APPLICATION OF A MAXILLOFACIAL SURGERY INSTRUMENT MANUFACTURED BY LASER SINTERING IN THE SAGITTAL SPLIT OSTEOTOMY

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Abstract: Mandibular sagittal split osteotomy (SSO) is an operation performed for correction of the malpositions of the jaw bone due to dentofacial deformities. In this operation, sharp rotary tools are needed to be used for the osteotomy of the mandible and this can induce some complications. For example, if the inferior alveolar nerve is damaged during the surgery, paralysis of the teeth, the lateral side of the tongue and the corner of the lip occur. To decrease the occurrence of such possible complications, we designed and manufactured a novel computer-assisted, patient-specific SSO guide and soft tissue retractor in our previous study. We first tested this apparatus on a cadaveric bone in vitro. Now, in this study, a surgical application of the instrument, which was designed and manufactured according to the requirements existed in the mandibular sagittal split osteotomies, was performed. This paper gives and discusses the first results obtained from the in vivo application of the apparatus.

Key words: sagittal split osteotomy, patient-specific, mandibula, laser sintering, biomechanics.

1. INTRODUCTION

In the area of maxillofacial surgery, sagittal split osteotomy (SSO) is routinely performed for the correction of mandibular deformities (Wolford, 1987). During the SSO operation, sharp rotary tools used for the osteotomy and, overretraction can induce complications (Matris, 1984). For example, if the inferior alveolar nerve is damaged, paralysis of the teeth, the lateral side of the tongue and the corner of the lip occur (Cansiz et al, 2014). Furthermore, if the inferior alveolar artery is damaged, serious hemorrhagic complications can occur. The inferior alveolar neurovascular sheet and its entrance to the mandible, the inferior alveolar foramen, must be identified properly for the protection of the neurovascular tissues. After the identification of the neurovascular sheet and the foramen, neurovascular tissues must be retracted away from the osteotomy site carefully for the protection. Since the retraction procedure is quite traumatic, hemorrhagic or neurological complications may occur. Uncontrolled use of rotary instruments during operation can lead to damage of the surrounding tissues or failure to achieve a proper osteotomy line. The unsuitable osteotomy line is one of the major factors of the bad split (Kriwalsky et al, 2008).

There are some surgical instruments designed for soft tissue retraction which are the modifications of the original Obwegeser mandibular channel retractor (Obwegeser, 1964). Although these retractors are simple and useful, they can not be suitable for all the patients due to their non-specific, standard geometry.

To decrease the aforementioned complications occurred in the SSO, we have designed and manufactured a novel apparatus in our previous study (Cansiz et al., 2014). This instrument can be seen as a subject-specific, computer assisted SSO guide and a soft tissue retractor. This instrument was first tested on a human cadaveric mandible in vitro (Cansiz et al., 2014). After evaluating the merits and shortcomings of this device in vitro, now, in the current study, the apparatus was used in a real SSO operation in vivo. This case study aims to report the first results of the performance of this surgery instrument.

2. MATERIALS AND METHOD

2.1. Design of the apparatus

The first step in the preoperative stage of the SSO is to determine the osteotomy line to which sharp rotary tool will follow for splitting the mandible. To be able to specify an exact osteotomy line, three dimensional model of the patient's mandible was required. Therefore, two dimensional computed tomography (CT) images of the patient's mandible was converted into a three dimensional solid body (Fig. 1).

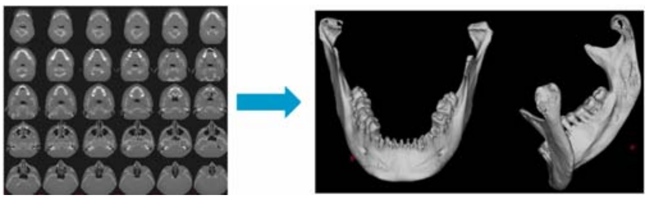


Fig. 1. Conversion of two dimensional computed tomography images into a three dimensional solid body model.

SSO is started on the medial surface of the mandibular ramus horizontally just above the mandibular foramen and reaches to the posterior border of the ascending ramus from the anterior. Following horizontal cut, a vertical osteotomy on the lateral surface of the mandibular corpus at the region of molar teeth including inferior border of the mandible is performed. Finally the horizontal and the vertical osteotomies are joined each other by a diagonal osteotomy between the anterior part of the horizontal osteotomy and the superior part of the vertical osteotomy (Cansiz et al., 2014).

The above-described osteotomy line was specified on the solid body model of the mandible (Fig. 2).

