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Bilateral sagittal split osteotomy in cadaveric pig mandibles: Evaluation of the lingual fracture line based on the use of splitters and separators

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Abstract

Objectives. To analyze the splitting pathways of the (lingual) fracture lines during a bilateral sagittal split osteotomy (BSSO) in cadaveric pig mandibles.
Study design. A BSSO was performed using splitters and separators. Special attention was paid to end the horizontal medial cut at the deepest point of the entrance of the mandibular foramen.
Results. Of all lingual fractures, 95% ended in the mandibular foramen. Forty percent of these fractures extended through the mandibular canal and 40% extended inferiorly along the mandibular canal.
Conclusion. Almost all lingual fracture lines ended in the mandibular foramen, most likely due to placement of the medial cut in the concavity of the mandibular foramen. The mandibular foramen and canal could function as the path of least resistance in which the splitting pattern is seen. We conclude that a consistent splitting pattern was achieved without increasing the incidence of possible sequelae.

Introduction

Bilateral sagittal split osteotomy (BSSO), originally described by Trauner and Obwegeser,[1] is traditionally used to correct mandibular anomalies in humans as part of surgical-orthodontic treatment, and many researchers have tried to perfect the procedure and improve its safety and reliability. The most common complications are bad splits (defined as unwanted fractures of the proximal or the distal segment of the mandible) and neurosensory disturbances resulting from injury to the inferior alveolar nerve (IAN) during surgery, which can have an impact on the daily life of patients.[2] Modifications to this technique have been proposed to address these issues.[3-6] Most techniques are based on the use of a chisel to separate the distal and proximal segments of the mandible.[7-12] Several decades ago, Wolford et al[6] emphasized the importance of the cutting technique to produce a clean split with a minimum amount of force and with minimal use of osteotomes. Other researchers already have advocated prying and spreading the mandible rather than splitting with chisels and mallets, as employed in BSSO,[13] and the use of Smith and Tessier spreaders have been described.[14] Compression of the IAN during splitting with blunt chisels has been shown to induce a decrease in sensory nerve reactions.[15]

Furthermore, Plooij et al. emphasized that the possible influence of the lingual fracture line (and its absence of control and visualization) could be a possible factor in damaging the IAN and influencing the fracture line due to placement of the (medial) bone cuts. Until now, no studies have been performed to evaluate the placement of the horizontal medial cut and to show a possible path of least resistance with regard to the lingual fracture pattern to the mandibular foramen of the mandible in 3 dimensions on cadaveric mandibles. We aimed to analyze the fracture lines in a BSSO using sagittal splitters and separators and to determine the influencing factors on the splitting pattern. We also aimed to find an explanation for the reduced risk of nerve damage and bad splits in BSSO by using sagittal splitters and separators based on the findings in other reports.[16,17] Our hypothesis was that by placing the medial cut in the concavity of and just above the mandibular foramen in combination with the use of sagittal splitters and separators and prying and spreading the mandibular segments, rather than driving chisels past the nerve, we can create a consistent fracture line at the lingual side of the mandible following the mandibular canal

To validate this approach as a safe and reliable technique, we performed a pilot study of cadaveric pig mandibles. The main aim of this pilot study was to evaluate the (lingual) splitting patterns in relation to the nerve canal and the placement of the medial cut, and to determine the incidence of unfavorable splits.

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Materials and methods

We evaluated the reliability of our splitting technique in 10 cadaveric pig mandibles. The mandibles were obtained from 6- to 7-month-old female pigs, with a mean weight of approximately 100 kg and a mixed dentition phase. The pigs were originally bred for consumption. The soft tissues were used for consumption, and the mandibles were boiled to remove any soft tissue residues. The mandibles were then refrigerated at 1–3°C. The average length of the mandibles was 20 cm (range, 17–23 cm), and they contained at least 1 unerupted molar, 2 erupted molars, and 2 erupted premolars. Because the pig mandibles were slated for destruction, we did not need to obtain an approval from our institution to use the mandibles in our study.

