Value of Diagnostic Ultrasound (Two-Dimensional, Duplex And Color Doppler) for the Assessment of Post-Operative Wound Healing in Orthognathic Surgery

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Contents

Introduction

Ultrasonography in medicine has been used as an imaging technology since 1950. Developments in computer technology have allowed modern ultrasound machines to produce real time high quality images of soft and hard tissues. Application of ultrasonography in the field of oral and maxillofacial surgery is a rapidly expanding phenomenon.

The role of ultrasonography in oral and maxillofacial surgery is very important because of, not just its role in the diagnosis of various types of lesions in oral and maxillofacial region but because of its significance in the post operative assessment of various procedures and research purposes by means of Two dimensional and Doppler studies which helped to assess the immediate post operative period, the progression of edema, haematoma and vascular status at the operative site. Subsequent studies helped to assess the nature and quantum of new bone formation when it was still uncalcified, but can be delineated by ultrasound as a soft tissue bridging the osteotomy gap.

Duplex and color Doppler studies helped to assess the vascularity in the new bone thereby depicting its viability.

Ultrasound studies at later date delineate calcified areas in the new bone indicating satisfactory healing of bone. At this stage corroborative evidence of bone healing could be obtained by radiograph also.

Our study is aimed at utilizing ultrasonography to the maximum for post operative assessment purpose. We were able to apply ultrasonography which is far more superior to CT/MRI in diagnosing the early stages of callus formation.

Most of the information offered by ultrasonography is provided by other advanced diagnostic aids also like CT and MRI but they are associated with high cost factor and other disadvantages like radiation exposure and allergic reactions to contrast media.

Review of Literature

Bell WH, Fonseca RJ, Kennedy JW, Levy BM[1]

Experimental models to investigate vascularization, revascularization, and bone healing associated with total maxillary osteotomy. Microangiographic and histologic studies showed minimal transient vascular ischemia, minimal osteonecrosis, and early osseous union.

Transection of the greater palatine arteries had no discernible effect on the circulation to the teeth and bone in the maxilla and its enveloping soft tissues. The results of experiments in animals and clinical studies indicate that palatal mucosa and labial-buccal gingiva provide an adequate nutrient pedicle for single-stage total maxillary osteotomies.

Bell WH, Kennedy JW[2] Fifteen adult rhesus monkeys were used as experimental models to investigate revascularization and bone healing associated with pedicled and nonpedicled vertical ramus osteotomies and to elucidate the problem of vascular ischemia of the proximal segment and healing of the osteotomized bone. Microangiographic and histologic studies of vertical ramus osteotomies in which the proximal segment was not pedicled to soft tissue showed intraosseous necrosis, vascular ischemia, and delayed healing. Similar studies of pedicled vertical ramus osteotomies showed early osseous union, minimal osteonecrosis, and minimal vascular ischemia. The results indicate that continuous circulation to the proximal segment is necessary to retain osseous viability and to support the clinical practice of pedicling the proximal condylar segment to the articular capsule and lateral pterygoid muscle.

Meyer MW, Cavanaugh GD[17] Subapical osteotomies were performed in the left quadrant of the mandibles and maxillas of five dogs and six monkeys. Two indirect methods, the isotope fractionation (*diffusible tracer*) and particle distribution (*nondiffusible tracer-15mu microspheres*) were used to quantitate local blood flow. To examine the effect of the surgery, blood flows in the alveolar bone, mucosa, and dental pulp of the segmented left quadrant and the corresponding tissues in the right quadrant were calculated and compared. It was assumed that the blood flows to the no noperated right quadrant could serve as the controls to those observed in the osteotomized segment. The fractional decrease in blood flows to tissues in the operated sides were similar in both experimental animals. The decrease was largest in the dental pulp, ranging from 54% to 82% on the average, and least for the mucosal tissue, ranging from 18% to 40%. Blood flows decreased by 48% to 74%, on the average, in the alveolar bone. In some animals, blood flow to mucosal tissue that served as the pedicle was actually greater than the blood flow in the corresponding tissue on the right side.

Bell WH, Schendel SA[3] Ten adult rhesus monkeys were used as experimental models to investigate revascularization and bone

healing associated with sagittal splitting of the mandibular rami by two different techniques. Microangiographic and histologic studies showed intraosseous ischemia in the margins of the osteotomized segments and areas where the pterygomasseteric sling had been detached. When the mucoperiosteum and pterygomasseteric sling were minimally detached from the proximal segment, intraosseous ischemia and necrosis were significantly reduced. The results support the use of a clinical technique of sagittally splitting the mandibular ramus, which maximizes attachment of the pterygomasseteric sling and mucoperiosteum.