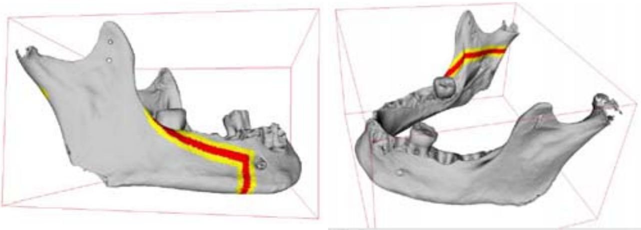


Fig. 2. Sagittal split osteotomy line (red line) specified onto the three dimensional model of the patient’s mandible.

The patient specific 3D model of the instrument was designed onto the surface of the cadaveric mandible according to the osteotomy line using the VR Mesh Studio software (VirtualGrid Company, USA) (Fig. 3).

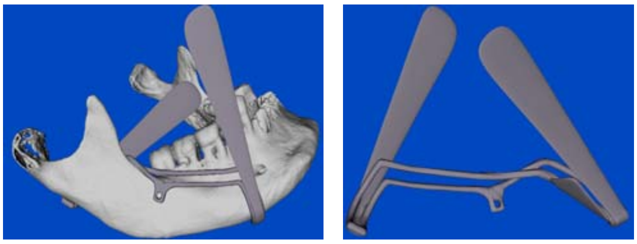


Fig. 3. The designed sagittal split osteotomy guide and soft tissue retractor.

Since the instrument is placed only in a single position on the mandible, positioning inaccuracy between the computer model and the real mandible would be restricted (Fig. 4).

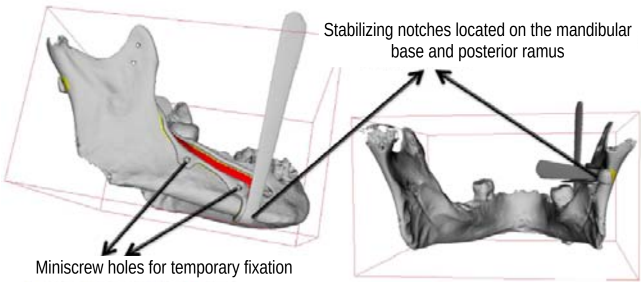


Fig. 4. Different views of the instrument placed on the mandible.

This instrument is a combination of soft tissue retractors and an osteotomy guide, which shows the generally accepted sagittal split osteotomy line starting from the posterior mandibular ramus and reaching the base of mandibular corpus (Fig. 5).

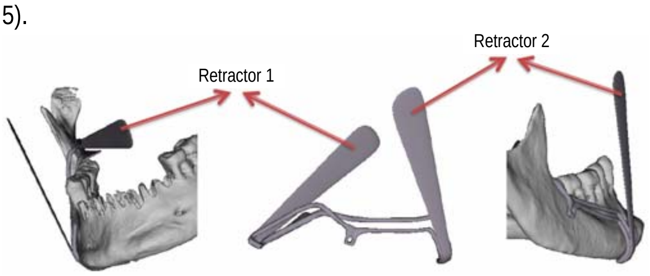


Fig. 5. Detailed views of the retractors

Although the main design purpose of these soft tissue retractors is to protect the surrounding anatomic structures from the rotary osteotomy instruments, they also provide good vision and eliminate the need for more tools (Fig. 6).

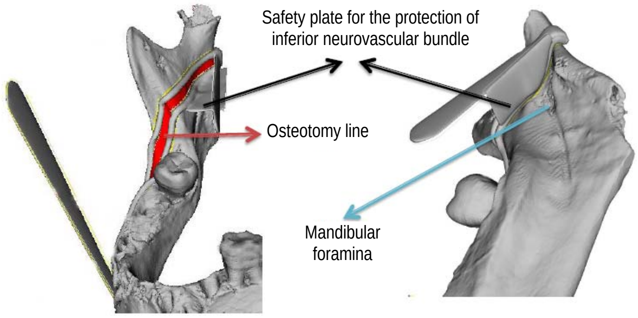


Fig. 6. Detailed views of the safety plates designed to protect the inferior neurovascular bundle.

2.2. Manufacture of the apparatus

Created three dimensional model of the instrument was manufactured using the metal laser sintering method (Fig. 7). In this technique, a high power laser was used to fuse small particles of stainless steel powders into a mass that has a desired 3D shape. In our case, stainless steel was preferred as the material of the instrument since it shows ductile and biocompatible characteristics (Nicholson, 2002). In addition, comparing with the titanium, which is widely used in medical device technology, stainless steel is a cheaper material. After the laser sintering of the stainless steel particles, instrument underwent heat treatment at 500 °C to improve the ductility.

