Journal of Cranio-Maxillo-Facial Surgery xxx (2016) 1–7

Contents lists available at ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

Slotplates revisited – A retrospective analysis

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ARTICLE INFO

Article history:
Paper received 14 May 2016
Accepted 25 October 2016
Available online xxx

Keywords:
Osteosynthesis
Postoperative complications
Morbidity
Orthognathic surgical procedures

ABSTRACT

Context: Slotplates were specifically designed to meet the special requirements of corrective surgeries of the facial skeleton. This design enables small readjustments of bone fragments in the midface and chin area during surgery without complete removal of plates and screws.
Objective, design, and setting: The aim of this study was to compare morbidity rates of slotplates versus meshplates after Le Fort I osteotomy, genioplasty and/or zygoma 'sandwich' osteotomy performed in a tertiary care centre.
Results: The investigators analyzed chart records of 190 patients, including a total of 257 surgeries. Slotplates were used in 109 patients, meshplates in 81 patients. Plate infection rates were 9.2% in the slotplate group and 7.4% in the meshplate group. Twelve patients (11.0%) from the slotplate group underwent plate removal versus four patients (4.9%) from the meshplate group.

In total, there were two cases of delayed union, both in the slotplate group, one progressed to non-union.
Conclusion: Due to the low study power significant differences between the two types of plates could not be detected. However, there is a slight tendency towards higher morbidity associated with the use of slotplates. The probability of mechanical weakness of the configuration being responsible for the fatigue fractures is also discussed in this article.

1. Introduction

Slotplates (Surgi-Tec NV, Sint-Denijs-Westrem, Belgium) were developed for orthognathic and other corrective surgery of the facial skeleton: Le Fort I osteotomy, genioplasty and zygoma 'sandwich' osteotomy (Mommaerts, 2002).

1. Small occlusal and esthetic readjustments can be made without plate removal.

It is not uncommon that the maxillary dentition does not perfectly fit the intermediate wafer, or occlude correctly, after release of intermaxillary fixation. The freedom of the slotted hole allows the surgeon to slightly release one (or two) screws of a plate and move the whole bone segment. When the correct position is found, the screws can be tightened again. Thus, there is no need to remove the plates completely and no new holes need to be drilled. This shortens operation time and enables the surgeon to work with more precision. This *slot principle* can also be used to achieve a more pleasing esthetic result in chin and zygoma positions.

2. Rigid yet easily malleable plates.

The thin 0.6-mm slotplates are made from grade 1 titanium (Mommaerts, 2002; International Titanium Association, 1999). They are easily malleable yet rigid enough to provide primary stability, albeit not under functional load. A double-armed connecting piece stabilizes the plate three-dimensionally, based on the stability of a quadrangle (Mittal et al., 2012).

3. Reduction of hardware volume and cost.

Slotplates can be fixed with only two screws: one at each site of the osteotomy (Mommaerts, 2002). However, in the 2014 series used in this study, the plate design includes two additional tabs ("devil horns") on the sides of the longitudinal slotted hole (Fig. 1). In these devil horns, a locking screw can be placed if deemed necessary. The locking screw is placed in an upward direction and

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http://dx.doi.org/10.1016/j.jcms.2016.10.020
1010-5182/

Please cite this article in press as: Zigterman BGR, Mommaerts MY, Slotplates revisited – A retrospective analysis, Journal of Cranio-Maxillo-Facial Surgery (2016), http://dx.doi.org/10.1016/j.jcms.2016.10.020

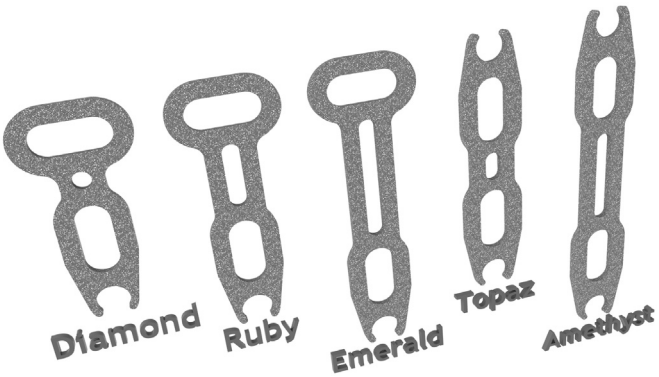

Fig. 1. The different slotplates.