Path MG, Nelson RL, Morgan PR, Meyer MW[20] Blood flows to various cephalic tissues were determined by the microsphere method before and after unilateral sagittal split of the mandible in macaque monkeys. Significant blood flow decreases were found in certain bony regions of the osteotomized mandible while blood flow to the masseter and medial pterygoid muscles on the osteotomized side was significantly increased. Judicious stripping of the mucoperiosteum and pterygomassteric sling may be an important consideration when planning the sagittal split approach to correct certain mandibular osteotomies.

Bell WH, Schendel SA, Finn RA[4] Vascularization, revascularization, and bone healing were studied after two different surgical techniques for surgical repositioning of single-tooth dento-osseous segments in adult mongrel dogs. Microangiographic and histologic studies of both one-stage and two-stage techniques for immediate surgical repositioning of single-tooth dento-osseous segments showed early but transient vascular ischemia, minimal osteonecrosis, and osseous union between most of the osteotomized segments. The attached soft tissue provided an adequate vascular pedicle for immediate repositioning of small dento-osseous segments by interdental and subapical osteotomies. The results of these clinically analogues studies support the clinical use of techniques that maximize the attachment of the gingiva to the mobilized dentoosseous segment.

Nelson RL, Path MG, Ogle RG, Jensen GD, Olson DV, Sokoloski PM, Meyer MW[18] The radioactive microsphere method was used to quantitate preoperative and postoperative blood flows in macaque monkeys when three different surgical approaches for anterior maxillary osteotomy were performed. Despite distinct variations in flap designs among the experimental groups, preoperative and postoperative determinations of blood flow were essentially

unchanged. Results of the study suggest that a palatal, labial, or combined mucoperiosteal pedicle should be adequate to preserve the flow of blood to tissues in the osteotomized segment.

Grammer FC, Carpenter AM[9] The viability of bone after sagittal splitting of the mandibular ramus by two techniques was studied. Decalcified sections of bone were studied with light microscopy; ground sections of bone labeled with tetracycline were studied with ultraviolet microscopy. The data indicate that avascular necrosis of the proximal fragment occurs after conventional Obwegeser-Dal Pont sagittal split osteotomy. Viability of the fragment was maintained by using a musculoperiosteal pedicle on the proximal fragment.

Stroud SW, Fonseca RJ, Sanders GW, Burkes EJ Jr[27]

Healing of autologous interpositional bone grafts after total osteotomy in the Macaca fascicularis monkey was studied using clinical, histologic, microangiographic, and autoradiographic methods at varying intervals up to six months. Results indicated that the autologous graft was very osteogenic and incorporated by host bone. Graft revascularization became apparent at two weeks postoperatively, and bone healing time was between two to four weeks. A hypervascular response was present to at least the six-

month healing stage. The palatal mucosa plus the facial gingiva provided an adequate nutrient pedicle for total maxillary osteotomies with interpositional bone grafting.

El Deeb M, Waite DE, Meyer MW[7] The radioactive microsphere method was used to quantitate blood flow to selected maxillary tissues before and during left-side cervical sympathetic stimulation in a group of 15 macaque monkeys, nine of which received Le Fort osteotomies. The sympathetic system to regulate blood flow appears to have been modified and has not returned to its normal regulatory status six weeks after the operation.

Sugg GR, Fonseca RJ, Leeb IJ, Howell RM[28] For purposes of examining the pulpal reaction to segmental osteotomy, six adult female Macaca fascicularis monkeys received identical anterior maxillary osteotomies involving the incisors only. The mobilized segment was displaced distally a distance of approximately 2mm, then splinted in place for a week. The healing and revascularization of the bone proceeded well, with no ischemic areas visible on the microangiograms other than in the animal examined immediately after operation. The osteotomy site was bridged with new bone at three months. The majority of the pulps of the mobilized segment and

all teeth examined distal to the segment remained vital. No degenerative change other than the temporary disappearance of sensory nerves was observed in the vital pulps of the segments. By the six-month period, the sensory nerve supply to the dental pulp had regenerated completely.

Boc T, Peterson L[6] Posterior alveolar osteotomies were performed on six mongrel dogs. The segments showed early transient ischemia, followed by complete revascularization and osseous healing. Results of the study indicate that this posterior segment will maintain its vascularity if a lingual nutrient pedicle is maintained.

