Clinical relevance of vascular distribution in the palate and vestibule – establishing the theoretical foundation of novel flap designs for graft harvesting and reconstructive procedures

Ph.D. Thesis

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INTRODUCTION

In periodontal and implant dentistry, the oral vestibule and palate are considered as target areas for various types of surgical flaps. In order to achieve successful surgical results, the knowledge of blood vessel distribution, which will affect the angiogenesis, circulation and primary wound healing, is crucial. During the design of different types of incisions, the mapping of blood vessels should be acknowledged by the surgeon to avoid any complications.

The oral vestibule is supplied mainly by sub-branches of the maxillary and facial arteries which are originating from the external carotid artery (ECA). The maxillary artery (MA) perfuses the upper and lower jaws including hard palate, maxillary tuberosity, maxillary sinus, vestibule, upper and lower teeth/gingivae. These are the infraorbital artery (IOA), the greater palatine artery (GPA), the posterior superior alveolar artery (PSAA), the anterior superior alveolar artery (ASAA), the inferior alveolar artery (IAA), the buccal artery (BA) and the mental artery (MEA). Two branches of the facial artery (FA), the inferior labial artery (ILA) and the submental artery (SA) supply the lower vestibule. The ILA, along with a third branch, the superior labial artery (SLA) anastomoses with the contralateral arteries forming a vascular network around the oral cavity and giving branches to the mucosa of the upper and lower vestibule. The SA passes beneath depressor labii inferioris and forms anastomoses with the ILA and mylohyoid branch of the IAA. This convoluted vascular circle, with an abundance of collateral sources of blood flow, is essential when different incisions/flaps are planned in the oral vestibule. The upper gingiva is mainly supplied by the branches coming from the PSAA, IOA, ASAA, SLA and GPA. The branches of the BA, IAA, ILA, SA and the sublingual artery (SUA) supply the lower gingiva. The gingivae receive their arterial supply through the supra-periosteal arteries. These arteries form anastomoses with blood vessels of the periosteum and periodontal ligaments.

The most demanding interventions in the upper/lower jaw include implant placement together with horizontal reconstruction of lost hard tissue guided bone regeneration (GBR) techniques, ridge augmentation procedures, sinus floor elevation, as well as periodontal pocket surgeries, root coverage, and vestibuloplasty procedures. The vast majority of these surgical indications are established by full thickness mucoperiosteal flaps with uni- or bilateral full thickness horizontal and vertical periosteal releasing incisions, allowing for a tension-free flap design. However, despite predicable treatment success, there are some well-known complications related to extensive flap mobilization, e.g. partial disruption of the periosteal blood supply, intraoperative haemorrhage, bone loss, partial flap necrosis, vertical scars, and shrinkage and distortion of the vestibule. These complications may impair the final functional and esthetic outcome of surgical interventions in both of the jaws. Moreover, detailed anatomical data is still scarce in the literature, and this limits clinicians desiring to overcome blood supply disturbances related to various mucosal dissection techniques. Therefore, establishing a solid anatomical basis for designing surgical interventions in the vestibule by detailed mapping of the arterial pathways is needed to allow for more advanced and sophisticated surgical interventions.

Another particular area of oral and periodontal surgeries is the palate. Generally, the suggested area for taking a subepithelial connective tissue graft (SCTG) is between the distal side of the canine to the mesial side of the first molar. The blood supply of the oral mucosa, and the palate in particular, shows a complex pattern, mainly supplied by branches of the maxillary, facial and ascending pharyngeal arteries, taking their origins from the external carotid artery (ECA).

The hard palate is mainly supplied by the GPA and the lesser palatine artery (LPA). The branches of the GPA travel within the lateral palatine groove to supply the mucosa, periosteum and palatal gingiva before entering the incisive canal to form an anastomosis with the nasopalatine artery (NPA) supplying the majority of the palatal mucosa and periosteum. The NPA enters the incisive canal to supply the anterior region of the hard palate (i.e. intermaxillary segment).