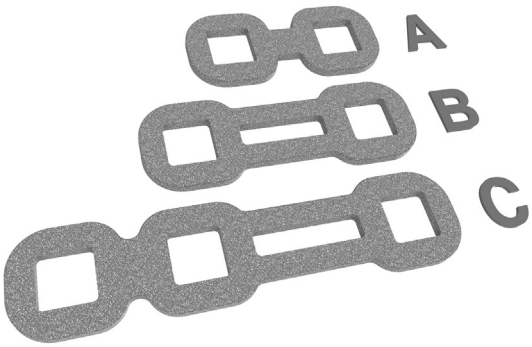

Fig. 2. Meshplate design.

prevents movement of the plate in the upper (vertical) slot due to chewing forces on the upper jaw.

The double-armed connecting piece in the plates allows the placement of a micro screw for fixation of bone grafts, which is especially useful in osteotomies with extrusion (down grafts), and zygoma 'sandwich' osteotomy.

4. The surfaces of both the slot- and meshplates used in this study are treated with sandblasting and acid etching to improve friction between the plate and the bone, and thus increasing plate stability (Cordey et al., 1979; Mommaerts, 2002; Surgi-Tec, 2015). The rough surface created by sandblasting is irregular, which is smoothened by the oxalic acid attack (Li et al., 2001). Furthermore, the oxalic acid removes the sand particles left behind after sandblasting and it creates secondary micro pores on the already roughened macro texture (Li et al., 2001; Medvedev et al., 2016). These surface modifications, have been shown to enhance the biological performance of dental implants: increased stem cell differentiation, boosted viability of osteoblastic cells and increased bone anchorage have all been reported (Medvedev et al., 2016; Ban et al., 1998).

The use of slotplates was evaluated in a pilot study of 20 patients, with fair results: the freedom of the slotted hole enables the surgeon to choose the thickest area of the bone for screw placement and also allows him to place screws safely between the dental roots (Mommaerts, 2002).

The present study retrospectively analyzes the morbidity rates of surgery using slotplates in the Universitair Ziekenhuis (UZ) Brussels and compares them to the outcomes of surgery using more conventional (square hole instead of slotted hole) but otherwise osteosynthesis plates made of titanium grade 1 of the same dimensions (i.e., meshplates) (Fig. 2). We hypothesized that slotplates provided similar morbidity rates compared to meshplates. Furthermore, we aimed to evaluate whether the slotted holes in these plates were beneficial during surgery.

2. Materials and Methods

2.1. Study population

All consecutive patients who underwent Le Fort I, chin, and/or zygoma 'sandwich' osteotomy using meshplates or slotplates in a tertiary care center in Belgium between January 2012 and December 2015 were included in this study. The patients undergoing operations in the first two years (2012–2013) received meshplates (Surgi-Tec NV, Sint-Denijs-Westrem, Belgium) while the others (undergoing operations in 2014–2015) received slotplates (Surgi-Tec NV, Sint-Denijs-Westrem, Belgium). Patients who did not sign an informed consent form or did not have one signed by a responsible person on their behalf were excluded. There were no other exclusion criteria. The study was approved by the Medical Ethics Committee of the UZ Brussel (B.U.N. 143201628172).

2.2. Interventions

All patients were operated on by the same surgical team. The type of slotplate was chosen intra-operatively by the surgeon (the names "Diamond," "Ruby," "Emerald," "Topaz," or "Amethyst" correspond to different lengths, see Fig. 1), taking into account the degree of bony displacement. In the control group, meshplates in various lengths were selected according to the same principle. All plates were fixed with two or three self-tapping screws ('Pentagon' 2.3 mm diameter; Surgi-Tec NV, Sint-Denijs-Westrem, Belgium) with a length between 5 and 9 mm. Intravenous antibiotics (1 g amoxicillin/clavulanic acid or 600 mg clindamycin) were administered in all patients intra-operatively. No further antibiotics were given after surgery was concluded.