Hellem S, Ostrup An experimental study was performed to evaluate a method for selective, multicolor arterial perfusion. In seven adult beagle dogs the lingual, facial and mandibular arteries on one side were cannulated and perfused selectively with different colored perfusates (*Microfil and Colorpaque*). Identification of the perfusates was achieved using a clearing technique combined with microradiography and histology. With this method, the vascular territories of the body of the mandible and its adjacent tissue could then be identified separately.

Scheideman GB, Kawamura H, Finn RA, Bell WH[23]

Changes in the process of wound healing and in the dental pulp were examined following anterior and posterior mandibular subapical osteotomies in pig-tailed macaque monkeys. Results of microangiographic and histologic investigations indicated that degenerative pulpal changes may occur following mobilization and repositioning of small dentoalveolar segments. The potential significance of such degenerative pulpal changes and the need for routine dental radiographic checkups following anterior and posterior mandibular dentoalveolar surgery are discussed.

Quejada JG, Kawamura H, Finn RA, Bell WH[21] A technique that maintains dual soft tissue pedicles to the palatal and labiobuccal areas in segmental total maxillary osteotomy was studied with respect to the effects on osseous revascularization and healing. Single-stage four-segment total maxillary osteotomies were performed by this method in five adult male rhesus monkeys. The animals were killed at intervals from immediately to 28 days after surgery. Histologic examination of the maxillae revealed that this technique is sufficient to support total maxillary osteotomy through 28 days. The soft tissue flap provided adequate blood supply to the anterior maxillary segment. All bony segments were mobilized, with

only transient effects on bone healing and viability. The marginal osteonecrosis observed did not appear to be progressive. The effects of this procedure on the pulp are not clear.

Nilsson LP, Granstrom G, Rockert

Microangiography was performed to evaluate changes in the vascular supply. Resorption of the compact bone was seen in the central part of the compact bone, in the lower border of the mandible and in the incisal part of the alveolar bone. There was resorption of the cementum and dentin in the molar teeth. Remodelling processes were seen in the compact bone starting from vascular channels and on the surface of the bone trabeculae, ten days after osteotomy. Microangiography revealed that there is a collateral vascular system existing across the midline via the symphysis region, via submucosal tissue, via the mucoperiosteal pedicle to the inferior border of the mandible and via the network of small vessels in the periodontal membrane. It was concluded that the circulation to the peripheral parts of the mandible could in part be kept up by a retrograde flow in the collateral systems when the main circulation had ceased.

Storum KA, Bell WH, Nagura Correlated microangiographic and histologic studies in adult rhesus monkeys indicate that a pedicled genioplasty involving osteotomy of the inferior mandibular border maintains circulation and osseous viability of the repositioned genial segment. Circulation to the dental pulps was also not discernibly affected when accomplished a minimum of 8 mm below the root apices.

VN**Krivenko OG, Gun'ko VI, Loginova NK, Chertykovtsev** [13] Regional maxilla hemodynamic changes were studied in 40 patients. After surgical correction of combined upper jaw deformations, the osteotomized fragment showed sufficient blood flow which originated from distal maxilla blood vessels. By 45 days after surgery the blood flow reached its preoperative level. More pronounced changes were detected in the regional blood flow in patients with combined jaw deformations after congenital labial, soft and hard palate clefts. In these patients, retardation of the blood flow restitution could reflect the scarification of the tissues of soft and hard palate, and lips.

Lanigan DT, Hey JH, West The sequelae of insufficient vascularity following maxillary orthognathic surgery can vary from loss of tooth vitality, to periodontal defects, to tooth loss, to loss of major maxillary

dentoalveolar segments. The results of a questionnaire mailed to oral and maxillofacial surgeons found this complication was most likely to occur with Le Fort I osteotomies done in multiple segments in conjunction with superior repositioning and transverse expansion. Significant palatal perforations definitely seem to compromise the already tenuous blood supply to the anterior maxilla. Suggestions are given regarding the prevention and treatment of this complication.

Stosic S, Cvetinovic M, Jovic N, Stosic T, Mijatovic D, Mirkovic Ultrasonography is a relatively new diagnostic aid in maxillofacial surgery. It can be used in maxillofacial surgery in three modifications: Doppler sonography, A-scan sonography, B-scan sonography. As clinicians we wanted to determine what contribution ultrasound examination has made to the diagnosis of superficial maxillofacial masses, when compared with clinical examination, intraoperative findings and with other methods of investigations. Since 1985 B-scan sonography has been performed in the examination of congenital, inflammatory and neoplastic masses of the head and neck The value of the ultrasound findings varied depending on the soft tissue lesions which were examined and the experience of the radiologists who performed the examination. The advantages of

the diagnostic ultrasound are in being noninvasive, without any known deleterious biological effect, rapid, painless, inexpensive and easily reproducible.