The mandibles were cut in the midline for this experimental study. We used both sides for our splitting technique and performed BSSO using the modified method described by Hunsuck[4] as previously reported.[16,17] Since the forceps and elevators provide intra-mandibular forces only, the mandible could easily be stabilized with the hand. The horizontal bone cut was performed with a Lindemann bur (2.3 × 22 mm; Meisinger, Germany). The cut was made just above the mandibular foramen; it ended just posterior to the lingula superior of the mandibular foramen at the deepest point of the entrance of the IAN (Figure 1a). Subsequently, the sagittal and vertical cuts were made with a short Lindemann bur (1.4 × 5 mm, Meisinger). The vertical cut was made just posterior to the most distal erupted molar. The inferior border was also cut using the short Lindemann bur; this was a perpendicular cut through the inferior cortex that must reach the medial side to prevent the lingual fracture line to run to the buccal side, creating a bad split. Splitting was performed using curved Smith Ramus separators (Walter Lorentz Surgical, Jacksonville, Florida, USA) and elevators. The elevator was positioned in the vertical bone cut, and the splitting separator was positioned in the sagittal bone cut. Once the superior aspect of the mandible started to split, we repositioned the elevator at the inferior border of the vertical cut to complete the splitting (Figures 1, 2, and 3). We then analyzed the 20 separated segments comprising 10 left- and 10 right-sided split osteotomies to evaluate the patterns of splitting (especially the lingual fracture lines), unfavorable splits, and the potential impact of these on the IAN.

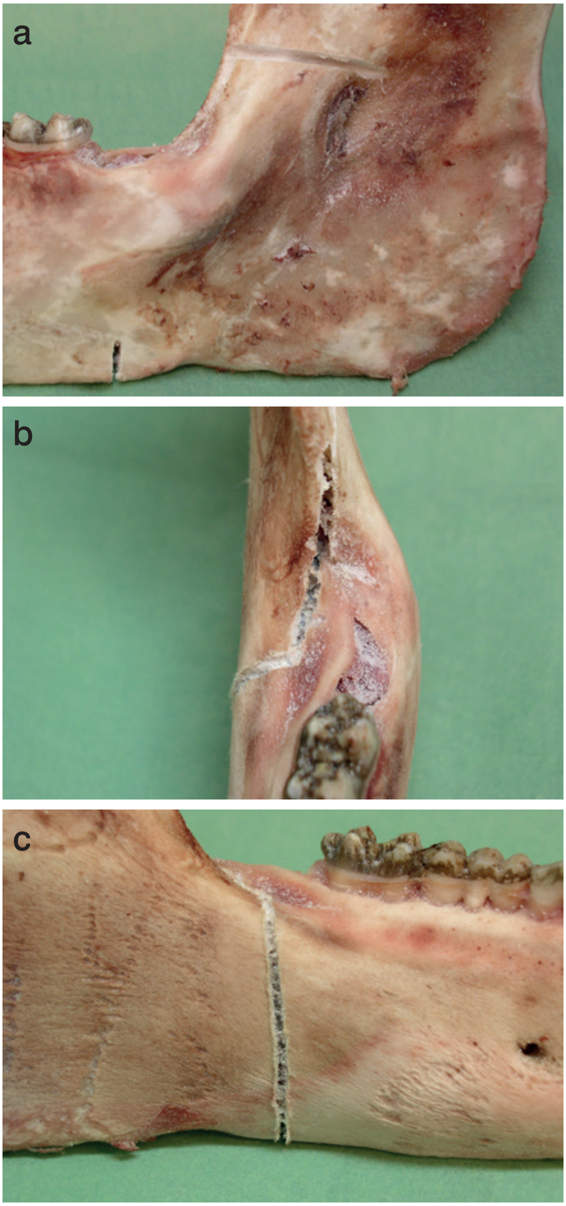

Figure 1 **a** Horizontal cut performed with a long Lindemann bur just above the mandibular foramen. The vertical cut, including the medial side, is also performed with the short Lindemann bur. **b** Sagittal cut between the horizontal and vertical cut. Note the follicle of the unerupted third molar. **c** Vertical cut made with the short Lindemann bur.

