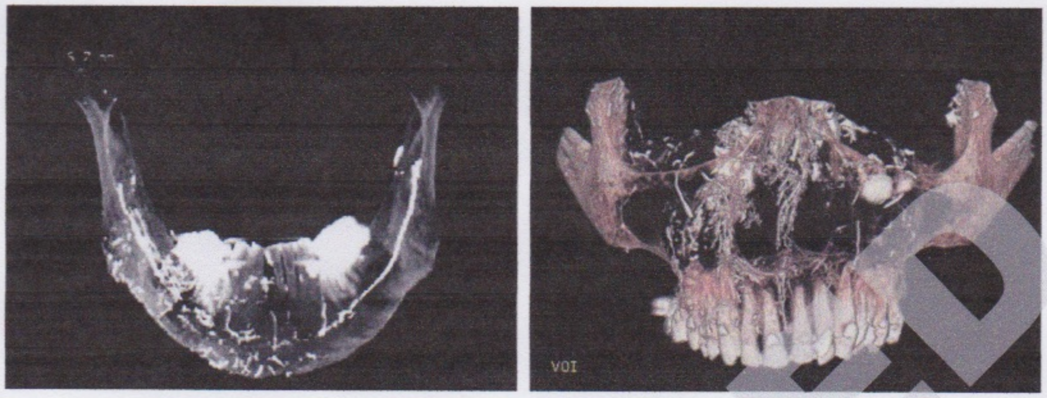








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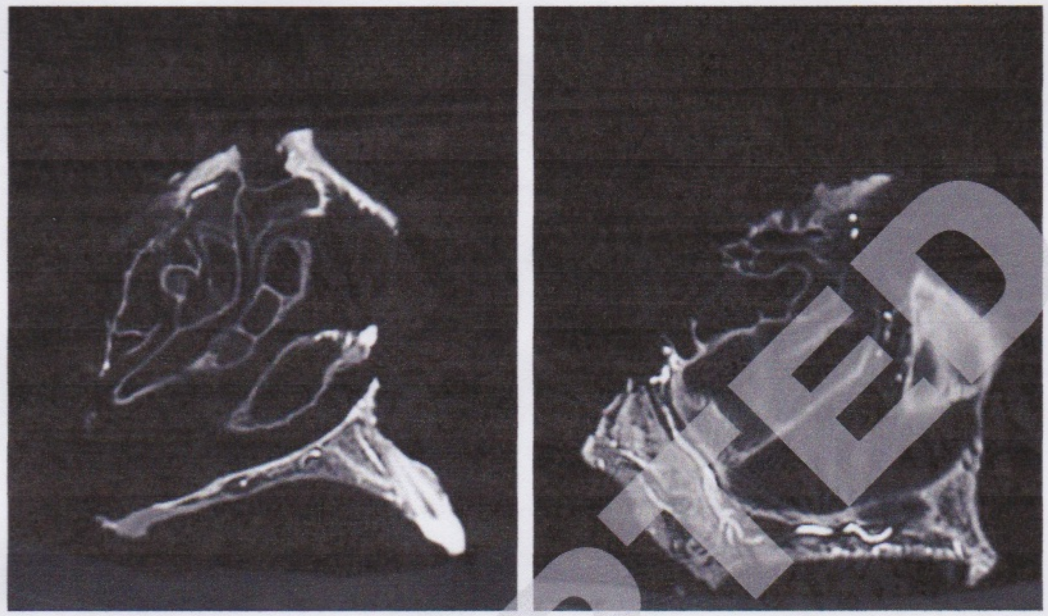