Patients who underwent orthognathic surgery received guiding elastics post-operatively. These patients were also instructed to adhere to a semi-liquid intake during the first post-operative week and a soft to soft-normal diet in the following 3 weeks.

2.3. Data collection

All data were collected retrospectively from electronic patient records. The medical images, which were available in digital form, were analyzed as well. All data was collected and analyzed by investigator BZ.

2.4. Outcome measures

The predictor variable was the type of plate (slotplate or meshplate) and the type of surgery (zygoma 'sandwich' osteotomy, genioplasty and/or Le Fort I osteotomy).

All outcome measures assessed are listed in Table 1. Infection was scored clinically: pain, redness, warmth, swelling and/or pus for which additional treatment was deemed necessary. Whether the infection was early onset (<6 weeks post-operatively) or late onset (>6 weeks post-operatively) was noted as well (Chow et al., 2007) Delayed union was scored if there was no bony healing after 3 months or more (Verhaar and van Mourik, 2008). Non-union was scored if the fracture was not stably healed after 9 months or more (Verhaar and van Mourik, 2008).

The secondary endpoint chosen was the number of times the "slot principle" was used. The slot principle was defined as the intra-operative re-adjustment of a bone segment by releasing one

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Table 1
Outcome measures.

General:
Gender
Age at surgery
Type of operation
Concomitant surgery
Surgery:
Used plates (type and amount)
Number of used screws per plate
Protrusion or setback in mm
Anterior extrusion or intrusion in mm
Slot principle used
Special notes
Morbidity:
Infection (early or delayed onset)
Palpability of the hardware
Root injury
Delayed union
Non-union
Plate removal
Reoperation

or two screws without complete plate and screw removal. This was scored by the surgeon post-operatively.

All patients were post-operatively evaluated in our outpatient clinic 1 and 3 weeks and 6 months after surgery. If indicated, patients were seen more frequently. Panoramic X-rays were taken 2 weeks preoperatively and 1 week and 6 months post-operatively. Clinical photos were taken preoperatively and 6 months post-operatively (final clinical pictures). If indicated, additional radiographs and cone-beam CT scans were performed.

2.5. Statistical analysis

Descriptive statistics were used to analyze the population and morbidity rates. A power analysis was carried out *a posteriori*. If the number of patients analyzed reached a power of 80% with $\alpha = 0.05$ for a specific endpoint, then the power was deemed sufficient to perform statistical analyses such as Fisher's exact test and Z-test. If the power was found to presently be lower than 80%, descriptive statistics were used.

3. Results

3.1. Demographics

From January 2012 to December 2015, a total of 190 patients met the inclusion criteria. In 109 patients, a total of 435 slotplates were used (2014–2015). In 81 patients, a total of 331 meshplates were used (2012–2013). The demographics of the two groups are described in Table 2.

Table 2
Demographics.

Parameter	Slotplates (n = 109)	Meshplates (n = 81)
Minimum follow up time > 6 months	91	81
Follow up time 3–6 months	18	0
Age (years)		
Mean (SD)	27,21 (11,628)	26,57 (9,780)
Median	24	24
Range	14–57	13–51
Sex		
Female (%)	65 (59,6%)	37 (45,7%)
Male (%)	44 (40,4%)	44 (54,3%)
Surgery		
Le Fort I osteotomy	81 (74,3%)	54 (66,6%)
Genioplasty	55 (50,5%)	51 (63,0%)
Zygoma 'sandwich' osteotomy	9 (8,6%)	6 (7,4%)
Unilateral	1 (0.9%)	0

There is no difference in the age distribution between the two groups, but somewhat more male patients underwent operations using meshplates (2012–2013). Follow-up time in the slotplates group was shorter on average because they were used in the later time period. Combinations of multiple surgeries were rather common, as illustrated by the type of surgery listed. There were no significant differences in segment displacement between the two groups (data not shown).

