Int. J. Oral Maxillofac. Surg. 2017; 46: 1306–1314
http://dx.doi.org/10.1016/j.ijom.2017.05.015, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Research Paper
Orthognathic Surgery

Simulation of three surgical techniques combined with two different bone-borne forces for surgically assisted rapid palatal expansion of the maxillofacial complex: a finite element analysis

S. C. Möhlhenrich[1,2], A. Modabber[2], K. Kniha[2], F. Peters[2], T. Steiner[2], F. Hölzle[2], U. Fritz[1], S. Raith[2]
[1]Department of Orthodontics, RWTH Aachen University Hospital, Aachen, Germany; [2]Department of Oral and Maxillofacial Surgery, RWTH Aachen University Hospital, Aachen, Germany

S.C. Möhlhenrich, A. Modabber, K. Kniha, F. Peters, T. Steiner, F. Hölzle, U. Fritz, S. Raith: Simulation of three surgical techniques combined with two different bone-borne forces for surgically assisted rapid palatal expansion of the maxillofacial complex: a finite element analysis. Int. J. Oral Maxillofac. Surg. 2017; 46: 1306–1314.

Abstract. Surgically assisted rapid palatal expansion (SARPE) is a common treatment to correct transverse maxillary deficiencies. Finite element analysis was simulated for six designs of SARPE based on a computed tomography scan of a human skull: median osteotomy with palatal (type A) or alveolar ridge (type B) bone-borne force, additional lateral osteotomy with palatal (type C) or alveolar ridge (type D) bone-borne force, and additional pterygomaxillary separation with palatal (type E) or alveolar ridge (type F) bone-borne force. The transverse expansion was about 1.0 mm. The distribution of von Mises stress and the displacement were evaluated. The largest stress distribution was after types A and B, followed by types C and D, and finally types E and F. Displacement increased simultaneously. Palatal bone-borne forces (types A, C, and E) led to higher stress distributions in the midface and maxilla, but to a more parallel expansion compared with alveolar ridge-borne forces (types B, D, and F). The largest bony displacements at the midpalatal suture were anterior in all models. Increased weakening of the bony pillar of the facial skeleton and the use of palatal bone-borne forces leads to a decrease in stress distribution in the midface and to a more parallel transverse expansion of the maxilla.

Key words: orthodontic; osteotomy; maxillofacial; surgically assisted rapid palatal expansion; finite element analysis method.

Accepted for publication 21 May 2017
Available online 10 June 2017

0901-5027/01001306 + 09

Surgically assisted rapid palatal expansion (SARPE) is a common treatment to correct transverse maxillary deficiencies as well as arch length in non-growing adolescents and adult patients. These conditions are characterized by a lateral crossbite, narrow palatal vault, dark spaces in the buccal corridors, and dental crowding, with frequent aesthetic and functional implications.

Various osteotomy techniques have been described for the surgically assisted expansion of the maxilla and different investigations have demonstrated the clinical effects of SARPE. However, with regard to the effects of pterygomaxillary disjunction (PMD) in particular, there is still no consensus. The zygomatic buttress and the pterygomaxillary junction are known to be the most rigid bony pillars of resistance[1]. While some authors advocate disjunction of almost all articulating maxillary structures to allow sufficient transverse expansion[2–4], others endorse SARPE with as few osteotomies as possible to reduce the risk of postoperative complications and morbidity[5–9]. Opponents of PMD miss an effect on the expansion[10–12] and conclude that SARPE provides a long-term stable orthodontic bite correction and permanently enhances the nasal airways as well as a transverse shift of the segments over the whole bony palate even without disconnection of the pterygomaxillary suture[13]. Proponents of PMD justify this as a different pattern of expansion[10].

The effects of the various surgical techniques on the skeletal outcome have been discussed in the recent literature. In a systematic review by Hamedi Sangsari et al., focus was placed on the influence of PMD during SARPE[14]. The authors concluded that the literature is inconclusive regarding the effect of PMD on the outcomes of SARPE and that further controlled trials are necessary. In a cadaveric study, it was found that SARPE without PMD resulted in a V-shaped transverse maxillary expansion, while SARPE with PMD led to a parallel transverse expansion[15].