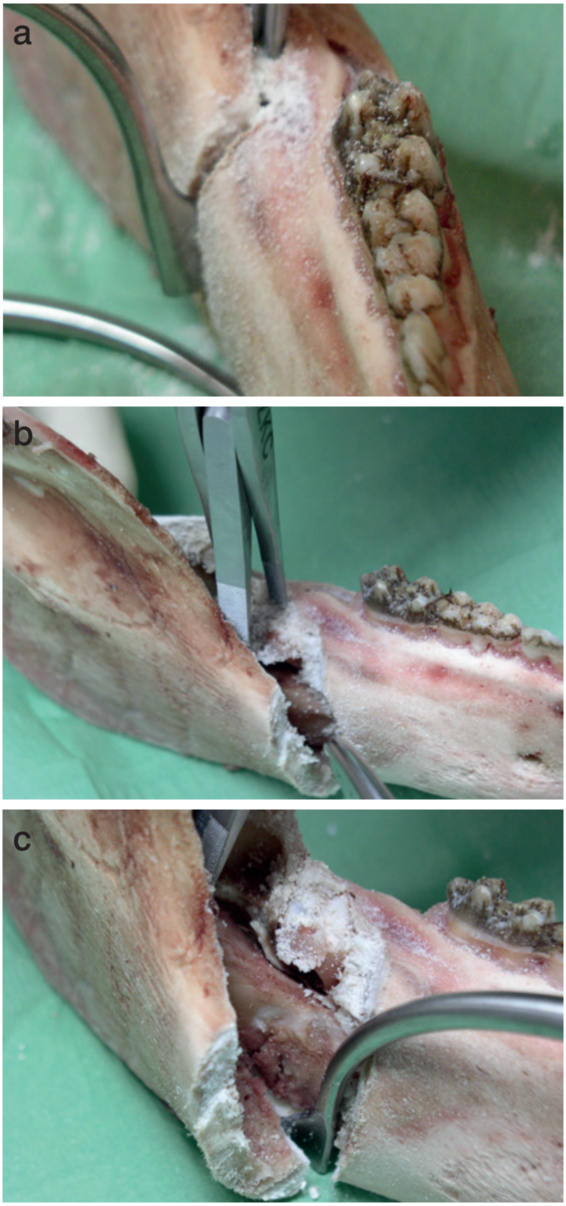

Figure 2 **a** Positioning of the sagittal splitter and separator for the sagittal and vertical cuts. Note that the separator is not yet at the inferior border of the vertical cut. **b** Unfolding of the split. Note that the separator is placed at the inferior border during the opening of the split. **c** Further unfolding of the split, also with the separator placed at the inferior border of the split.

Figure 3 Example of a lingual fracture line observed after performing the sagittal split. The fracture runs along the inferior border of the mandible, however not starting in the superior extension of the vertical lingual cut, and then runs inferior to the mandibular canal (40%) to the mandibular foramen (95%).