Following oral surgical interventions, it is highly important to be aware of the interrelation between these anatomical entities, for optimizing incisions and flap designs, to minimize intraoperative bleeding, and to offer the most optimal circumstances for wound healing and revascularization. In order to elevate a flap, which allows surgical intervention to be followed by undisturbed wound healing, accurate information regarding the size and division of muscular, mucosal and periosteal vasculature is necessary. There are several types of maxillofacial/oral surgical or periodontal treatments for which a well-established knowledge of secure incision lines and surgical approaches would be highly beneficial: harvesting of SCTG, free gingival graft (FGG), removal of impacted canines, and flaps to allow implant placement. Although the morphological features of vestibular and palatal structures have previously been thoroughly investigated, clinicians still frequently face anatomical challenges during surgeries, and there is a growing need for a comprehensive macroscopical mapping of the palatal mucosal blood supply in order to avoid dangerous intraoperative and postoperative complications.

Although useful in investigations of the blood flow in oral mucosa, *in vivo* methods like angiography, laser Doppler or laser speckle analysis are only capable of providing indirect information on blood vessel function and structures. Thus more accurate *ex vivo* macro- and microscopical investigations are required to achieve a solid anatomical background for the physiological observations made by blood flow analysis methods.

Several staining methods exist that might be used to visualize the blood vessels of the oral vestibule and palate for macroscopical analysis, such as latex milk injection or corrosion casting. These can all be used in human cadavers by injecting a substance through the ECA. In general, the colored latex milk is injected into the vessels to analyze the path of the branches and sub-branches of the different vessels. After a proper embalming period of the cadaver by Thiel's solution and flushing of the vessels, they are injected with the latex milk. The corrosion casting method uses solidifying material such as methacrylates in order to discover the three dimensional structure of blood vessels within tissue. Having a fresh corpse without prior fixation is suggested before casting in order to prevent complications in the steps of the injection due to solidification and retraction of vascular tissues. After casting procedures, the corrosion, dissection, washing and drying will be the next steps before achieving the final outcome. The vessels can be identified during dissection.

OBJECTIVES

My PhD research in clinical and human cadaver studies was conducted to find answers to the main question: *How can an incision/flap, designed according to accurate anatomical knowledge of the vascular distribution, contribute to acceptable angiogenesis, wound healing and less intraoperative bleeding beyond current therapeutic approaches?*

The clinical and human cadaver studies were performed with the following aims:

- To introduce a novel surgical technique without damaging the collateral blood vessels, together with reconstruction of lost hard and soft tissues around dental implants, describing a partial thickness flap design with predictable two layer periosteal-mucosal wound closure.

- To establish a detailed macroscopic mapping of the anastomoses of the vestibular and palatal blood vessels by applying anatomical methods on cadavers, in order to bridge the gap between basic structural and empirical clinical knowledge.

- To provide clinicians with a good basis to understand the anatomical background of intra- and postoperative complications, as well as early wound healing events in SCTG and proper incision/flap design, depending on anatomical location.

MATERIALS AND METHODS

The present thesis reports on a clinical study (I) and a human cadaver research study (II), which are summarized. The clinical case report study was conducted at the Department of Periodontology, Semmelweis University, and involved patients undergoing treatment of alveolar hard and soft tissue defects. Cadaver research was carried out at the Department of Anatomy, Histology and Embryology, Semmelweis University, Budapest, Hungary and the Department of Macroscopical and Clinical Anatomy, Medical University of Graz, Austria.