Bone-borne expanders are becoming increasingly popular compared to traditional tooth-borne devices. While tooth-borne devices are popular and easy to install and handle, the primary advantage of bone-borne devices is direct transmission of the expansion forces to the bone and the fact that they reduce dental tipping, root resorption, cortical fenestration, and orthodontic relapse. However, in this respect, there is also no consensus in the current literature about the ideal device. Only a small number of clinical investigations have directly compared the dentoskeletal effects of bone-borne and tooth-borne SARPE[16–21]. In comparisons between tooth-borne and bone-borne devices, neither short-term nor long-term advantages in dental and skeletal effects have been found. However, hybrid devices (tooth–bone-borne) generate similar skeletal effects, different dental movement patterns, and fewer dental and periodontal side effects. Therefore, they could be a beneficial alternative to conventional tooth-borne devices for SARPE procedures. Furthermore, it has been reported that bone-borne devices produce greater widening of the skeletal nasal floor and fewer dental side effects in the first molars[22].

The treatment effects of SARPE with temporary anchorage devices (TADs) for transverse expansion can be compared using biomechanical variables such as displacement, strain, and stress through the finite element analysis method (FEM)[23–28]. In addition to the influence on the transverse development of the palate, a further focus of research is the analysis of the effects of varying the surgical protocol or the type of expander on the craniofacial structures.

Recently, an investigation using FEM analyzed the influence of four different designs of rapid maxillary expander and demonstrated significant differences among the TADs[27]. All types exhibited downward displacement and demonstrated more horizontal movement in the posterior area. The combination of micro-implants placed lateral to the midpalatal suture and conventional hyrax arms on the first premolar and first molar showed the most transverse displacement. The rotational movement of the dentoalveolar unit was larger for the bone-borne devices with or without hyrax arms. SARPE without palatal implants showed the most transverse displacement. The stresses around the devices with micro-implants were more concentrated on the palate than on the alveolar ridge. The authors recommended applying TADs to the palatal slopes to support expanders for the efficient treatment of maxillary transverse deficiencies. It appears that no study has yet completely evaluated the effects of

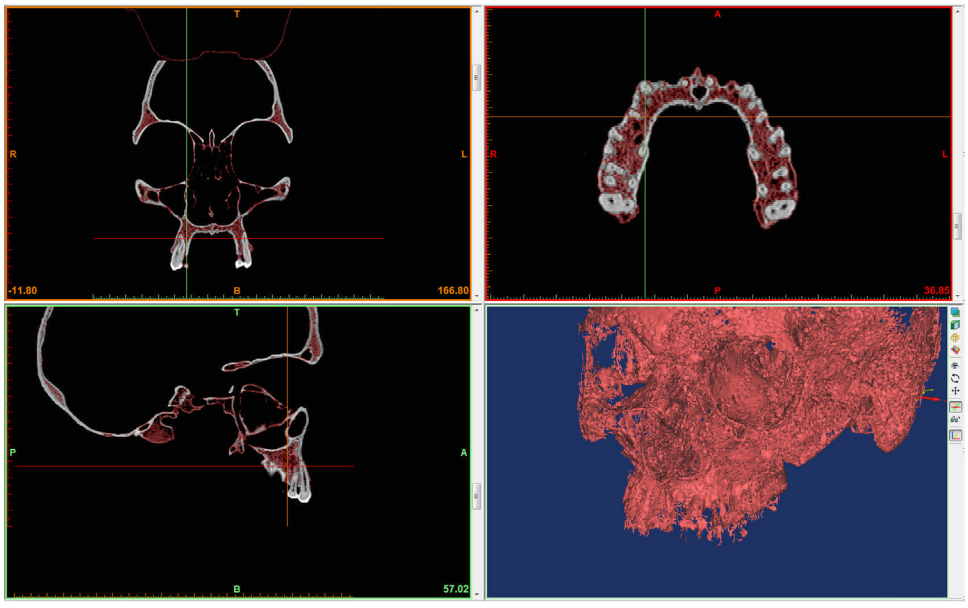

Fig. 1. Process of segmentation of the compact and trabecular bone.