Discussion

Mandibular Midline Distraction (MMD) and Surgically Assisted Rapid Maxillary Expansion (SARME) are well established surgical treatments to correct transverse discrepancies of maxilla and mandible[1-3]. The primary aim of this thesis was to outline the long-term effects of these treatment modalities, specifically dental and skeletal stability. To better understand the underlying principle, a biomechanical study comparing the effects of different bone-borne distractors used in MMD was performed. A clinical study focusing on the complications associated with MMD was presented. Finally, a study regarding patient satisfaction, expectations and experience on MMD and SARME was conducted to put the treatment into the patient's perspective. A literature update concerning MMD in general, and another specifically aimed on the use of 3D techniques in MMD were provided.

MMD

Biomechanical study

MMD as a technique was introduced by Guerrero et al. at the end of the last century[4]. In this first report a tooth-borne distractor was used, a hyrax distractor was cemented on two teeth on each side, preferably a premolar and a molar. In the early years of this century, Mommaerts et al. introduced the Transmandibular Distractor and the Transmandibular Distractor-Flex (TMD-Flex), a distractor attached to the bone, a bone-borne distractor[5]. The rationale for a bony attachment of the distractor was the assumed better biomechanical aspects. Some authors reasoned that a tooth-borne distractor would induce more tipping of the teeth and increase the risk for fenestration, as the distraction force is applied directly to the teeth[6]. In addition, it has been assumed that as a result of the vector of the tooth-borne distractor in relation to the hemi-mandibles, a V-shaped widening would be created. In this situation, less basal bone is expected to be gained, which would theoretically result in higher relapse rates. Another aspect of widening the mandible is the effect it has on the temporomandibular joints (TMJ). It has been suggested that the distraction forces applied to the mandible cause stress on the TMJ. Which in turn could result in temporomandibular dysfunction and unwanted condylar adaptation[7]. The TMD-flex distractor was introduced to prevent these issues. The design involves a more flexible bone-borne distractor, which would induce a more rotational widening of the condyles rather the being pushed lateral.[8] However, proponents of this theory argue that due to the more flexible distractor more stress will be induced due to tipping of the hemi-mandibles and more relapse would be expected. Therefore, the Rotterdam Mandibular Distractor (RMD), a rigid bone-borne distractor, was introduced[9].

In the study presented in chapter 4 it was shown that due to the flexible nature of the TMD-flex distractor the vector created with the distractor will, in fact, be more stressful

to the joints. An in-vitro model was used with 9 different human cadaver skulls that underwent MMD. Both a non-rigid distractor (TMD-Flex) and a rigid bone-borne distractor (RMD) were applied. The result showed that the TMD-flex caused more horizontal tipping and, more interestingly, an increase in vertical tipping of the hemi-mandibles. This movement introduces a V-shaped distraction gap using a non-rigid bone-borne distractor, less basal bone will be made, which could reduce stability. Regarding stress on the condyles, more stress is expected using a non-rigid distractor as a more rotational movement was observed, with the same amount of lateral movement. Therefore, the study suggests from a purely biomechanical point of view the use of a rigid rather than a non-rigid bone-borne distractor. However, as this study is a cadaver study, conclusions must be drawn with caution.

The main drawback of this study is the fact is that an in vitro model including cadaver head was used. In this model, the amount of soft tissue was limited, and as the masticatory muscles could affect the distraction vector it could influence the outcome. In addition, when the study was initiated bone-borne distractors were regarded as superior to tooth-borne distractors. Therefore, this type of distractor was not incorporated in the study design. However, as clinical results are comparable and patient experiences are better using a tooth-borne distractor nowadays, it is more commonly used. It would be advisable to incorporate both tooth- and bone-borne distractors in future study designs, since a direct comparison does not exists.

Complications

The review in chapter 3 showed that a relatively low complication rate in MMD was reported. Most complications were reported in studies with a primary aim to assess the biomechanical aspects of MMD. Two studies have been conducted to specifically assess the complications in MMD using a tooth-borne distractor.[10, 11] To objectively assess and compare surgical complications the Clavien-Dindo classification system is an excellent tool[12]. With the study presented in chapter 7 complications in MMD using a bone-borne device were systematically assessed using the standardised Clavien-Dindo classification.[12] Although this classification is not specifically designed for the oral and maxillofacial field, in future studies it should be more often used to compare complications rates with other authors and surgical interventions.