Study I (clinical/case report study)

Three nonsmoking patients with generalized chronic periodontitis were treated: a 63-year-old woman (Case 1), a 52-year-old man (Case 2), and a 56-year-old woman (Case 3). Patients presented posterior partial edentulism (Applegate-Kennedy Class II, mandible; Class I, mandible; Class II, mandible, respectively) with class C alveolar defects according to the horizontal, vertical and combination (HVC) classification. In each case, non contained periodontal defects were found at neighboring teeth (mandibular right first premolar, one-wall defect; mandibular right first premolar, one-wall defect; mandibular right canine, one-wall defect, respectively). Patients presented good general health, completed initial periodontal treatment, and maintained proper oral hygiene. Full mouth plaque and bleeding scores were less than 20% in all cases prior to surgeries. In all three cases, horizonto-vertical ridge augmentation utilizing a novel split-thickness flap design was performed to ensure optimal three-dimensional implant positioning and long-term stability of peri-implant hard tissues. The same surgical technique was utilized in all cases: implant placement with a simultaneous ridge augmentation procedure. If optimal peri-implant soft tissue stability could not be ensured upon thinned alveolar mucosa, hard tissue reconstruction was followed by additional soft tissue grafting at membrane removal. Following abutment connection, fixed implant-retained partial dentures were fabricated.

Nine months postoperatively, soft tissue augmentation was carried out upon insufficient mucogingival conditions. The width and thickness of keratinized tissue was less than 2 mm over the grafted area, as confirmed by direct intraoperative measurements. Therefore, soft tissue augmentation was performed during stage-two surgery 9 months after ridge augmentation and implant placement. The same flap design was applied as for the augmentation procedure. Flap elevation was, however, only minimally extended to allow for membrane and titanium pin removal. Three months after soft tissue augmentation, bone block fixation screws and cover screws were removed following elevation of a minimally invasive partial-thickness flap.

To assess crestal bone changes, intraoral radiographs were taken at baseline, immediately after surgeries, as well as at abutment connection, and 12, 24, 36, 48, and 60 months after prosthetic loading. The distance between implant shoulder and the crestal bone was measured at the mesial and distal aspects of each fixture. Implant height was used for calibration. In Case 1, conventional computed tomography (CT) analysis was made prior to augmentation; in Cases 2 and 3, cone beam CT (CBCT) analysis was performed. In all three cases, additional CBCT analysis was performed 9 months postoperatively. Only qualitative radiographic evaluation was performed on CT scans (Windisch et al., 2017).

Study II (human cadaver study)

a) Ten head specimens from Austrian cadavers (six males, four females, two edentulous, eight dentate, 43-95 years of age) were prepared for analysis of vascular pathways of the oral vestibule (mucosa and periosteum) with their clinical impact on incision and flap design in oral surgery and implant dentistry. In this study all cadavers were injected with latex milk (manuscript under preparation).

b) Ten head specimens from six Hungarian cadavers (three males, three females; one dentate, five edentulous, 65-84 years of age) and four Austrian cadavers (two males, two females; two dentate, two edentulous, 59–90 years of age) were prepared for the macroscopic analysis of the blood vessels supplying the palatal mucosa. Their clinical implications for flap design and soft tissue graft harvesting were inspected. Four cadavers were stained with the corrosion casting method and the other six cadavers with latex milk injection (Shahbazi et al., 2018).

The corpses were fixed with Thiel’s solution. The ECAs were dissected. In both techniques, before injection, the vessels were rinsed with phosphate buffered saline (PBS) and other solutions. Then careful injection was continued.

RESULTS

Study I

Post-operative findings

The healing procedure after surgeries were uneventful in all cases, without any serious local or systemic adverse events. Only moderate post-operative swelling was observed, no membrane exposure occurred until membrane removal. In Case 1 and Case 3, 9 months postoperatively the midcrestal vertical thickness of the alveolar mucosa decreased to less than 2 mm. Thus, in Case 1 and Case 3, connective tissue grafting was performed, and abutment connection followed 3 months later. Healing of the donor site and the grafted area occurred without complications, the midcrestal thickness of keratinized mucosa increased to more than 2 mm 3 months after soft tissue grafting. In Case 2, the midcrestal vertical thickness of the alveolar mucosa exceeded 2 mm immediately before membrane removal, and so soft tissue grafting was not indicated. After 9 months of healing, complete pocket resolution without gingival recession was observed at sites with periodontal attachment loss.