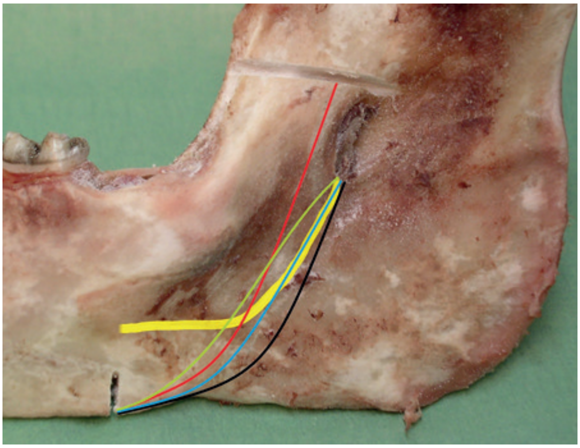

Figure 4 Lingual splitting patterns after performing a SSO. Yellow line: IAN; Blue line: the lingual fracture extended through the mandibular canal (40%); Black line: the lingual fracture originated inferior to the mandibular canal and continued and ended inferior to the canal (40%); Green line: the lingual fracture started inferior to the canal, crossed and ran superior along the mandibular canal (20%). Red line: unfavorable fracture that ended just in front of the mandibular foramen. All other lingual fracture lines ended in the concavity of the mandibular foramen (95%).

Results

On analysis of the fracture lines in relation to the mandibular foramen, we found that all but one (95%) of the lingual fractures ended in the mandibular foramen (Figure 3 and 4). The exception was an unfavorable fracture that ended just in front of the mandibular foramen. This originated from the inferior border and extended along the inferior border to cross the mandibular canal, then upwards ventrally of the mandibular foramen to the horizontal cut, which resulted the IAN still being positioned in the proximal segment (figure 4).

In relation to the mandibular canal, 40% of lingual fractures originated inferior from the vertical cut and extended through the mandibular canal, and 40% of them originated inferior to the mandibular canal and continued and ended inferior to the canal. The remaining 20% started inferior to the canal, crossed and ran superior along the mandibular canal and ended in the concavity of the mandibular foramen (Figure 3 and 4).

In relation to the inferior border, 6 lingual fracture lines (30%) originated directly from the inferior part of the vertical cut but did not run through the inferior border; instead, they extended more superiorly from the origin, eventually reaching the mandibular foramen. The remaining 70% of fractures continued through this inferior border. The average length of the fracture line at the inferior border was 11 mm (range, 7–34 mm) (Figure 3 and 4).

When the fractured segments were analyzed, no sharp bone interferences directed toward the mandibular canal causing possible damage to the IAN, were observed.

Discussion

BSSO is a relatively safe procedure for the correction of mandibular anomalies as part of surgical-orthodontic treatment. Since it is an elective procedure, it is very important to minimize the possible side effects of surgery, and modifications to existing splitting techniques should be designed to minimize complications. This pilot study shows that prying and spreading the mandible during the sagittal split osteotomy (SSO) with sagittal splitters and separators and placement of the medial cut into the concavity of the mandibular foramen leads to a predictable splitting pattern and could potentially minimize the risk of damage to the IAN and bad splits. This technique, with instruments which are especially created for prying and spreading the mandible and not driving chisels along the IAN to the mandibular border ('mallet and chisel technique'), is easy to perform and to learn (e.g.,for residents). Furthermore, prying and spreading the mandible could lead to a lower incidence of postoperative hypoesthesia, like suggested in earlier studies. [13,16,17] Using this pig model, allows good inspection of the lingual splitting patterns after SSO (compared to its absence of control and visualization due a clinical setting), which have never been analyzed in this way before. However, this pig model also has a superior visibility of the mandibular foramen when performing the bone cuts, while this degree of visualization is less in a clinical case.

The pig study model has been used successfully as a study model in earlier studies,[9,12,18-20] because there are similarities between the pig and human mandible, but caution is necessary when extrapolating the results. Pigs have longer mandibles and more teeth than humans. We placed our vertical cuts posterior to the most distal molar in the pig mandible, which is comparable to the cutting position used in humans. Unerupted molars were in situ in all the mandibles, but the fracture line always ran downwards and did not follow the follicular space of the non-erupted molar. Previous studies have also performed BSSO with the third molars in situ in the clinical setting, with no significant increase in the occurrence of bad splits or damage to the IAN compared to BSSO after removal of the third molars.[16,17] The mandibular canal is larger in pigs and has a pronounced divergent form at the beginning of the mandibular foramen. The region of the mandibular angle in pigs contains more cortical bone and less cancellous bone, which can influence the splitting pattern. However, in a normal split, this part of the mandible will be part of the proximal segment,[7] and therefore will not influence the splitting pattern.