Ellis E 3rd, Carlson DS, Billups J[8] Twenty-three adult female rhesus monkeys underwent advancement of the mandible by the sagittal split ramus osteotomy. Twelve had the proximal and distal segments wired together and underwent 6 weeks of maxillomandibular fixation (*MMF*). Eleven animals had bicortical bone screws placed between the segments and no postsurgical MMF. Overall, the results showed that the two groups of animals underwent markedly different patterns of osseous healing. The osteotomy sites in the MMF animals were filled with callus, which then formed bone. In contrast, no callus was found in the majority of the rigid fixation osteotomy sites; direct bony deposition was found instead. The results of this investigation show that, like long bones, the sagittal osteotomy can heal by direct or indirect means depending on the rigidity of the fixation.

Bell WH, You ZH, Finn RA, Fields RT[5] Vascular ischemia has been associated with improper soft tissue flap design, stretching of the palatal vascular pedicle, bony segmentation, transection of the

descending palatal vessels, or hypotension. This study examined Le Fort I osteotomy wound healing after some of these surgical maneuvers. Clinically analogous four-segment Le Fort I osteotomies were accomplished through circumvestibular incisions in nine adult rhesus monkeys and the animals were killed at 0, 3, 7, 14, and 28 days after surgery. Revascularization and bone healing were studied by microangiographic and histologic techniques. The findings indicated that the palatal mucosa or labial-buccal gingiva and mucosa provide adequate nutrient pedicles for Le Fort I osteotomies accomplished through a circumvestibular type incision. It was concluded that segmentalization, stretching of the vascular pedicles, or transection of the descending palatine vessels have only transitory discernible effects on revascularization and bone healing.

Takashi Hirai, E mestk Handers, Gregory Saggers[29] In this study, usefulness of ultrasonography to examine facial bone fractures was evaluated and compared with other diagnostic measures. Use of 15MHz allows identification of even 0.1mm wide disruptions of bony surface and also about post operative condition of apposed bone fragments, instantly.

Li W, Wang D[15] This study was designed to elucidate biological basis of cortex-to-cortex bone healing after oblique ramus osteotomy. 12rhesus monkeys were subjected to oblique ramus osteotomy bilaterally, and the operated sites were examined by microvascular irrigation section and histology techniques. The results showed that, besides the blood supply from the attachment of lateral pterygoid muscles and capsule of temporomandibular joint to the medial segments, the blood supply from the attachment of medial pterygoid muscles also played an important role. Cortex-to-cortex bone healing was achieved by the formation of a large volume of scab surrounding the operated sites.

Marsh DR, Li Optimising the results of fracture treatment requires a holistic view of both patients and treatment. The nature of the patient determines the priority targets for outcome, which differ widely between the elderly and the young, and between the victims of high and low energy trauma. The efficacy of treatment depends on the overall process of care and rehabilitation as well as the strategy adopted to achieve bone healing. The rational basis for fracture treatment is the interaction between three elements: (i) the cell biology of bone regeneration; (ii) the revascularisation of devitalized

bone and soft tissue adjacent to the fracture; and (iii) the mechanical environment of the fracture. The development of systems for early fracture stabilization has been an advance. However, narrow thinking centre only on the restoration of mechanical integrity leads to poor strategy. The aim is to optimize the environment for bone healing. Future advances may come from the adjuvant use of molecular stimuli to bone regeneration.

Wiley Liss Le Fort[30] Maxillary osteotomy carries a risk of injury to the descending palatine arteries which vascularize the bulk of the mucosa of the bony palate. Some authors believe that injury to these arteries in the greater palatine canal is intrinsic to the procedure without any consequence for the trophicity of the mucosa or bony palate. In order to assess the risk of injury to the descending palatine arteries during such surgery, and to demonstrate the supplementary vascularization which would avoid ischemia of the palate, we carried out a study of the vascularization of the palate on 11 fresh cadavers. We used intra-arterial injection of colored latex and dissection of the vessels running to the palate. The study was done without osteotomy in the first subject, after a Le Fort 1 osteotomy in the five following subjects and after a Le Fort 1 osteotomy and ligation of the two

descending palatine arteries in the last five subjects. Our results show that injury of the descend ing palatine arteries is not intrinsic to the procedure in spite of mobilization of the palatine plateau. When the descending palatine arteries are ligated there is diminution in coloration of the mucosa of the bony palate but there is substitution by the arteries vascularizing the soft palate, essentially the ascending palatine artery and the pharyngeal branch arising from the ascending pharyngeal artery. However, this substitute vascularization has individual variations.