Intraoperative findings at membrane removal

Following membrane removal, a non-mineralized periosteal-like layer was seen on top of the reconstructed alveolar crest, which was partially removed to allow for abutment connection. Implants were clinically stable in all cases. New hard tissue formation was confirmed by visual assessment and probing. The vertically and horizontally enlarged alveolar ridge displayed a similar clinical appearance to neighboring native bone in all cases. Implant surfaces and bone block fixation screws were completely covered by newly formed hard tissues.

A comparison of the mean bone to implant/screw contact at first surgery and at membrane removal demonstrated a mean crestal bone regeneration of 3.08 ± 1.25 mm. After 4 weeks of soft tissue healing, implants were prosthetically loaded. At regular follow-up visits of 12, 24, 36, 48, and 60 months after prosthetic loading, peri-implant probing depth (PD) did not exceed 4 mm in any of the cases. Neighboring teeth previously receiving periodontal regenerative treatment also showed maintenance of PD, gingival recession (GR), and clinical attachment level (CAL) recorded at implant loading (data not shown). In Cases 1 and 3, no soft tissue recession occurred, whereas in Case 2, 1 mm of recession was detected on the lingual aspect of the inserted implants. A high level of oral hygiene was maintained throughout the follow up period. Neither bleeding on probe (BOP) nor absence of keratinized mucosa were detected in any of the cases. Prosthetic complications did not occur.

Intraoral radiographs outcomes

On intraoral radiographs taken immediately after surgery, the border between native crestal bone and grafting material could be clearly identified, as well as contours of the titanium membrane, titanium pins, and bone block fixation screws. Nine months postoperatively, on intraoral radiographs taken prior to membrane removal, harvested autogenous bone and xenograft particles could not be distinguished from the earlier native bone margins. At 12 months after prosthetic loading, signs of positive bone remodeling and crestal bone maintenance were similar, as shown on intraoral radiographs in all cases, despite the fact that different grafting materials were used. Moreover, radiographic results showed maintained alveolar crest contours at 60 months follow-up in all three cases.

Cone beam computed tomography outcomes

Baseline CT/CBCTs and 9-month postoperative CBCTs demonstrated successful hard tissue reconstruction. Fixtures were surrounded by dense radio-opaque areas resembling native alveolar bone, and remaining xenograft particles could not be distinguished from adjacent bone. In all cases, thickening of the outer cortical layer of mandibular bone was observed.

Study II

Results of the vascular survey analysis in the vestibule

At the vestibule of the anterior maxilla, in the most superficial mucosal layer, main vertical arteries with transverse anastomoses were detected prior to dissection. In the anterior surface of the maxilla the vertical vessels coming from the SLA and IOA repeatedly divided below the mucogingival junction, and terminal arteries further descended towards the mesial and distal aspect of each papilla in dentate cadavers. Opposed to the anterior maxilla, main arteries were horizontally orientated in the molar area of the posterior maxilla, but vertical branches were observed too. Each of the main vertical and the bifurcated sub-branches were anastomosed with adjacent vessels through horizontal branches. In the lower vestibule the transverse course of ILA originating at the level of lower first molar was successfully presented. At the vestibule of the anterior mandible, vertical branches were received from the ILA. Among these vessels many horizontal anastomoses were detected, and a higher density of superficial mucosal vessels were observed at the area of premolars and molars. These arteries supply the mucosa and the periosteum of the anterior mandible together with the sub-branches of the SA.