The changes of the bony characteristics during preparation of these cadaveric pig mandibles used for SSO analyses have not been described in the literature. Thus, when analyzing the results, it is necessary to take this potential effect into consideration[21].

Bone is a composite of nanometer-sized carbonated apatite crystals (hydroxyl-apatite, containing calcium and phosphate) deposited in an organic matrix of collagen fibers with a hierarchical structure. The main constituent of the organic matrix, representing 90% of its weight, is type I collagen. When the collagen would be removed (using an alkali), one will experience 'stiff bone'. On the other hand, when all the minerals (using an acid) would be removed, one will experience 'flexible bone'. These chemical reactions will most likely not appear during a boiling or refrigerating process.

Bone collagen has a specific cross-link profile. This cross-linking influences the structure and physical properties and determines the viscoelasity of bone. Thermally induced denaturation of collagen influences the overall condition of the structure and cross-links in the collagen network. However, several studies showed that denaturation of Type I collagen in bone occurs only when temperature exceeds 120 °C and the degree of denaturation rises to approximately 50% at 160 °C. [23,24] During our short boiling process of the pig mandibles, the temperature never exceeded 100 °C and

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thus, it is most likely that the bone characteristics will not have changed extensively. This complies with our (subjective) feeling of the SSO's during this pilot study.

The fracture lines in this study were almost optimal, running from the inferior part of the vertical cut more or less perpendicular to the inferior border, along the mandibular canal to the mandibular foramen. The fracture lines along the inferior border or the mandibular canal to the mandibular foramen (80% of the fracture lines) seemed to follow the path of least resistance and this was probably due to the introduction of the sagittal separator immediately to the inferior border during the unfolding of the split (Figure 2c and 4). The superior extension of the inferior lingual border cut (ie., lingual vertical cut), as shown in figure 1, is meant to secure a fracture line in the lingual cortex instead of a buccal fracture line thus preventing a bad split. Using this higher extension of the lingual vertical cut, the possibility exists of the entire inferior border remaining within the proximal segment. In our experience (during our earlier reported prospective study[17] and BSSO cadaver courses) this has no influence on the retention of the IAN in either proximal or distal segment; not performing a proper vertical cut on the lingual side, did increase the amount of buccal bad splits. Entrapment of the IAN in the proximal segment is, in our opinion, more influenced by the transversal and vertical position of the canal, which may vary extensively as illustrated by Yoshioka et al.[22]

We analyzed the fracture lines that could potentially damage the IAN; we did not find any sharp bone fragments pointing toward the mandibular canal. A bad split at the site of a BSSO may be defined as unwanted fractures of the proximal or the distal segment of the mandible (buccal or lingual cortical plate fracture), and the reported incidence of these ranges from 0.5% to 5.4%.[8] We did not observe any bad splits in this study, and we observed only one unfavorable fracture during the splitting process, where the nerve was still attached to the proximal segment because the fracture line ended just ventrally to the mandibular foramen. None of the other splits resulted in the IAN being attached in the proximal segment.

We placed our vertical cut just posterior to the most distal erupted molar, unlike Bockmann et al.[9] and Schoen et al.[12], who placed it more or less at the middle of the first molar. A more anterior vertical cut produces a longer fracture along the lingual site, and therefore, in our opinion, this may result in a greater risk of unfavorable fracture along the lingual side, and potentially a greater risk of avascular necrosis in the ventral part of the buccal cortex. Schoen et al.[12] demonstrated splitting lines running along the mandibular canal (type A) or the inferior border (type B) and found that the an extra inferior bone cut along the inferior border will lead to more type B fractures. We also observed that 70% of fractures ran more or less along the inferior border and believe that this occurred due to placement of the forceps at the inferior border when performing the vertical cut and the unfolding of the split, despite not using a inferior extra bone cut, as described by Schoen et al[12]