Our study shows that MMD is a relatively safe technique to widen the mandible, as most of the complications that occurred were minor. The results show that a significant part of the complications encountered during distraction were device related. Due to the position of the distractor, saliva and food easily accumulates in the buccal fold adjacent to the distractor, causing dehiscence and inflammation or local infection. Due to the buccal position of the distractor, pressure ulcers were observed. Anamnestically, 6.8% of the patients had mild joint-related symptoms (joint clicking, tenderness). This can be

considered mild and is in accordance with other studies. Especially considering the prevalence of these complaints in the general population.

Long-term study

Severe transverse mandibular discrepancy is associated with crossbite, crowding and a v-shaped mandible. In the past, existing treatment modalities, both surgically and orthodontically did not show reliable expansion of the mandible[2]. Therefore, the only option to overcome transverse discrepancies was extraction therapy. Although tooth extraction is a relatively cost-effective and low-burden treatment, it can change facial appearance, and healthy tooth material is sacrificed. With the introduction of distraction osteogenesis in the maxillofacial region, a new treatment modality became available, including MMD. The literature review presented in chapter 3 regarding MMD pointed out that different studies have been conducted proving it to be an effective modality to overcome mandibular discrepancies[2]. However, most studies were retrospective cohort studies with a short follow-up time. To advocate for MMD as an alternative to extraction therapy, it is necessary that long-term stable results can be achieved.

The study presented in chapter 5 showed that MMD using a bone-borne device results in widening of the mandible, both skeletal and dental. In addition, it shows that the outcome is stable in the long-term. This suggests that MMD should be considered as an alternative for tooth extraction therapy. The dental and skeletal results are comparable to the study King et al. presented using a tooth-borne distractor[13]. Although some notable differences are to be mentioned. Using a tooth-borne device King et al. showed a significant relapse in the premolar region and less anterior widening was achieved. These differences can be attributed to two effects of tooth-borne distractors: 1. dental expansion; 2. a different type of widening pattern[14]. The dental expansion occurs as a result of the direct force of the distraction on teeth pushing them outside the alveolar ridge. During the post-distraction orthodontic phase, teeth will be orthodontically aligned into the middle of the alveolar ridge, creating relapse. The widening pattern of a tooth-borne differs to that of a bone-borne distractor as the vector of the tooth-borne distractor is more posteriorly and cranially. A bone-borne distractor allows for a more parallel widening of the hemi-mandible in the sagittal plane. As the vector is positioned more caudal and is more rigid due to the direct fixation to the bone. Hereby, both widening at a basal bone as alveolar expansion is obtained. This would create a better fundament and decreases the risk of relapse. In addition, more anterior widening is expected using a bone-borne distractor as the vector is positioned more anteriorly than with using a tooth-borne distractor. This is in accordance to the finite element studies presented in the systematic review on the 3D effects of MMD. From a mechanical perspective this might indicate that a bone-borne distractor is more advisable for the correction of transverse discrepancies.

The biomechanical and complications study showed that little effects on the temporomandibular joints are observed in MMD. This is in accordance with the findings from the long-term study. Where only temporary changes were seen in ramal angle and none in intercondyle distance.

The decision to use either a bone- or tooth-borne distractor is made on more factors than the biomechanical aspects alone. A major disadvantage of bone-borne devices is the fact that a second surgery has to be performed to remove the distractor, being both inconvenient and costly. In addition, the device causes more discomfort to the patients. This together resulted in a shift in the use of a tooth-borne distractor instead of a bone-borne distractor in the Oral and Maxillofacial department of the Erasmus MC.

SARME

Long-term study

A comprehensive literature overview and a study on the dental and skeletal effects of SARME after 1 year with a prospective randomised controlled trial was provided by Koudstaal et al.[1, 15] The main outcome regarding biomechanical effects between tooth- and bone-borne distractors in SARME showed no significant differences[16]. Although relatively well studied still no consensus has been reached on either to use a bone- or tooth-borne distractor. The study presented in this thesis does not aim to answer that question. Different reasons are proposed to support the choice of a distractor. These might include preference of surgeon and/or orthodontist and costs.

Multiple studies have been performed on the effects of SARME, even with the use of more advanced 3D imaging techniques, the conclusion remained the same: SARME is a solid technique to widen the maxilla.[17, 18]. However, to be a viable alternative to extraction therapy for crossbites, crowding and black corridors, the long-term stability needed to be proven still. Magnussen et al. and Anttila et al.[19, 20] presented long-term studies on this topic, however, a different technique was used, which involved the release of pterygoid plates. The pterygoid plates are the most posterior point of resistance for the expansion of the maxilla. By releasing these pterygoid plates, it is expected that a more parallel widening can be achieved and less distractor force is needed. However, this is a far more invasive technique and has the potential for severe complications (bleeding) and would be less advisable[21].