Results of the vascular survey analysis in the palate and maxillary tuberosity

The course of the greater palatine artery was clearly presented by applying corrosion casting and latex milk injection techniques, the former showing the complete mapping of blood vessels along with osseous surroundings, the latter allowing for layer-by-layer dissection and demonstration of the soft tissue environment. Major and secondary branches of the GPA and it's relation to the palatine spine, variation in division of the sub-branches, different anastomoses with NPA, LPA as well as with contralateral branches of the GPA, were recorded. Another important record of patients with an edentulous upper jaw revealed that due to the resorption of the bone, the GPA developed a curvy pathway, especially at the area of the molars-premolars. Also, some penetrating intraosseous branches at the premolar-canine area were observed. The blood supply around the maxillary tuberosity was also presented. As soon as the greater palatine artery emerges out from the greater palatine foramen, it sends one or two branches toward the tuberosity. Also, the lesser palatine artery sends one or two branches forming anastomoses to this area. At the level of the 2nd molars the distance of the GPA branches from the gingival margin was 11.3 ± 0.9 mm on average (ranging from 10 to 13 mm). In all the cadavers, a high amount of adipose and dense connective tissues were detected, together with numerous vessels. In those cadavers showing signs of obesity, an increased amount of adipose tissue was observed in the posterior palate compared to cadavers without signs of obesity.

DISCUSSION

The results of our studies have pointed to the important role and correlation of flap/incision design with angiogenesis, circulation, regeneration and periodontal wound healing. The split thickness flap was designed to eliminate damage to collateral vessels in patients presenting chronic periodontitis with localized three-dimensional alveolar defects. This flap design is different from the surgical approach suggested by Tinti for augmentation procedures, which has been the standard protocol for vertical GBR during the last two decades. Vertical and horizontal releasing incisions, in combination with mucoperiosteal flaps, completely dissect the vascular architecture of the periosteal layer. In comparison to this full-thickness approach and previous split-thickness flap designs for ridge augmentation, our novel, improved partial-thickness flap design was characterized by the following key elements: i) A split-thickness flap was elevated following mid-crestal incision, with a horizontal intracrevicular extension over two adjacent teeth. ii) Neither periosteal nor vertical releasing incisions were applied. iii) Ultimately, complete gap-free closure between the periosteal and lingual flaps was achieved by flap mobilization, this being the most significant attribute to allow for optimized postoperative blood supply. Optimal peri-implant soft tissue conditions were established in all reported cases; inserted implants were successfully loaded, and fulfilled the implant success criteria during 5 years of follow-up.

Clinical results were comparable to available long term data reported after vertical augmentations. Follow-up radiographic findings supported the clinical observations, demonstrating 5 years of crystal bone stability without any clinically-significant remodeling around the inserted implants. The composite graft, a 1:1 mixture of particulate autogenous bone and xenograft materials, was used as a safe alternative in GBR procedures. Locally-harvested autogenous bone particles and minor tenting bone blocks combined with bovine derived xenograft (BDX) were the grafting materials of choice in our case report.

Two-layer wound closure resulted in improved flap revascularization during early wound healing, resulting in primary intention wound healing. Horizontal flap extension onto neighboring teeth, along with the split-thickness flap design, allowed additional tension-less handling and flap mobilization, compensating for the lack of vertical releasing incisions. The gap-free suturing of the intact periosteum with the mobilized oral flap withstood all kinds of muscular tension during the initial healing period and facilitated proper blood supply of the outer mucosal layer. Thus, membrane exposure due to muscle pull could be prevented in the early period of healing, resulting in primary wound closure in all reported cases. Soft tissue coverage was maintained throughout the whole healing period up to membrane removal in all cases, and no membrane exfoliations occurred.

Clinically-sufficient new hard tissue formation was observed at membrane removal in all cases. The need for bone harvesting could be minimized due to space maintenance provided by nonresorbable membranes and the tenting effect of micro-bone blocks. Thus, surgical interventions could be limited to one operation site. Newly-formed hard tissues resembling native bone were observed at membrane removal, regardless of the applied grafting material (autogenous bone and BDX in Case 1 and Case 3; autogenous bone alone in Case 2). This indicated the significance of primary intention wound healing over non-resorbable membranes as an ultimate prerequisite for horizonto-vertical ridge reconstruction, provided by a predictable flap design and suturing approach. Direct clinical and radiographic measurements confirmed the complete fill of treated horizonto-vertical defects around the inserted implants.

