Comparison of the Stability of Mandibular Sagittal Osteotomy Fixation between Two Types of Titanium Miniplates: A Biomechanical Study in Sheep Mandibles

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Abstract

This study aimed to compare the biomechanical stability of the fixation of mandibular sagittal split osteotomy of the ramus by two types of titanium miniplates in sheep mandibles. Seven preserved sheep mandibles with similar weight and size were selected, dissected with complete removal of soft-tissue structures, and sectioned in their midline. After performing sagittal split osteotomy, 5 mm of advancement was standardized and samples were divided into two groups according to the type of titanium miniplate (GI = seven hemimandibles were fixed with straight titanium miniplate, GII = seven hemimandibles were fixed with L-shaped titanium miniplates), and then subjected to compressive load. The means (standard deviation) of the compressive load and extension values were 70.68 N (22.26) and 63.36 mm (15.60) to straight miniplates, and 78.80 N (32.54) and 70.55 mm (5.42) to L-shaped miniplates. After comparison and statistical analysis, the results showed no significant difference between the two types of titanium miniplates.

Keywords

- ▶ osteotomy
- ▶ sagittal split ramus
- ▶ orthognathic surgery

Mandibular sagittal split osteotomy is a widely used technique for correcting dentofacial deformities and is a common and standard procedure that renders high-quality rates.^{1,2} Initially described by Trauner and Obwegeser in 1957, some authors have proposed technical modifications to make its execution more simple, reduce morbidity and complications, and increase stability through larger contact between the osteotomized segments.^{3–5}

The design of this osteotomy results in a large bone contact area which allows stable internal fixation

application.^{6,7} Internal fixation, either by bicortical screws or miniplates and monocortical screws, or both (hybrid technique), has been reduced or even eliminated intermaxillary fixation at postoperative period as well as a quick return to the masticatory function of the patient.⁸

Use of titanium miniplate for the fixation of the sagittal split ramus osteotomy was suggested by McDonald in 1987. Particularly, it is advantageous in cases of great advancement where the overlap of the segments is minimal. In addition, it can be performed through intraoral approach, which has

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lower risk of inferior alveolar nerve injury and provides minimum condylar sag.^{9,10}

Condylar position is a major concern of the surgeons by the fact that there is no guarantee that the mandible condyle will be repositioned in the same way as it was at the preoperative period. Condylar sag can induce malocclusion, temporomandibular joint derangements, and condylar remodeling and resorption. Such concerns led to the development of titanium miniplates, which enabled muscle passivity in the mandibular condyle position after stable internal fixation minimizing joint disorders.¹¹

The aim of this study was to evaluate the stability of the mandibular sagittal split osteotomy fixation in sheep mandibles by a L-format titanium miniplate and statistically compare with the commonly used straight titanium miniplates.

Materials and Methods

Seven preserved sheep mandibles with similar form and weight were obtained and had their soft tissues (muscle, periosteum, etc.) stripped off and then washed in clean water. Samples were packaged and kept in plastic bags and properly refrigerated for their preservation (►Fig. 1).

After being kept in an adequate environment and local temperature, midline osteotomy was performed in the mandibles generating two hemimandibles. Then, sagittal split ramus osteotomy, described by Bell et al³, was performed in all samples using a 702-bur, high-speed drill handpiece. Horizontal osteotomy was performed 2 mm above the lingula, while vertical osteotomy was performed 5 cm from the posterior border of the mandibular ramus.

After complete separation of the segments, an advancement of 5 mm was standardized and then the samples were fixed with the titanium miniplates (►Fig. 2). The hemimandibles were divided into two groups according to the type of titanium miniplate (GI = sagittal split ramus osteotomy fixed with 2.0 system straight titanium miniplate and four 6-mm monocortical screws; GII = sagittal split ramus osteotomy fixed with 2.0 system L-shaped titanium miniplate and four 6-mm monocortical screws) (►Fig. 3).

Using a computer-assisted fatigue test machine (Kratos; InstronCorp, Norwood, MA), samples were submitted to load

Fig. 1 Sheep mandible obtained and its soft tissues were stripped off.

Fig. 2 Standardized advancement of 5 mm.

tests by a velocity of 1 mm/minute. The progressive load appliance on molar region generated a resistance load (peak load in N) and a displacement (peak displacement in mm) values. After the first failure of the titanium miniplates detected by the system, the load test continued until the total loss of resistance of the samples generating final load and displacement values.

