INTRODUCTION

Although it was Le Fort in 1901 who gave description of the natural loci minoris resistancia in the fractures pattern of midface, it was Cheever in Boston who published his experiences over the osteotomy and downfracture of the maxilla for the resection of nasopharyngeal tumor in 1870 [1, 2]. Wassmund followed by Axhausen applied this technique for the correction of the developmental malocclusion in 1927 [1, 2]. In 1942 Schuchard introduced a very important modification to this operation by disjunction the maxillary tuberosity from the pterygoid process. Classically it was described as a blind approach using a curved osteotome, which is placed at the pterygomaxillary junction and tapped to separate the junction. He also stressed that stability of the entire procedure depends on the complete mobilization of the maxilla from the pterygoid process [1, 2]. Moore and Ward in 1949, and Dingman and Harding in 1951 mobilized maxilla after the malunited Le Fort I fracture. In 1954 the same procedure was used for the correction...
of the post-cleft deformity by Gilles and Rowe [1, 2]. Hugo Obwegeser described autogenous bone grafting into the gaps created after pterygomaxillary disjunction as a method of relapse prevention [1, 2]. The major contribution to this surgical technique, making it a working horse of the orthognathic surgery was done by Bell, who on animal model performed a hemodynamic studies on blood supply to the downfractured and mobilized maxilla [1, 2]. Imperfection of standard technique led to decrease the risk of complications and several new methods have been suggested. Wikkeling, Tacoma and Laster et al. recommended use of the „swan’s neck” osteotome or the „shark fin” osteotome to separate the pterygomaxillary junction [3, 4]. Ultrasonic bone curette or oscillating saw were also suggested [5]. Safe separation was obtained by tuberosity osteotomy. On the contrary Precious et al. had successful results with maxillary downfractures and pterygomaxillary disjunction performed without the osteotomes. The constant improvements of the surgical technique based on the good understanding of the anatomical limitations caused that this procedure, previously considered to be very dangerous, now is routinely applied in maxillofacial surgical wards. However, one should keep in mind that only the full compliance to the surgical rules of the maxilla downfracture can prevent the occurrence of serious complications, like: injury to the sinus cavernosus and thus to the cranial nerves (III, IV, VI, V1 and V2), injuries to the orbit even with the possibility of blindness, disruption of descending palatal nerve and vessels, injury to the structures of the pterygopalatal fossa, massive bleeding from maxillary artery or pterygopalatal plexus (Fig. 1) [6–8].

MATERIAL AND METHODS

Our experience is based on over 1280 Le Fort I osteotomies performed in the years 1998–2014. In 2008 we introduced modification of the well known procedure moving the line of the maxillary mobilization from pterygomaxillary junction frontally to the maxillary tuberosity. We also found that the presence of erupted or unerupted third molars made the osteotomy and the downfracture easier, safer, and the line of the fracture very predictable. In the classic method of maxillary separation from the pterygoid process the curved chisel or osteotome is inserted and locked between the maxillary tuberosity and the lateral plate of the pterygoid process. Then the surgeon’s index finger palpates palatally the hamulus and the maxillary tuberosity. By fine tapping of the proceeding osteotome the pterygomaxillary junction separates. The osteotome is directed forwardly to the palatally located finger thus protecting the mucosa from the possible

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Fig. 1. Horseshoe maxillary osteotomy (segmentation) and complete mobilization of the maxilla.
iatrogenic tear (Fig. 2). The next possible step to make the downfracture more predictable is osteotomy of the posterior wall of the maxillary sinus performed by straight osteotome. But it also carries the risk of the simultaneous cutting of the pterygoid process, which consequently may produce serious complication during downfracture (mentioned above). If we restrain from the completion of the osteotomy of the posterior wall the final fracture will also become unpredictable. It can move up really high, making the mobilization very difficult and also dangerous with the possible complications similar as with the fractured pterygoid process [9]. In 2007 we operated on the patient with open bite, who mistakenly had the third upper molars left in place. After the initial extraction of these teeth through the vestibular approach, we had a natural marking points in post-extraction dental sockets to start with the osteotomy. We inserted the sharp curved osteotome into the created gap and performed the maxilla osteotomy easily and without complications, with index finger placed palatally expecting the on-coming blows and ensuring the correct direction of the osteotome and preventing the undesired tears of the mucosa (Fig. 3A–B). Improving the technique during the next procedures we came to the conclusion that the curved chisel (osteotome) should be aimed downwardly, medially and a little bit anteriorly – first at the level of maxillary tuberosity than moved up every 2 mm up to 10–12 mm directed at the same angle.