In our case report, minor three-dimensional alveolar defects were treated around simultaneously-inserted dental implants. As a result of this, the mean measured vertical bone formation of 3.08 ± 1.25 mm was lower than that obtained in two-stage augmentation protocols reported previously. Significant remodeling of mucogingival conditions is a frequently-occurring phenomenon following bone grafting procedures, often requiring vestibuloplasty or widening of the peri-implant keratinized mucosa. Such interventions were not needed in the presented cases, possibly due to lack of the vascular distortion usually originating from periosteal and vertical releasing incisions. Only a minor soft tissue augmentation was performed in Case 1 and Case 3: a subepithelial connective tissue graft was transplanted to ensure optimal peri-implant soft tissue thickness. The proper width and thickness of keratinized tissues is of high clinical importance; this may have contributed to the long term stability of peri-implant soft and hard tissues observed during the 5-year follow-up after prosthetic loading. There are no relevant data referring to the success of vertical augmentation in patients with chronic periodontitis. All treated cases presented attachment loss and non-contained defect morphology in the close vicinity of the grafted area. These periodontal defects have been treated successfully, resulting in complete defect resolution. This is well in line with the previous results reporting on simultaneous ridge augmentation and periodontal regeneration.

According to the present results, reconstruction of localized, three-dimensional alveolar defects with a vertical component of 2 to 5 mm was demonstrated by applying the introduced novel partial-thickness flap design without periosteal or vertical releasing incisions, allowing for complete two-layer closure of soft tissues above the augmented sites. The extent and duration of surgeries were minimized by utilizing a simultaneous approach and avoiding bone harvesting from donor sites. Thus, patient morbidity was kept within reasonable limits.

The clinical success of our empirically-developed surgical approach and flap design led to further questions related to flap revascularization. We, thus, initiated a human cadaver study to bridge the gap between basic anatomical and empirical clinical knowledge, in order to better understand intra- and postoperative complications, as well as early wound healing events of palatal and vestibular surgical interventions.

In our findings related to the blood supply of the upper oral vestibule in human cadavers, the orientation, direction and division of the PSAA, IOA and SLA with various superficial anastomoses were detected. Some of the anatomical characteristics were well in line with clinical observations related to post-surgical wound healing made in the daily practice. The anterior section of the upper vestibule did exhibit a typical straight orientation of arteries in the mucosal layer which were moving toward the interdental papillae and supplied the gingivae. The paucity of dense vascular structures in the midbuccal areas implicates spoiled blood circulation. This confirms the observation of inept consequences (scars, gingival recessions) if vertical releasing incisions are designed at the midline gingival zenith of front teeth. In the posterior dentate maxilla, according to the transverse path of significant branches in the mucosa, vertical releasing incisions might disturb the circulation between distal and mesial tissues. In the lower vestibule, the critical location of the ILA was observed. The horizontal course of this artery became superficial together with the vertical branches moving toward the papillae. Also higher density of superficial blood vessels were found in the mucosa at the level of the molars. By these novel findings, any vertical incision in the lower vestibule between the first molar and second premolars should be avoided to prevent from bleeding complications and minimize the risk of injury to the circulation of arterial network.

The palatal mucosa is the most frequently-used donor site for connective tissue graft harvesting. Nevertheless, there is only scarce data on the palatal anastomoses that possibly influence intraoperative bleeding and postoperative blood supply of palatal donor sites. SCTGs are usually harvested from an area between the canine and the second molar of the palate by leading a horizontal incision, and the tissue is then harvested by either the trapdoor technique or the single incision approach. These approaches, depending on the number, direction and depth of incisions, might produce a certain risk for arterial damage and a compromised postoperative blood supply. According to our results, several cases of contra- and ipsilateral anastomoses between the GPA, NPA and LPA were demonstrated in the cadavers studied. This might provide an anatomical basis for physiological experiments investigating whether additional submucosal deposition of local anesthetics to contralateral major palatal foramen and/or nasopalatal foramen might be necessary to reduce intraoperative bleeding during palatal surgeries, e.g. SCTG harvesting and sinus floor elevation. Moreover, based on the presence of newly-found contralateral anastomoses, we think that in surgeries concerning the palate, contralateral blood circulation might also be affected. Therefore, bilateral connective tissue harvesting may lead to impaired postoperative blood supply and flap necrosis.