The study presented in chapter 6 showed the long-term follow-up results of SARME without a pterygoid split. Dental cast study showed that an overall expansion was achieved in the canine, premolar and molar region. In addition, the palatal width was increased, the palatal depth was not significantly affected. Regarding the stability only a small decrease was observed in the canine and molar region in the post-distraction

and 1-year follow-up time-points. These effects are likely the result of the orthodontic treatment. Almost no movement is observed during the long-term follow up. This indicates that SARME is a stable method to widen the maxilla.

The cephalometry analysis showed a non-significant widening at molar level and to a lesser extent widening at nasal level. This indicates little maxillary tipping of maxillary segments might occur. However, the dental cast analysis showed no relapse, therefore this tipping might be clinically irrelevant.

Patient experience and satisfaction in SARME and MMD

Little is known on the experiences, expectations and satisfaction of patients before, during and after SARME and MMD. Although both are less invasive than a (segmental) LeFort 1 and Bilateral Sagittal Split Osteotomies, quite some discomfort can be expected during the treatment planning. In the study presented in chapter 8 at different time points pre- and post-operatively patients were allowed to give their opinion. Two questionnaires were used. A post-surgical patient satisfaction questionnaire (PSPSQ) consisted of 9 questions regarding different aspects of orthognathic surgery.[22] The visual analogue scale questionnaire consisted of 8 questions related to aesthetics, pain and distractor. The PSPSQ was administered at the long-term follow-up timepoint with a mean of 6.5 years and are based on the experiences of patients who underwent SARME. The VAS was administered pre-operatively and at different time-points the first year postoperatively.

The main outcome of the PSPSQ was a high satisfaction rate of the patients after the treatment period. A footnote to this conclusion is that a few patients did not advise the treatment to others. This might implicate that patients perceived their treatment as something a patient should be 'fit' for. This suggests that patient selection is an important aspect of these treatment modalities. Although some patient had secondary orthognathic surgery, scores were high for an improved bite.

The VAS questionnaire questions related to the satisfaction are in concordance with the PSPSQ questionnaire and patient were satisfied with the aesthetic result. Regarding pain, relative low scores were given for both SARME and MMD. Although pain is perceived differently by patients, the analgesics provided were apparently sufficient. In the MMD group, bone-borne distractors were used and were more disturbing perceived as the SARME distractor.

CONCLUSION

Both SARME and MMD are expected to be reliable methods techniques to overcome transverse discrepancies of respectively the maxilla and mandible. However, as long-term experiences were sparse in literature, the general aim of this thesis was to assess

the long-term dental and skeletal effects of SARME and MMD. The studies provided in chapters 5 and 6 show that both SARME and MMD are reliable and stable methods to widen maxilla and mandible on the long term. Therefore, both techniques should be considered by an orthodontist and oral and maxillofacial surgeons in transverse small maxilla and mandible cases.

To test the hypothesis that a rigid bone-borne distractor would reduce skeletal tipping and stress on the temporomandibular joints, an in vitro study was performed. The study presented in chapter 4 shows that with a rigid bone-borne distractor less tipping and rotational movement was observed. This would theoretically lead to less stress on the temporomandibular joints during distraction.

There have not been any systematically designed studies looking at complications with the use of MMD. In chapter 7, using the Clavien-Dindo complication classification system, a retrospective cohort study was presented. The study shows that MMD is a relatively safe method to widen the mandible. Although complications do occur, the majority are minor and transient.

Little was known regarding patient's satisfaction and experiences during and after SARME and MMD. The study provided in Chapter 8 shows high satisfaction rates and although some inconveniences during the procedures are to be expected, SARME and MMD are well accepted by patients in general.

The systematic reviews and studies in this thesis show that SARME and MMD are stable methods to widen the maxilla and mandible and provide an adequate alternative treatment option for extraction therapy.