For better mobilization of the maxilla in case of major advancements (more than 8 mm) the Authors propose the following modifications:

- after downfracture, the maxilla is mobilized with forceps (spreaders) originally designed for the mandibular split BSSO (bilateral sagittal split osteotomy). The spreader is located where the line of osteotomy crosses the zygomatico alveolar crest (slightly below the zygomatic buttress) (Fig. 1). The act of mobilization is performed by opening the spreader of the one side while the opposite side is pushed upward by surgeon’s index finger creating the one arm lever which easily stretches the retromaxillary tissues. This method cannot be applied in every operated maxilla. The limitations are the quantity and quality of the bone in the zygomatico alveolar crest (zygomatic buttress);
- with the benefits of piezo cutting systems preservation and mobilization of the palatine descending vessels has become much easier comparing to the traditional reciprocating or rotating devices. Also the time consumption is comparable to the usage of traditional tools. Bleeding in the operated
The retromaxillary area is significantly decreased and this is the result of the shock wave phenomenon associated with the piezo cutting devices – the operation field is clear. Recently introduced long (10 cm) cutting tips allow safe osteotomy of the maxillary tuberosity with the preservation of the mucous membrane – which is not always possible with osteotomes or chisels. With the short cutting tips such modification was not possible due to the relatively big bulk of the piezo handpiece;

- for the better forward mobilization of the maxilla the Authors introduced the horseshoe osteotomy of the hard palate performed after maxillary downfracture with piezo (Fig. 1B).

Inadvertent fracture of the palatal shelf (lamina horizontalis is off the palatal bone) should not be considered as complication. During downfracture hard palate can break at the line of the junction between the palatal process of the maxilla and the horizontal plate of the palatal bone. This could be symmetrical on both sides, or asymmetrical. The symmetry is achieved by mobilization of the horizontal plates from the palatal process of the maxilla on one side and from the palatal bone on the other (Fig. 1D).

By mobilizing the horizontal plates of the palatal bone and combining this procedure with the horseshoe osteotomy of the maxillary palatal process. The mobilization of the palatal mucosa is easier and safer (tear prevention) and allows for bigger maxillary advancement. The other benefit of the segmentation of the hard palate is that during major maxillary posterior impactions we do not create a „step” between the parts of the hard palate (frequent patient complaint), but we make new smooth vault (Fig. 2).

This procedure (segmental hard palate osteotomy) is also advised to apply after downfracture when we have hard palate in one piece (palatal process is not separated from the palatal bone) especially in posterior impaction cases. By pushing the hard palate upward we are markedly narrowing posterior nostrils – this could be prevented by segmental hard palate osteotomy (Fig. 2).

The other benefit of the maxillary mobilization through the tuberosity is the possibility to insert interpositional bone grafts with excellent stability. Comparing to the pterygomaxillary disjunction in this situation we have two relatively big bone plates with cancellous bone – ready to accept and heal the graft. In cases, where primarily the upper third molars were removed and secondly the maxillary advancement was performed one have to deal with a large gap that if not treated properly, could result in unstable new position of the maxilla and following malocclusion, malunion or both.

The suggested treatment in this situation is autogenous bone grafting. Preferably the interpositional bone graft should be squeezed into the gap created by the removal of third molars and maxillary advancement. For better stability the block is fixed to the zygomatic buttress by plate. For easier fixation the Authors suggest to attach the straight palate (4–5 holes) to the harvested bone block extraorally then insert it into the gap in maxillary tuberosity through the vestibular incision using free end of the plate as a handle and fix the plate to the cephalic part of the maxilla in the most desired position. Such policy is advised in big advancements where the maxillary advancement and the dental socket treated a cavity bigger than 1 cm with wide communication with the sinus. For smaller gaps, e.g. when there was no third molar in situ and when the created space was the result of the maxillary movements, the Authors suggested utilization of biomaterials (Osteovit®, Bio-oss®) that are produced in block not granules. The stability of the graft is provided by surrounding bone – the material is simply pressed into the gap. Plate fixation is not advised.

The promote healing in places where bone grafts or biomaterials where inserted the authors apply the „blobs” of PRF (platelet rich fibrin) obtained from the patients blood. Such natural film is isolating the site of osteotomy and grafts from the incision wound, provides, in our opinion, faster and uncomplicated healing. In four cases where buccally erupted third molars where removed during the maxillary advancement we had to treat persistent oroantral fistulas.