3.2. Slotplates

In total, 435 slotplates were used in 109 patients. In almost half of the plates (44.6%), an additional third locking screw was used. In zygoma 'sandwich' osteotomies, only Amethyst plates were used. Data regarding slotplates use are summarized in Table 3.

3.3. Meshplates

In total, 331 meshplates were used in 81 patients. Most of them (89.4%) were fixed with two screws. Data regarding meshplate use are summarized in Table 4.

3.4. Statistics

A power analysis was performed using G*Power 3.1.9.2 software (Faul et al., 2007) If Fisher's exact testing is used, the achieved power of our study is 10.18% with an actual $\alpha = 0.0320$. Using Z-testing, the power achieved is a bit higher, but still too low (power = 13.91%; Critical Z = −1.6445). A simulation of the sample size necessary to achieve a power of 80% with an $\alpha = 0.05$ was performed, indicating that a total sample size of 3588 subjects is needed to assess significant differences between both groups. Inferential statistical analysis was not chosen because the risk of Type II error is too high.

3.5. Morbidity

In 21 patients (19.3%), morbidity was recorded in the slotplate group, while in the meshplate group 13 patients (16.1%) showed morbidity.

Table 3
Slotplates: differentiated on location and number of used screws.

Plate	Total	2 screws	3 screws
Diamond total	*189*	*99*	*90*
Diamond in upper jaw	153	65	88
Diamond in chin	36	34	2
Ruby total	*208*	*118*	*90*
Ruby in upper jaw	145	59	86
Ruby in chin	63	59	4
Emerald total	*19*	*15*	*4*
Emerald in upper jaw	10	6	4
Emerald in chin	9	9	0
Topaz total	*1*	*1*	*0*
Topaz in chin	1	1	0
Amethyst total	*18*	*8*	*10*
Amethyst in upper jaw	1	1	0
Amethyst in zygoma	17	7	10
Total slotplates used:	*435*	*241*	*194*

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Table 4
Meshplates: differentiated on location and number of used screws.

Meshplates	Total	2 screws	3 screws
2 Holes meshplate total	*156*	*156*	*0*
in upper jaw		97	0
in chin		57	0
in zygoma		2	0
2 Holes + 1 micro hole meshplate total	*160*	*133*	*27*
in upper jaw		87	24
in chin		42	0
in zygoma		4	3
3 Holes meshplate total	*15*	*7*	*8*
in upper jaw		4	8
in chin		2	0
in zygoma		1	0
Total meshplates used	*331*	*296*	*35*

3.6. Plate removal

Plate removal was the most frequent after-effect in the slotplate group (12 patients, 11.0%). In the meshplate group, plates were removed in four patients (4.9%). The details on plate removals are listed in Table 5.

More plates were removed in the slotplate group than in the meshplate group: 7,6% of the used slotplates, versus 3.7% of the used meshplates The timing of plate removal ranged from 3 to 22 months in the slotplate group and between 9 and 41 months in the meshplate group. One slotplate, removed because of infection and palpability, was found to be broken. This was a Ruby plate placed at the right aperture. The bone was normally healed.

3.7. Palpability

Eight patients (7.3%) in the slotplate group complained of painful palpability of the plates, in six of them the plates were removed. In the meshplate group, two patients (2.5%) complained of painful palpability, in one of them the plates were removed.

3.8. Infection

Infection of the plates was observed in 10 patients in the slotplate group (9.2%) and five patients in the meshplate group (6.2%). All early infections were treated with a disinfectant mouth rinse and antibiotics for 1 week. In two patients in the slotplate group a prolonged antibiotic treatment was indicated. Another two patients in the slotplate group experienced both early onset and late onset infections. The seven cases of late onset infection in the slotplate group were treated with plate removal, in three cases having been preceded by antibiotics. The two cases of late onset infections in the meshplate group were treated with antibiotics, and one of these patients underwent plate removal at 41 months post-operatively during another elective surgery.

3.9. Reoperation

Nine patients in the slotplate group required revisional surgery. Two of these will be described in the delayed and non-union sections.