Fig. 7. Manufactured instrument by laser sintering technology.

3. APPLICATION OF THE INSTRUMENT IN A SAGITTAL SPLIT OSTEOTOMY OPERATION

In this case, SSO was performed for mandibular advancement to correct mandibular retrognaty. The computer assisted, patient specific sagittal split osteotomy guide and soft tissue retractor was used at the right side and the other side was performed by conventional instruments. On the anterior side of the ramus and the buccal side of the corpus, a diagonal full-thickness mucoperiosteal flap was elevated. At the lingual side of the ramus, mandibular lingula and at the buccal side of the corpus mental foramina was identified. A periosteal elevator was used to retract the inferior alveolar bundle and the instrument's curved notch inserted to the posterior border of the ramus. Then, periosteal elevator was removed and the inferior alveolar bundle stayed under the protection shield of the instrument. After that, instrument was placed properly by attaching the other notch of the device to the mandibular basis (Fig. 8).

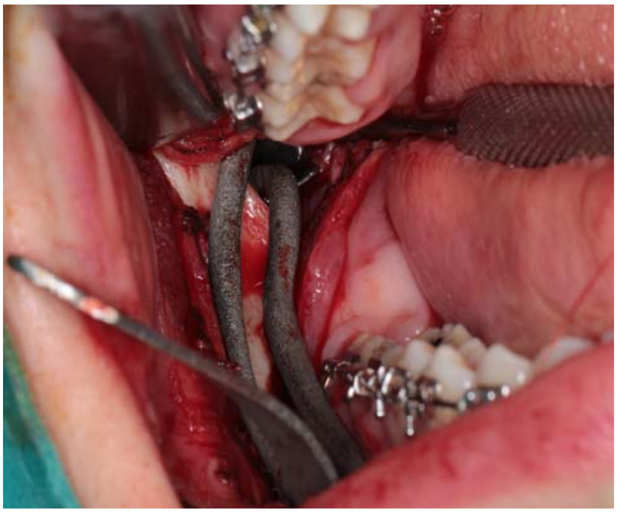
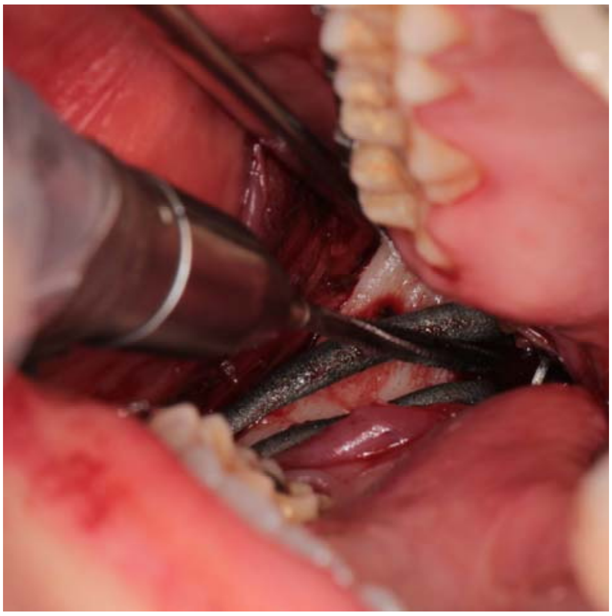
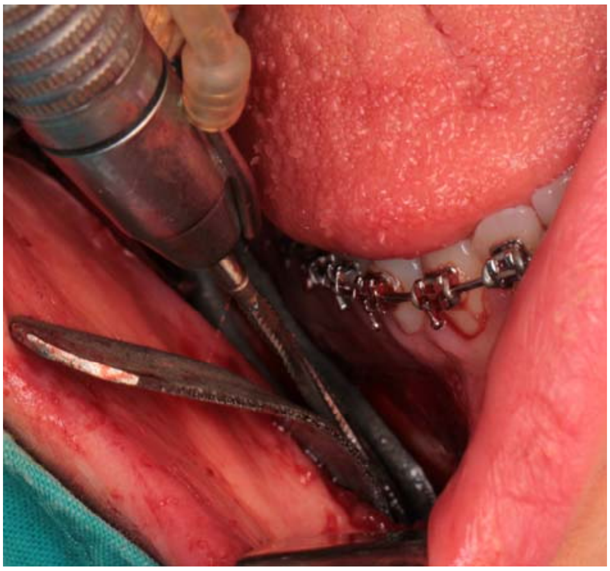


Fig. 8. Application of the instrument

One 5-mm miniscrew was used to fix the instrument to the mandible to prevent the disengagement during the operation. After the application of the instrument, osteotomy was performed by using lindeman bur without any other retraction instrument (Fig. 9a, b). After the completion of the osteotomy the instrument was removed and splitting procedure was completed by using conventional SSO technique.