In two cases local scarring and stichting solved the problem, but in two cases the successful closure of the fistula...
was achieved by buccal fat pedicled flaps. Such complica-
tion should be anticipated when during the extraction of
the third molar via vestibular approach the tear of the mu-
cosa appears. Meticulous suturing, bone and PRF grafting
should be applied in such cases – as prevention of the pos-
sible fistula.

RESULTS

We found that maxilla always broke in the line of the os-
teotomy and the risk of disruption of descending palatine
nerve and vessels was very low (Fig. 4). This technique gives
additional advantage, it creates a very well defined space for
autogenous bone blocks grafts in cases of more than 6 mm
maxilla advancement. Moreover it decreases the opera-
tion time and makes the removal of excessive bone safer in
cases demanding posterior maxillary impaction (clock-wise
rotation movement of the maxillary complex). We experi-
ence no major complications when performing osteotomy
in this way. Meticulous packing with the Spongostan® or
Surgicel® into the post-extraction sockets of erupted molars
and precise suturing of the mucosa prevented the forma-
tion of orosinus fistulas. No serious intra- and postop-
erative complications were observed. In only 6 cases out of
157 we observed the disruption of the palatine descending
vessels.

DISCUSSION

Le Fort I osteotomy has become the procedure of choice
for surgical treatment of maxillofacial deformities. Post-
terior split is conventionally achieved by pterygomaxil-
rary disjunction using an osteotome; although, osteotomy
through the tuberosity is much more safe. However, it is not
as popular as the classic procedure. Only 7% of British surgeons perform it, 15% of them use leverage only while the rest separates conventionally [10].

Many different techniques are used to achieve pterygomaxillary separation. Straight or curved osteotome is often used classically through a blind approach to the pterygomaxillary suture. „Swan neck” and „shark fin” modifications of osteotomes have also been described to improve the safety of this operation [3, 4]. Precious et al. reported that pterygomaxillary separation can be achieved successfully by leverage alone without the chisel [11]. They described the use of Tessier’s spreaders and digital manipulation to achieve pterygomaxillary separation followed by maxillary mobilization. In their study the occurrence of pterygoid plate fractures was at 80%, which was equal with or without the osteotome.

Concerns about the risk of haemorrhage or nerve disruption as a result of pterygomaxillary separation led to the development of safer osteotome techniques anterior to the pterygomaxillary region. Dupont et al. used a transbucal approach to a vertical osteotomy through the tuberosity [12]. Trimble et al. mentioned an intraoral vertical osteotomy in the region of the tuberosity [13]. Rohner et al. described an endoscopically assisted LFI osteotomy to ensure preservation of the descending palatine artery [14]. Ueki et al. recently advocated the use of an ultrasonic bone curette to mobilize structures described above [15]. This study is best to our knowledge first to describe the osteotomy through the cavity of extracted third molar.

The incidence of serious complications after Le Fort I osteotomy ranges from 1.1–6.4% [16]. Approximately 1% of patients suffer from excessive bleeding, especially during bimaxillary surgeries. In our material it was only 1 patient (0.6%), who needed blood transfusion.

Vascular complications can arise from direct trauma to vessels because of the blind technique of the osteotomy, and unwanted fractures can extend to the pterygopalatine fossa, base of skull, and orbit. Kanazawa et al. give predictive factors of pterygoid plate fractures after separation without osteotome what can lead to vessels of nerves disruptions [5]. One of them, long tuberosity, is excluded thanks to tuberosity osteotomy.

The vessel most often involved is the descending palatine artery. We observed disruption of those vessels in 6 cases (4%) comparing with 20 (out of 161, 12%) during separation in the pterygomaxillary region. Less often the maxillary artery and its terminal branches, the pterygoid venous plexus, the internal carotid artery (without complete separation), and internal jugular vein may be damaged.

CONCLUSIONS

Le Fort I osteotomy executed through the maxillary cavity of the extracted third molar is a safe and predictable procedure. Maxilla always fractures below the level of the pterygomaxillary junction, thus preventing the possible trauma to the content of the pterygopalatine fossa and surrounding structures – the plexus pterygoideus [17]. There is also a profound decrease in blood loss – almost 40% (an average 400 ml blood loss in the previous procedure to 250 ml in case of the cut through the tuberosity) [17, 18]. Certainly, it is also better to wait with the third molars extraction until the time of the osteotomy. They presence in situ regardless the fact of being erupted or unerupted is the advantage of the planned Le Fort I osteotomy.

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REFERENCES