One patient needed revisional surgery 2 weeks after the initial surgery due to an excessively mobile upper jaw after trimaxillary surgery (Le Fort I osteotomy, bilateral sagittal split osteotomy [BSSO], and genioplasty). Re-fixation of the plates was adequate to stabilize the bony segments.

Revisional surgery was also necessary in the case of a 32-year-old female who underwent sliding genioplasty (2-mm protrusion, midline correction, fixed with two Diamond plates using two screws each). At post-operative week five, a root injury was discovered: one of the osteosynthesis screws had pierced the root of the left lower canine tooth, resulting in a periapical infection. This complicated into a pathologic symphyseal fracture. The osteosynthesis material in the chin was removed and the fracture stabilized by two Modus Mandible 2.0 Trauma plates (Medartis, Basel, Switzerland). At the time of the revisional surgery, the genioplasty was completely healed. After the second surgery, the mandible remained stable, but three lower incisors needed to be removed.

The other cases of revisional surgery in the slotplate group were performed for non-plate-dependent reasons including: redo of jaw angle prosthesis, infection at a plate placed in BSSO, keloid excision, revisional BSSO, septoplasty after Le Fort I osteotomy, and closure of an oro-nasal fistula.

In the meshplate group, we saw six patients requiring revisional surgery. In three of these, the secondary operation was necessary because of an incorrect post-operative position: two redo bimaxillary surgeries performed after 3 weeks and 27 months, and a redo Le Fort I osteotomy 5 months post-operatively. There was one patient who needed a redo BSSO after mandible fracture due to crash intubation during recovery. Two other patients had their BSSO screws removed.

3.10. Delayed union

We observed two cases of delayed union in the slotplate group and none in the meshplate group. Both cases of delayed union occurred after Le Fort I osteotomy.

Table 5
Plate removal: location, indication and number of plates.

Location	Indications for plate removal	Slotplate group		Meshplate group	
		Number of patients (%)	Number of plates (%)	Number of patients (%)	Number of plates (%)
Chin	Infection	2 (3,64%)	4 (3,67%)	0	0
	Infection and palpability	1 (1,82%)	2 (1,83%)	0	0
	On patients request	0	0	1 (1,96%)	2 (1,98%)
Le Fort I	Infection	4 (4,94%)[a]	7 (2,27%)	1 (1,85%)	2 (0,91%)
	Infection and palpability	3 (3,70%)	10 (3,24%)	0	0
	Palpability	2 (2,27%)	6 (1,94%)	1 (1,85%)	4 (1,98%)
	On patients request	1 (1,23%)	4 (1,29%)	1 (1,85%)	4 (1,98%)
Zygoma	Infection upper jaw	1 (10%)[a]	1 (5,88%)	0	0
Total		13 (11,92%)[a]	34 (7,82%)	4 (4,93%)	12 (3,63%)

[a] Remark: one patient had plates from both the Le Fort I osteotomy and zygoma 'sandwich' osteotomy removed.

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The first case of delayed union was a 34-year-old female who underwent trimaxillary surgery with paranasal onlays. Her upper jaw moved 4 mm anteriorly with an anterior intrusion of 4 mm. The upper jaw was fixed with two Diamond and two Ruby plates, both with two screws per plate. At 5 months post-operatively, revisional surgery using local anesthesia was indicated because of a mobile upper jaw. The Ruby plate at the right aperture was broken and replaced with a meshplate. There were no obvious loose screws. Four months later, the patient presented with the same problem of a mobile upper jaw, and again opted for redo surgery, now with the placement of bone grafts obtained from the superior iliac crest. All existing osteosynthesis plates were removed and replaced by Medartis Modus Mandible 2.0 Trauma plates (Medartis, Basel, Switzerland), resulting in a good bone healing.

The second case of delayed union progressed to a non-union.