Plooy et al. described in their study 4 different lingual splitting patterns: the lingual splitting scale (LSS 1-4: LSS1 'true' Hunsuck split; LSS2 'obwegeser' split; LSS3 split through the mandibular foramen; LSS4 other splitting type i.e. bad split)[7]. Performing the Hunsuck technique, the medial cut should be made behind the mandibular foramen and a small curved osteotome should be used to separate the cortices and create a fracture behind the mandibular foramen. The medial cut should be high enough to allow enough space through the osteotome, above the entrance of the IAN. In contrast, in this study, we used splitters and separators and extended the medial cut in the concavity of the mandibular foramen, just behind the lingula and just above the entrance of the mandibular foramen.

Plooy et al. intended to perform a 'true' Hunsuck every time, but stated that in only 51% of the cases the split ran as a 'true' Hunsuck (LSS 1). In 32% of the cases, it ran as a LSS 3 split (split through the mandibular foramen), as we intended to perform. They described also the combination of the placement of the horizontal medial cut in relation to the lingual fracture line; they emphasize more dorsal placement of the medial cut, which increases the amount of 'true' Hunsuck splits and decreases the amount of lingual fractures through the foramen by placing the medial cut more anteriorly.[7] This is in line with the findings of our pilot study.

The use of the chisel during a BSSO is, in our opinion, one of the causes of neurosensory disturbances involving the IAN. As previously reported,[6,9] chiseling downwards from the superior to the inferior border and passing or driving along the IAN increases the risk of damage to the IAN, particularly when using blunt chisels.[15] Hence, we used sagittal splitters and separators instead, for prying and spreading the mandible, however other instruments could be used.

In conclusion, our findings suggest that prying and spreading the mandible during the SSO in cadaveric pig mandibles, with the use of splitters and separators. provides a consistent splitting pattern. Creating an intended split running through the mandibular foramen along the mandibular canal could possibly follow the path of least resistance. Also, the need to place the medial horizontal cut in the concavity of the mandibular foramen (more anteriorly) could mean less mobilization of the IAN. On the basis of these results, we are currently conducting further research using human cadaveric mandibles to evaluate and validate this technique for the analysis of the pattern of the lingual fracture line and reduction of post-operative hypoesthesia of the IAN without increasing the incidence of possible other sequelae.