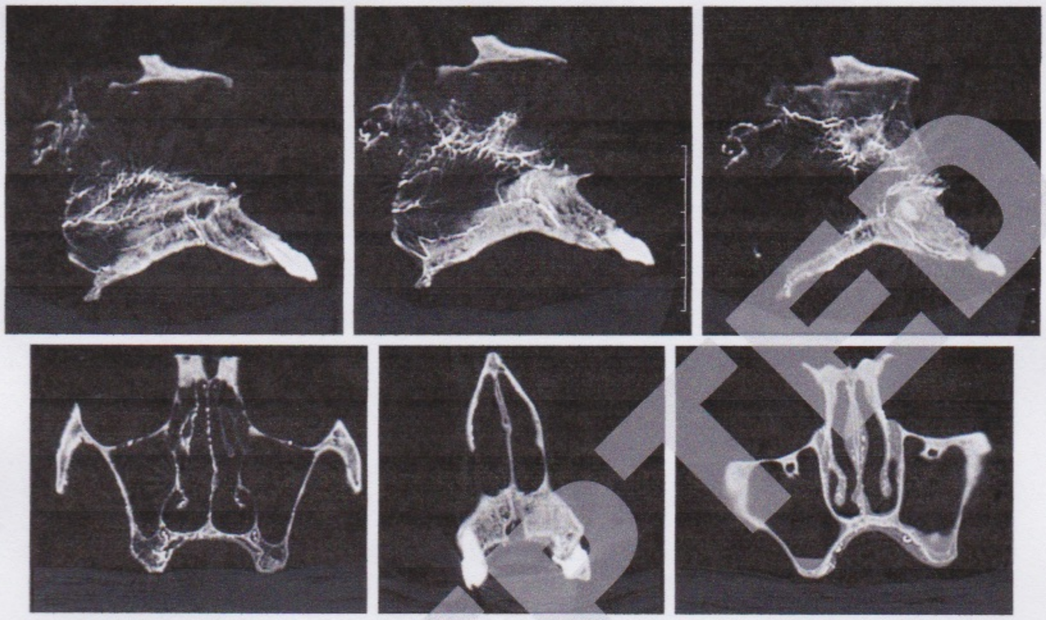

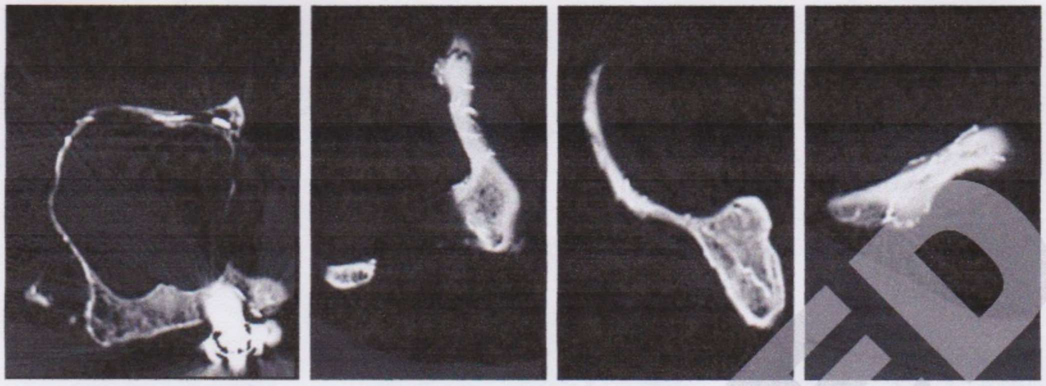

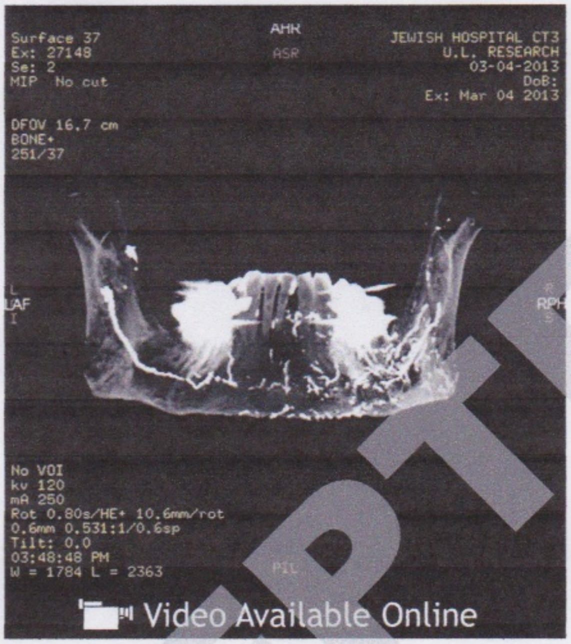
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JEWISH HOSPITAL CT3
U.L. RESEARCH
03-04-2013
DoB:
Ex: Mar 04 2013
DFOV 16.7 cm
BONE+
251/37
LAF
RPH
No VOI
kv 120
mA 250
Rot 0.80s/HE+ 10.6mm/rot
0.6mm 0.531:1/0.6sp
Tilt: 0.0
03:48:48 PM
W = 1784 L = 2363
PIL
Video Available Online