3.11. Non-union

The one case of non-union was a 40-year-old man who underwent a Le Fort I osteotomy with 8 mm protrusion and 4 mm anterior extrusion, fixed with four Ruby plates, each with two screws per plate. Bony contact was limited, but bone grafts were not used. The locking screw was not used on any of the plates. At 6 months post-operatively, his upper jaw was still mobile and loose screws at the zygomatic buttress plates were palpable. Revisional surgery using local anesthesia was indicated. Loose screws were found in both the zygomatic buttress plates and the left aperture plate. The screws were tightened on the zygomatic buttresses, and an extra plate was placed at the left side (Ruby, 2 screws). The right aperture Ruby plate was found to be broken, and was replaced by a new Ruby plate with two screws. Eleven months after the second surgery, the upper jaw still remained slightly mobile, indicating this case was a non-union. The patient had no complaints, and thus a conservative treatment was chosen.

3.12. Slot principle

The slot principle was carried out in the upper jaw in 12 patients (14.8% of the Le Fort I osteotomies), in genioplasty in 2 cases (3.6%), and one time in a zygoma 'sandwich' osteotomy (10%).

4. Discussion

In this retrospective analysis, osteosynthesis morbidities after orthognathic and diverse corrective surgeries of the facial skeleton with the use of slotplates were evaluated. Outcomes were compared with a control group consisting of patients receiving meshplates. No statistically significant difference could be found between the morbidity rates of 19,3% in the slotplate group versus 16,1% in the meshplate group due to the low study power. Hardware removal was the most frequent after-effect; in 11.0% of the patients in the slotplate group and 4.9% of the patients in the meshplate group, plate removal was indicated. In the literature, reported complication rates after general orthognathic surgery vary between 9.0% and 18.6% (Panula et al., 2001; Chow et al., 2007; Jedrzejewski et al., 2015). In studies regarding Le Fort I osteotomy, an overall complication rate of 4–9% is reported (de Mol van Otterloo et al., 1991; Kramer et al., 2004; Garg and Kaur, 2014). However, these studies did not solely focus on osteosynthesis-related complications, and often include general intra-operative complications, making comparison difficult.

"Non-planned" hardware removal of 3–27.5% is reported in the current literature (Panula et al., 2001; Califano et al., 2002; Bhatt et al., 2005; Chow et al., 2007; O'Connell et al., 2009; Haraji et al., 2009; Bonanthaya and Anantanarayanan, 2013). Plate infection was the main reason for removal in our study, which seems to be in line with the current literature (Califano et al., 2002; Bonanthaya and Anantanarayanan, 2013). Plate removal due to painful palpability is rarely reported in literature (Bhatt et al., 2005; O'Connell et al., 2009; Bonanthaya and Anantanarayanan, 2013). It is likely that plates are more often removed in daily practice than is reported in the literature. The general morbidity of this second intervention is extremely low and policies regarding plate removal vary to a great extent between different centers.

The infection rates in both groups (9.2% in the slotplate group and 6.2% in the meshplate group) were at the high end of that reported in the literature, with reports varying between 4 and 7.4% (Panula et al., 2001; Chow et al., 2007; Jedrzejewski et al., 2015). This difference could be explained by our antibiotic regimen: only a single dose of prophylactic antibiotics were administered perioperatively. A review article by Chow et al. (2007) showed a significantly higher infection rate in patients who received a single dose of antibiotics preoperatively compared to prophylactic antibiotic administration for several day. Infection rates are sometimes presented in terms of individual plates (Rosenberg et al., 1993; Cheung et al., 2004). However, in this retrospective analysis, it was difficult to attribute an infection of the right upper jaw to one or two plates.

Two patients presented with delayed union of the maxilla in the slotplate group, one eventually developing a non-union. There were no patients with delayed or non-union in the meshplate group. Rates of delayed or non-union of the maxilla after Le Fort I osteotomy have been reported between 1.0 and 2.6% (Kramer et al., 2004; Imholz et al., 2010; Bonanthaya and Anantanarayanan, 2013). The main reason for delayed or non-union, as reported in the literature, is osteosynthesis instability (Imholz et al., 2010). Studies also report larger bone defects as a risk factor for delayed or non-union (Assael and Prein, 1998; Doherty et al., 2010; Eser et al., 2015). The first patient with delayed union had experienced delayed unions two times during the follow up period of 18 months. The first time the bone fragments were fixated with four slotplates, the second time one of the slotplates was replaced by a meshplate. Serological evaluation did not show any signs of bone disease, malnutrition, or other reasons for impaired bone healing (TSH, PTH, Vitamin D, phosphorus, calcium, magnesium, and renal function all within normal limits). The second case of delayed union, which eventually progressed into a non-union, could be explained by the large extrusion of the upper jaw without fixing bone grafts (anterior extrusion of 4 mm, protrusion of 8 mm). In this case, the possibility of obtaining a bone graft was not discussed with the patient beforehand, so grafts were not obtained during the surgery. As a result of this last case, the use of locking screws was extended. The locking screws prevent loosening of the screws in the upper slot due to chewing forces.