References

1. Trauner R, Obwegeser H. 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 Surg Oral Med Oral Pathol* 1957;10:677-689.
2. Philips C, Kim SH, Tucker M, Turvey TA. Sensory retraining: burden in daily life related to altered sensation after orthognatic surgery, a randomized clinical trial. *Orthod Craniofac Res* 2010;13:169-178.
3. Dal Pont G. Retro-molar osteotomy for correction of prognathism. *Minerva Chir* 1959;14:1138-1141.
4. Hunsuck EE. A modified intraoral sagittal splitting technic for correction of mandibular prognathism. *J Oral Surg* 1968;26:250-253.
5. Epker BN. Modifications in the sagittal osteotomy of the mandible. *J Oral Surg* 1977;35:157-159.
6. Wolford LM, Bennett MA, Rafferty CG. Modification of the mandibular ramus sagittal split osteotomy. *Oral Surg Oral Med Oral Pathol* 1987;64:146-155.
7. Plooij JM, Naphausen MT, Maal TJ, Xi T, Rangel FA, Swennnen G, et al. 3D evaluation of the lingual fracture line after a bilateral sagittal split osteotomy of the mandible. *Int J Oral Maxillofac Surg* 2009;8:1244-1249.
8. Falter B, Schepers S, Vrielinck L, Lambrichts I, Thijs H, Politis C. Occurrence of bad splits during sagittal split osteotomy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010;110:430-435.
9. Böckmann R, Schön P, Frotscher M, Eggeler G, Lethaus B, Wolff KD. Pilot study of modification of the bilateral sagittal split osteotomy (BSSO) in pig mandibles. *J Craniomaxillofac Surg* 2011;39:169-172.
10. Hanzelka T, Foltán R, Pavlíková G, Horká E, Sedý J. The role of intraoperative positioning of the inferior alveolar nerve on postoperative paresthesia after bilateral sagittal split osteotomy of the mandible: prospective clinical study. *Int J Oral Maxillofac Surg* 2011;40:901-906.
11. Kim YK, Kim SG, Kim JH. Altered sensation after orthognathic surgery. *J Oral Maxillofac Surg* 2011;69: 893-898.
12. Schoen P, Frotscher M, Eggeler G, Kessler P, Wolff KD, Boeckmann R. Modification of the bilateral sagittal split osteotomy (BSSO) in a study using pig mandibles. *Int J Oral Maxillofac Surg* 2011;40:516-520.
13. Mehra P, Castro V, Freitas RZ, Wolford LM. Complications of the mandibular sagittal split ramus osteotomy associated with the presence or absence of third molars. *J Oral Maxillofac Surg* 2001;591:854-858.
14. Precious DS, Lung KE, Pynn BR, Goodday RH. Presence of impacted teeth as a determining factor of unfavorable splits in 1256 sagittal-split osteotomies. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998;85:362-365.
15. Teerijoki-Oksa T, Jääskeläinen SK, Forssell K, Forssell H, Vähätalo K, et al.: Risk factors of nerve injury during mandibular sagittal split osteotomy. *Int J Oral Maxillofac Surg* 2002;31:33-39.
16. van Merkesteyn JP, Zweers A, Corputty JE. Neurosensory disturbances one year after bilateral sagittal split mandibular ramus osteotomy performed with separators. *J Craniomaxillofac Surg* 2007;35:222-226.
17. Mensink G, Zweers A, Wolterbeek R, Dicker G, Groot RH, van Merkesteyn JP: Neurosensory disturbances one year after bilateral sagittal split osteotomy of the mandibula performed with separators: A multi-centre prospective study. *J Cranio-maxillofac Surg* 2012;40(8):763-7.
18. Burn AK, Herring SW, Hubbard R, Zink K, Rafferty K, Lieberman DE: Dietary consistency and the midline sutures in growing pigs. *Orthod Craniofac Res* 2010;13:106-113.
19. Nickel J, Spilker R, Iwasaki L, Gonzalez Y, McCall WD, Ohrbach R, et al. Static and dynamic mechanics of the temporomandibular joint: plowing forces, joint load and tissue stress. *Orthod Craniofac Res* 2009;12:159-167.
20. Papadaki ME, Troulis MJ, Glowacki J, Kaban LB. A minipig model of maxillary distraction osteogenesis. *J Oral Maxillofac Surg* 2010;68:2783-2791.
21. Steiner T, Raith S, Eichhorn S, Doebele S, Trainotti T, Müller, et al. Evaluation of a new optical measuring system for experiments on fractured mandibles. *Clin Oral Invest* 2012;16:1535-1542.
22. Yoshioka I, Tanaka T, Khanal A, Habu M, Kito S, Kodama M, et al. Relationship between inferior alveolar nerve position at the second molar in patients with prognathism and possible occurrence of neurosensory disturbance after sagittal split ramus osteotomy. *J Oral Maxillofac Surg* 2010;68:3022-3027.
23. Yamashita J, Li X, Furman B,2 Rawls H, Wang X, Agrawal C. Collagen and Bone Viscoelasticity: A Dynamic Mechanical Analysis. *J Biomed Mater Res* 2002; 63:31-36.

24. Trebacz H, Wojtowicz K. Thermal stabilization of collagen molecules in bone tissue. *Int J Biol Macromol* 2005;37;257–262.

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