We also successfully demonstrated the existence of the intraosseous GPA branches of palatal arteries, which have not been documented previously. A similar anatomical relation is known in the lower jaw, where nutritive sub-branches of the sublingual arteries penetrate the lingual cortical layer of the mandible. Based on anatomical and clinical experiences with lingual intraosseous arteries, their palatal counterparts might be responsible for the nutrition of the maxilla and possibly the Schneiderian membrane. Nevertheless, due to their small diameter, they do not pose a significant risk for profuse intraoperative bleeding when compared to lingual nutritive branches. The distribution of the palatal intraosseous branches showed a pattern running parallel to the pathway of the GPA.

According to our present findings in edentulous cadavers, due to the resorption of the alveolar ridge, the area for the pathway of the GPA might decrease in apico-coronal and oro-vestibular dimensions, and the GPA would exhibit a more undulating pathway. We were able to demonstrate that, in edentulous cases, the GPA and its sub-branches became more superficial, which might increase the risk of GPA injury during any type of palatal flap preparation, e.g. connective tissue graft harvesting or during augmentation procedures. Due to this specific curvy outline of arteries, the distance of the GPA from the crest was reduced by 3-4 mm, thus increasing the risk for arterial injury during connective tissue harvesting. Therefore, at edentulous sites, superficial removal of a FGG can be a more secure clinical procedure for connective tissue harvesting, as opposed to the single incision or trapdoor techniques. Apart from the detailed description of the palatal arterial pathways, we were also able to visualize the blood supply of the maxillary tuberosity. The GPA and LPA send one or two minor branches here, which provide for the nutrition of this area. The tuberosity is considered as a possible alternative for the hard palate for SCTG or FGG harvesting when applying the distal wedge procedure. The fact that the GPA and LPA branches directed towards the tuberosity are significantly smaller and have lower density compared to palatal arteries might be the reason for prolonged graft revascularization and incorporation, and this is likely to be associated with frequent partial or total necrosis of tuberal FGGs.

CONCLUSION

Study I

The presented two-layer split-thickness flap without damaging of collateral vessels, combined with the GBR technique utilizing titanium membranes, autologous and xenograft materials resulted in a predictable three-dimensional reconstruction of hard tissues. The reconstructed peri-implant hard tissues showed excellent stability up to 5 years after functional loading. The newly-introduced surgical approach can be utilized for the localized horizonto-vertical reconstruction of edentulous alveolar ridges and adjacent periodontal defects along with simultaneous implant placement.

Study II

a) The vascular survey findings of the oral vestibule represent a sound anatomical background for currently used split thickness surgical techniques performed in the vestibule for reconstructive surgical interventions. By the latex milk injection, the orientation (vertical or transverse), division and anastomoses of the vessels were demonstrated. This might help clinicians designing novel surgical approaches aimed at reducing postoperative wound healing complications.

b) In the palatal vascular distribution study, corrosion casting and latex milk injection methods were successfully applied to investigate the pathways of the GPA, NPA and LPA and their sub-branches with their complex network of the anastomoses. Previously unknown intraosseous branches of the GPA were detected. Furthermore, we were able to study the curved alteration of GPA pathways in edentulous sites and the tuberal blood supply.

The combination of clinical and anatomical findings have shed light on findings with relevance to vestibular and palatal blood supply, offering a powerful tool for the design and execution of surgical interventions involving the hard palate and oral vestibule.

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