Both cases of delayed union had a broken Ruby plate at the right aperture. Broken plates are virtually always seen in cases of delayed union (Kramer et al., 2004; Imholz et al., 2010; Bonanthaya and Anantanarayanan, 2013). The other patient in which a Ruby plate was broken did not experience compromised bone healing.

Both slot- and meshplates are made from titanium grade 1, with excellent malleabilty and ductility characteristics (International Titanium Association, 1999). The slotplates were subjected to a force test (unpublished personal communication with the manufacturer). This test consisted of bending the plates with manual pliers: 90° in one direction, then 180° in the other direction. These 180° movements were repeated. The first slotplates broke after four or more of these movements. The breaking point was in the interconnective struts, suggesting these are the most fragile parts of the plates. We advised the company to broaden the plates, so that they remain thin and easily malleable but their three-dimensional

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structure is stronger, decreasing the risk of breaking and improving the rigidity. The broader slotplates were subjected to the same manual testing: these plates broke after eight of these movements. Microcracks have been found in titanium mandibular reconstruction plates after plate bending (Martola et al., 2007). These cracks could also develop in the thin miniplates bent during orthognathic surgery. Pre-bent advancement plates have been designed for this purpose, but these cannot adequately adapt to the surgical movements of the bone segments (Lye et al., 2008). Microcracks are therefore inevitable; the surgeon should bend plates no more than three or four times before inserting them into the patient. It was not recorded how many times the broken plates were bent during surgery.

The "slot principle" was used in 13.8% of slotplate cases to correct the bone segment position after initial fixation. However, we only began documenting the use of the slot principle in the second year that the slotplates were used. If we extrapolate the results, we may estimate that the slot principle is used in around 20% of the cases. The freedom provided by the slotted holes was used numerous times to select a screw location where the bone was strong and thick enough or to place the screw in between roots. This is perceived as an asset by the surgeon, but its value cannot be further quantified in the present study.

Ironically, there was one patient with a root injury in the slotplate group. The low height and extreme thinness of the symphysis of this patient contributed to this complication. According to the classification of Driemel et al. (2005) the presented case represents a type Ia root injury: direct pulp injury, with the highest risk of causing pulpitis, apical periodontitis, and tooth loss. Literature reports dental root injuries as a complication of genioplasty in 0.76–1.56% of cases (Panula et al., 2001; Chan and Ducic, 2015; Posnick et al., 2016).

Slotplates can achieve their final contouring by 'plate bending on the bone': the thin plates are contoured to the underlying bone when the screws are tightened. Because the slotplates are made from titanium grade 1 they do not have much material memory and over-bending is redundant. The thicker plates of 1.0 mm or more have a tendency to pull the bone segments up towards the plate if the plates are not perfectly adapted to the bone (Patel and Langdon, 1991). On the other hand, semi-rigid fixation can allow micro movements between the bone segments which, in one experimental animal study, led to improved bone healing due to decreased stress shielding (Goodship and Kenwright, 1985). A few retrospective trials in orthognathic surgery showed good long-term stability with semi-rigid fixation, but in other studies, semi-rigid fixation played a role in less optimal bone healing (Politi et al., 2002; Schell et al., 2005; Fedorowicz et al., 2007; Palomares et al., 2009; Mavili et al., 2009; Karakoyun et al., 2015; Samsami et al., 2015).

Almost all facial corrective interventions are elective, which makes our field an optimal candidate to introduce enhanced recovery after surgery (ERAS) protocols. Interestingly, we found one ERAS program in head and neck oncology, but none in facial corrective or orthognathic surgery (Coyle et al., 2016).