Reinert Ultrasonography has gained acceptance in maxillofacial surgery as a first-choice diagnostic tool in soft tissue masses of the head and neck. To date, A-mode sonography of the maxillary sinus is only performed in children and pregnant women. However, B-mode sonography is primarily performed in the assessment of all cervical lymph nodes because of its superior sensitivity in comparison to CT and MR, as well as in diseases of the salivary glands, solid tumors, and monitoring of distraction osteogenesis of the mandible. With color-coded ultrasonography as a combination of B-mode and blood flow information, vessels of the head and neck area or of planned flaps can be examined in a noninvasive manner. This is especially

important in secondary microsurgical reconstructions. Moreover, the blood flow in any soft tissue masses can be evaluated. In spite of all texture and image analysis techniques, positive and negative lymph nodes cannot be differentiated in a safe manner. Three-dimensional sonography, e.g., panoramic pictures, and contrast enhancement are new technologies that will improve diagnostic accuracy of head and neck ultrasonography.

Herman Kolbeck, Krummrey[11] Ultrasonography was found to be a non-invasive predictor of bone regenerate strength in the early phase of distraction osteogenesis which may reduce the need for radiographs which cannot pick up callus formation earlier.

Stetzer K, Cooper G, Gassner R, Kapucu R, Mundell R, Mooney MP[24] The development of fibrous nonunions after orthognathic surgery is thought to result from an interaction of biomechanical stress and the differential and more rapid migration of fibroblasts (*compared with osteoblasts*) into the wound site during healing. The present study was designed to test this hypothesis through the manipulation of guided tissue regeneration and osteotomy fixation techniques in an experimental rabbit model. Radiographic and

histomorphometric analyses revealed that rigidly fixed defects, covered with membrane, showed the most rapid and organized new bone formation. The rigidly fixed defects with the membrane averaged approximately 40% more new bone in the osteotomy site compared with the rigidly fixed defects with no membrane. Nonrigidly fixed defects with no membrane showed an ingrowth of fibroblasts and fibrous nonunions. These experimental results suggest that an interaction between the decreased fibrous tissue ingrowth through guided tissue regeneration and osteotomy segment stability from rigid fixation prevented postoperative fibrous nonunions and facilitated new bone regeneration and osteotomy site healing in this rabbit model.

Kaban, Thurmuller, Glowachi[12] Qualitative (*ultrasonography*) and quantitative (*ultrasonography*) have been shown to be accurate and reliable methods of evaluation of distraction osteogenesis–the corticotomy gap, new bone formation, bone maturity, fluid collection etc., Clinician can obtain series studies and use this information to make a rational decision to remove distraction devices in a timely manner. This approach may result in reduction in overall treatment time.

Summary and Conclusion

Ultrasonography has been used as a instant, noninvasive method to monitor the post-operative healing and revascularization at the osteotomy site. The status of bone–the vascularity, callus formation and viability of bone is a very important factor, in assessing the successful outcome of various surgical procedures. This information is not offered by routine radiographs, which cannot detect bony changes before 4 weeks. Ultrasonography is a reliable alternative, to study the callus formation. Early stages are seen as hypoechoic areas with flecks of calcification seen as hyperechoic structures. Doppler study clearly shows the angiogenesis in the gap between the bony fragments.

Bone Scintigraphy also does not reveal the vascularity and calcification in the earlier stages. Isotope uptake for calcification in bone formation is possible only after a few weeks. Ultrasonography is a reliable alternative, to study the callus formation at the earliest.

Colour flow imaging including power Doppler studies and duplex Doppler study provide useful information about vascularity and viability of structures at the treated area such as callus.

The ***advantages*** of ultrasonography over other diagnostic modalities like CT and MRI may be summarized as follows.

From the patient's point of view

- Easily tolerated by the patient as it is a non-invasive procedure.
- Inexpensive.
- Radiation free.
- Quick to perform, less time consuming.
- Reproducible.
- Can be used even in children.

From the Surgeon's point of view

- Ultrasonography gives a good degree of diagnostic accuracy.
- Provides basis for selection of additional imaging modalities.
- Provides necessary information about Pre and post operative assessment of Osteotomy site.

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