(a)



(b)

Fig. 9. Different views (a,b) of the sagittal split osteotomy by using rotary instruments.

4. RESULTS AND DISCUSSION

SSO described by Trauner and Obwegeser (1957) is a common operation technique used for the correction of mandibular deformities. Although SSO is a well-known and widespread procedure, it requires careful planning and attentive operation technique to avoid complications.

Overretraction of the soft tissues and using the sharp rotary tools for the osteotomy can induce complications especially during the approach on the medial side of mandiblar ramus (Al-Bishri et al., 2005). Careful identification and protection of inferior alveolar neurovascular bundle are required to prevent complications. On the other hand, unsuitable obligue and vertical osteotomies are the major factors of bed splitting. Uncontrolled use of rotary instruments during operation can lead to damage of the surrounding soft tissues or failure to achieve a proper osteotomy line.

To avoid the SSO complications explained above, a computer assisted, patient specific sagittal split osteotomy guide and soft tissue retractor was designed and produced by using laser sintering method (Khaing et al., 2001; Cansiz et al., 2015). This instrument was designed to avoid complications such as soft tissue injuries, excessive edema, nerve and vessel damage caused by rotary instruments and failures to perform correct osteotomy line. Using the instrument also makes operation field more comfortable to work and easy to see by reducing the need for extra assistance.

Although it is advantageous to use this custom made instrument, the design and production process of the device is challenging. It requires a CAD operator to work on the design in cooperation with the surgeon who will operate the patient. Also, it is still hard to fabricate this kind of custom made, complex geometrical shaped objects with newly introduced laser sintering method. As a result of these factors, preoperative preparation period is elongated. In addition, this process brings extra costs.

5. CONCLUSION

Since the SSO is a specific operation, which requires a technical sensitivity, the use of the proposed instrument will be able to eliminate the most of the operator related complications. After elimination of the limitations of the instrument, it is expected to provide

i)shorter operation duration,

ii)less time need for the general anesthesia and accordingly less time for the exposure to the bacterial contamination,

iii)reduction of the complications and the operation costs due to shorter operation time,

iv)reduction of the corticosteroid need given for the edema control and,

v)reduction of the postoperative hospitalization period and the increase of the healing process .

REFERENCES

1. Al-Bishri, A., Barghash, Z., Rosenquist, J., Sunzel, B. (2005), *Neurosensory disturbance after sagittal split and intraoral vertical ramus osteotomy: as reported in questionnaires and patients' records, International* Journal of *Oral and Maxillofacial Surgery*, 34, 247-251.
2. Cansiz, E., Arslan, Y.Z., Turan, F., Atalay, B. (2014), Computer-assisted design of patient-specific sagittal split osteotomy guide and soft tissue retractor, *Journal Medical and Biological Engineering*, 34(4), 363-367.
3. Khaing, M.W., Fuh, J.Y.H., Lu, L. (2001), Direct metal laser sintering for rapid tooling: processing and characterisation of EOS parts, *Journal of Materials Processing Technology*, 113, 269-272.
4. Kriwalsky, M.S., Maurer, P., Veras, R.B., Eckert, A.W, Schubert, J.S. (2008), Risk factors for a bad split during sagittal split osteotomy, *British Journal of Oral and Maxillofacial Surgery*, 46,177-179.
5. Matris, C.S. (1984), Complications after mandibular sagittal split osteotomy, *Journal of Oral and Maxillofacial Surgery*, 42(2), 101-107.
6. Nicholson, J.W. (2002), *The Chemistry of Medical and Dental Materials*, Royal Society of Chemistry, UK, 2002.
7. Obwegeser, H. (1964), The indications for surgical correction of mandibular deformity by the sagittal splitting technique, *British Journal of Oral Surgery*, 1, 157-171.
8. Trauner, R., Obwegeser, H. (1957), The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. I. Surgical procedures to correct mandibular prognathism and reshaping of the chin, *Oral Surgery Oral Medicine Oral Pathology*, 10, 667-689.
9. Wolford, L.M., Bennett, M.A., Rafferty, C.G. (1987), Modification of the mandibular ramus sagittal split osteotomy, *Oral Surgery, Oral Medicine, Oral Pathology*, 64(2), 146-155.

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