Surface 9
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Se: 2
MIP No cut
AHL
ASL
JEWISH HOSPITAL CT3
U.L. RESEARCH
03-04-2013
DoB:
Ex: Mar 04 2013
DFOV 16.7 cm
BONE+
252/9
R
RHP
P
L
LFA
A
No VOI
kv 120
mA 250
Rot 0.80s/HE+ 10.6mm/rot
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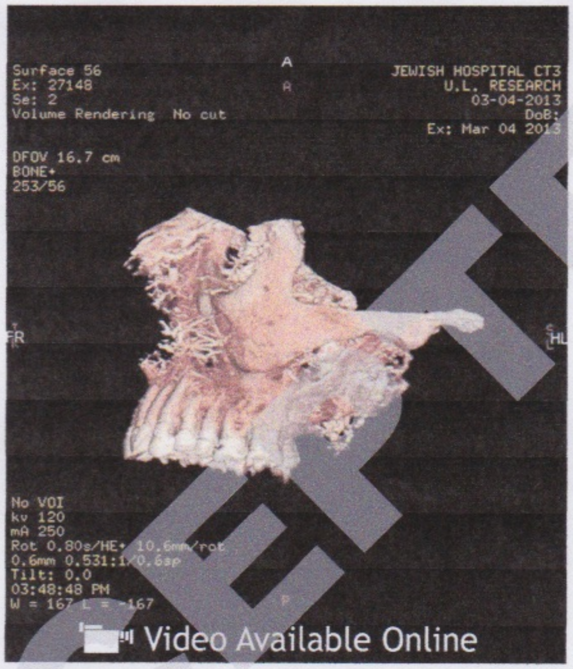
PIR
Video Available Online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Se: 2
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A
JEWISH HOSPITAL CT3
U.L. RESEARCH
03-04-2013
DoB:
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DFOV 16.7 cm
BONE+
253/56
R
L
No VOI
kv 120
mA 250
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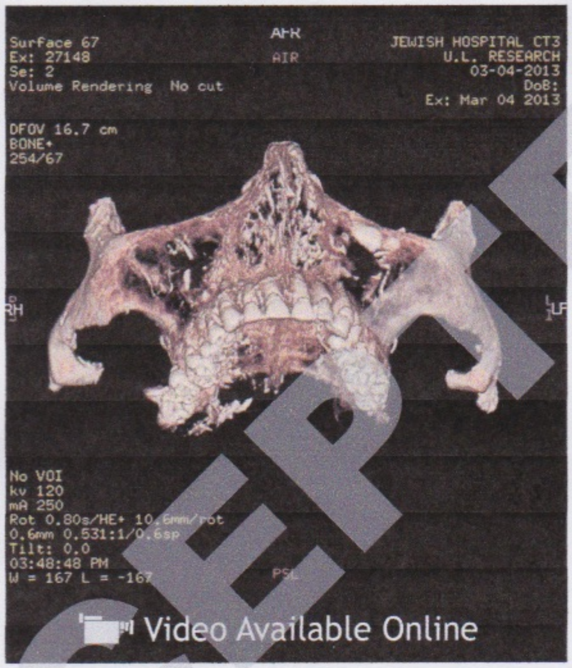
Video Available Online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Ex: 27148
Se: 2
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U.L. RESEARCH
03-04-2013
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Ex: Mar 04 2013
DFOV 16.7 cm
BONE+
254/67
RH
LF
No VOI
kv 120
mA 250
Rot 0.80s/HE+ 10.6mm/rot
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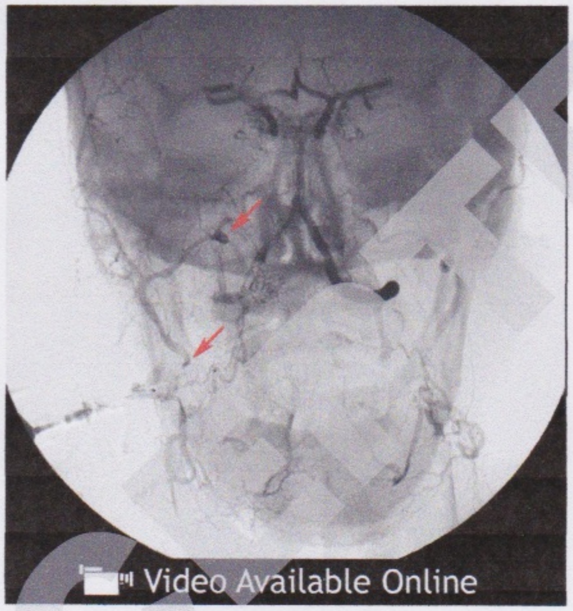
Video Available Online