Results

The values of the peak load and displacement of both groups are shown in ►Table 1. These values varied from 48.72N to 146.60N for loading and from 42.22 to 84.33 mm for displacement. ►Table 2 shows the mean values and standard deviation of peak load and displacement of both groups.

Data were submitted for statistical analysis and compared by a paired comparison method using Student's *t*-test. Differences were considered significant at $p = 0.05$ and with a 95% confidence interval. There is no significant statistical difference between the two groups.

Discussion

Several mechanical studies use two points of load: one is where the sample is fixed and the other one is where the load is applied.^{12–14} Moreover, as in this study, some authors have suggested the displacement until the system failure moment achieves four measures: load and displacement peak, and final load and displacement.^{15,16}

According to the literature, the ideal material for biomechanical tests is the human mandibular bone. However, due to legal and ethical reasons as well as standardization of samples, other materials are suggested as alternative materials.¹⁵ The reason for choosing sheep mandibles in this study is because of their similarity in shape, size, and structure to human mandibles. In addition, they have been used in experiments involving sagittal split osteotomy and fixation in many studies.¹⁷

Most surgeons elect the sagittal split osteotomy technique as the first option for mandible advancement.⁷ In addition, as suggested by some authors, a 5-mm advancement was established for the standardization of samples.^{18,19}

Fig. 3 Groups I and II.

Table 1 Maximum values of loading and displacement and loading values at miniplate fracture moment

Sample	Maximum loading values (N)		Maximum displacement values (mm)		Loading values at the fracture (N)	
	Straight	L	Straight	L	Straight	L
1	112.36	69.79	68.01	76.18	6.20	48.76
2	91.32	83.21	73.78	64.35	37.45	83.17
3	59.62	51.84	45.54	72.50	43.22	33.05
4	54.14	48.72	84.33	73.32	33.40	48.72
5	58.36	77.32	72.64	73.01	9.18	77.17
6	62.04	74.10	57.01	61.45	7.60	28.51
7	56.93	146.60	42.22	73.04	46.74	57.96

Nowadays, different fixation methods are described and some authors suggested the use of bicortical screws which present higher stability among them.²⁰ However, the technique of miniplate and monocortical screws has its advantages, such as avoid compression between the bone segments reducing risk of nerve damage, reduce the displacement trend of the proximal segment, and prevent condylar sag.^{7,10,20} Due to these reasons, studies such as this must be done to demonstrate the proper stability of this technique.

Harada et al²¹ evaluated bite forces of patients who underwent orthognathic surgery in pre- and postoperative periods. The values found varied between 98N and 239N. In the postoperative period of 2 weeks, the bite forces varied between 29N and 70N. These values are lower than the mean values of this study. In addition, some authors suggested that the necessary forces to cause the system failures are higher than the masticatory forces at the immediate postoperative period.^{14,22}

Table 2 Mean values and standard deviation of loading and displacement, and loading at the miniplate fracture moment

	Maximum loading values (N)	Maximum displacement values (mm)	Loading values at the fracture (N)	p^a
Group I	70.68 (22.26)	63.36 (15.60)	26.26 (17.91)	0.05
Group II	78.80 (32.54)	70.55 (5.42)	53.91 (20.60)	0.05

^aStudent's *t*-test (95% confidence interval).

Authors compared straight and L-design titanium miniplates using finite element analysis and observed an area of higher concentration of fatigue in the folding region of L-design miniplate.²³ After a finite element analysis using resorbable miniplates, other authors also suggested that resorbable L-design miniplates feature large areas of fatigue concentration in folding region, leading to a greater tendency to fracture.²⁴ Furthermore, both studies showed similar data for straight and L-design titanium miniplates concluding that there is no statistically significant differences between the two types of miniplates.^{23,24}

Conclusion

The use of 2.0 system straight titanium miniplate has been proved as a reliable method of performing sagittal split osteotomy. Therefore, when the L-design titanium miniplates do not present differences about the stability when compared with the straight titanium miniplate, it can be supposed that they have enough properties for clinical use. In addition, L-design titanium miniplates may facilitate the installation of the posterior monocortical screws. However, the authors believe that, despite the results of this study, biomechanical tests must continue to be conducted to demonstrate the effectiveness of different designs of miniplates and apply clinically in the future.

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