LITERATURE

1. Koudstaal MJ, Poort LJ, van der Wal KG, Wolvius EB, Prahl-Andersen B, Schulten AJ. Surgically assisted rapid maxillary expansion (SARME): a review of the literature. *Int J Oral Maxillofac Surg* 2005;34:709-14.
2. de Gijt JP, Vervoorn K, Wolvius EB, Van der Wal KG, Koudstaal MJ. Mandibular midline distraction: a systematic review. *J Craniomaxillofac Surg* 2012;40:248-60.
3. Verstraaten J, Kuijpers-Jagtman AM, Mommaerts MY, Berge SJ, Nada RM, Schols JG, et al. A systematic review of the effects of bone-borne surgical assisted rapid maxillary expansion. *J Craniomaxillofac Surg* 2010;38:166-74.
4. Guerrero CA, Bell WH, Contasti GI, Rodriguez AM. Mandibular widening by intraoral distraction osteogenesis. *The British journal of oral & maxillofacial surgery* 1997;35:383-92.
5. Mommaerts MY. Bone anchored intraoral device for transmandibular distraction. *The British journal of oral & maxillofacial surgery* 2001;39:8-12.
6. Proffit WR, White RP, Sarver DM. Contemporary treatment of dentofacial deformity. St. Louis: Mosby; 2003. ix, 751 p. p.
7. Bell WH, Harper RP, Gonzalez M, Cherkashin AM, Samchukov ML. Distraction osteogenesis to widen the mandible. *The British journal of oral & maxillofacial surgery* 1997;35:11-9.
8. Mommaerts MY, Polsbroek R, Santler G, Correia PE, Abeloos JV, Ali N. Anterior transmandibular osteodistraction: clinical and model observations. *J Craniomaxillofac Surg* 2005;33:318-25.
9. de Gijt JP, van der Wal KG, Kleinrensink GJ, Smeets JB, Koudstaal MJ. Introduction of the "Rotterdam mandibular distractor" and a biomechanical skull analysis of mandibular midline distraction. *The British journal of oral & maxillofacial surgery* 2012;50:519-22.
10. Mommaerts MY, Spaey YJ, Soares Correia PE, Swennen GR. Morbidity related to transmandibular distraction osteogenesis for patients with developmental deformities. *J Craniomaxillofac Surg* 2008;36:192-7.
11. von Bremen J, Schafer D, Kater W, Ruf S. Complications during mandibular midline distraction. *The Angle orthodontist* 2008;78:20-4.
12. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Annals of surgery* 2004;240:205-13.
13. King JW, Wallace JC, Winter DL, Niculescu JA. Long-term skeletal and dental stability of mandibular symphyseal distraction osteogenesis with a hybrid distractor. *Am J Orthod Dentofacial Orthop* 2012;141:60-70.
14. Kim KN, Cha BK, Choi DS, Jang I, Yi YJ, Jost-Brinkmann PG. A finite element study on the effects of midsymphyseal distraction osteogenesis on the mandible and articular disc. *The Angle orthodontist* 2012;82:464-71.
15. Koudstaal MJ, Wolvius EB, Schulten AJ, Hop WC, van der Wal KG. Stability, tipping and relapse of bone-borne versus tooth-borne surgically assisted rapid maxillary expansion; a prospective randomized patient trial. *Int J Oral Maxillofac Surg* 2009;38:308-15.
16. Koudstaal MJ, Smeets JB, Kleinrensink GJ, Schulten AJ, van der Wal KG. Relapse and stability of surgically assisted rapid maxillary expansion: an anatomic biomechanical study. *J Oral Maxillofac Surg* 2009;67:10-4.
17. Nada RM, Fudalej PS, Maal TJ, Berge SJ, Mostafa YA, Kuijpers-Jagtman AM. Three-dimensional prospective evaluation of tooth-borne and bone-borne surgically assisted rapid maxillary expansion. *J Craniomaxillofac Surg* 2012;40:757-62.

18. Zandi M, Miresmaeili A, Heidari A. Short-term skeletal and dental changes following bone-borne versus tooth-borne surgically assisted rapid maxillary expansion: A randomized clinical trial study. *J Craniomaxillofac Surg* 2014.
19. Magnusson A, Bjerklin K, Nilsson P, Marcusson A. Surgically assisted rapid maxillary expansion: long-term stability. *European journal of orthodontics* 2009;31:142-9.
20. Anttila A, Finne K, Keski-Nisula K, Somppi M, Panula K, Peltomaki T. Feasibility and long-term stability of surgically assisted rapid maxillary expansion with lateral osteotomy. *European journal of orthodontics* 2004;26:391-5.
21. Politis C. Life-threatening haemorrhage after 750 Le Fort I osteotomies and 376 SARPE procedures. *Int J Oral Maxillofac Surg* 2012;41:702-8.
22. Posnick JC, Wallace J. Complex orthognathic surgery: assessment of patient satisfaction. *J Oral Maxillofac Surg* 2008;66:934-42.