ERAS protocols focus only partially on the surgery itself. However, in an attempt to shorten the procedure time and cost, slotplates can contribute in two ways. Although we did not record our surgery times, surgeons perceive that the time spent on plate bending is dramatically shortened and re-adjustment of the bony segments is more comfortable and predictable without burring new holes and placing new screws. Furthermore, only 2 or 3 screws are necessary to fix the bone segments with slotplates, saving even more time. The slotplates are thin and small, so with these plates a more minimally invasive surgery can be achieved, contributing to an ERAS practice as well.

Research into the long-term stability of Le Fort I osteotomies, genioplasties, and zygoma 'sandwich' osteotomies has been done, but only in patients receiving thicker (1.0 and 2.0 mm) titanium or bioresorbable plates (Bettens et al., 2002; Cheung et al., 2008; Landes et al., 2014; Convens et al., 2015; Eser et al., 2015; Kumar Lakshman et al., 2015).

The weakness of the presented study is its design, a retrospective analysis using the electronically available medical records, and the size of the groups, not allowing for inferential statistical analysis. The records are well kept, but in many cases the notes contain only a few sentences out of which the researcher has to distill the important information. This type of research has a high risk of overlooking postoperative complaints. This causes major bias. The two types of plates compared are made from the same titanium alloy, this enhances the feasibility of comparison.

We recommend further prospective research into the slotplates, including observation of the long-term stability of Le Fort I, zygoma and chin osteotomies with the use of slotplates.

5. Conclusion

Due to the low power of our study we could not find any statistical significant differences between the two types of plates. However, there is a slight tendency towards worse morbidity outcomes in the group receiving slotplates. Hardware removal and infection were found to be the most frequent plate-related morbidity factors in both the group receiving slotplates and the patients who received meshplates. All measured morbidity parameters had slightly higher rates in the slotplate group compared to the group receiving meshplates. In absolute numbers, more slotplates were removed than meshplates.

The slot principle was used in one out of five patients; in these cases, the special design of the slotplate was useful for the surgeon.

Disclosure

This study was not funded in any way.

Addendum

The malunion and nonunion prompted us to request the company to make the arms more sturdier and to make the circle of the hole for the locking screw complete (Fig. 3).

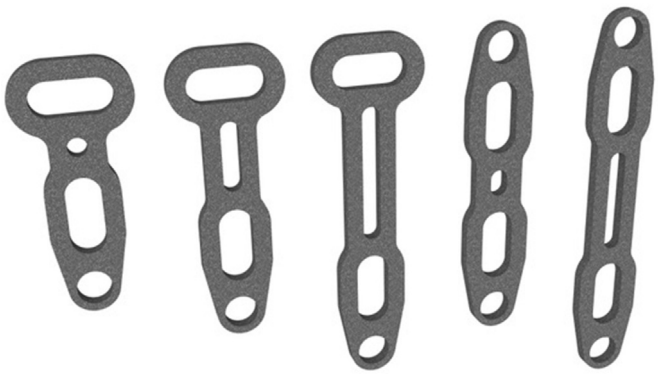

Fig. 3. As a result of this study, the company changed the design. The arms have been broadened by 0.35 mm to increase the S–N fatigue curve. The circle of the hole for the third screw has been made complete.

Please cite this article in press as: Zigterman BGR, Mommaerts MY, Slotplates revisited – A retrospective analysis, Journal of Cranio-Maxillo-Facial Surgery (2016), http://dx.doi.org/10.1016/j.jcms.2016.10.020

Acknowledgements

We would like to thank Drs. Goubau, Nout, Büttner and Mr Parra for their help in writing this article. Furthermore, we thank Surgi-Tec for their support in our research into the slotplates, especially for providing the images of the slot- and meshplates.

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Please cite this article in press as: Zigterman BGR, Mommaerts MY, Slotplates revisited – A retrospective analysis, Journal of Cranio-Maxillo-Facial Surgery (2016), http://dx.doi.org/10.1016/j.jcms.2016.10.020