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Biomechanical evaluation of different angle-stable locking plate systems for mandibular surgery

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ABSTRACT

Purpose: To compare the initial stability and stability after fatigue of three different locking systems (Synthes®, Stryker® and Medartis®) for mandibular fixation and reconstruction.
Method: Standard mandible locking plates with identical profile height (1,5 mm), comparable length and screws with identical diameter (2,0 mm) were used. Plates were fixed with six screws according a preparation protocol. Four point bending tests were then performed using artificial bone material to compare their initial stability and failure limit under realistic loading conditions. Loading of the plates was performed using of a servo hydraulic driven testing machine. The stiffness of the implant/bone construct was calculated using a linear regression on the experimental data included in a range of applied moment between 2 Nm and 6 Nm.
Results: No statistical difference in the elastic stiffness was visible between the three types of plate. However, differences were observed between the systems concerning the maximal load supported. The Stryker and Synthes systems were able to support a significantly higher moment.
Conclusion: For clinical application all systems show good and reliable results. Practical aspects such as handling, possible angulation of screw fixation, possibility of screw/plate removal, etc. may favour one or the other plating system.

1. Introduction

Fractures of the atrophied mandible, reconstructions with free vascular bone grafts, pathological fractures (after cysts or extensive wisdom tooth extraction), and comminuted fractures are often treated with the help of different types of miniplate locking systems that have been developed in the past few years and are available on the market. The main advantage of these systems in vitro is greater stability compared to that of conventional plates (Gutwald et al., 1999). Additional theoretical advantages of these systems are stable fixation of bone fragments and grafts, reduced risk of screw loosening and dislocation, absence or reduction of plate pressure on periosteum, and finally simplified plate adaptation (Haug et al., 2002; Kirkpatrick et al., 2003; Ellis and Graham, 2002). Locking systems achieve stability through a mechanism that locks the screw to the plate and creates a firm interconnection. This locking mechanism can be achieved with different techniques. Up to the present, there are three types on the market. The “Lock-System” (Synthes, Switzerland) represents a technique in which the locking principle is based on a geometrical connection between a thread in the screw head and its counterpart in the plate hole. With the “SmartLock-System” (Stryker, Germany), deformation of metal (titanium) occurs at the contact surface when screws are tightened, resulting in a rigid connection between two metallic parts (screw and plate) by so-called cold welding. In the third one, the “TriLock” system (Medartis, Basel, Switzerland), a spherical conical screw head locks with the plate hole by friction. Even though there are several locking principles involved in the products on the market, there are no studies comparing the initial stability and stability after fatigue testing of these systems in a standardized protocol.

The purpose of this study was to compare the stability of the three different locking systems for mandibular fixation, using plates with identical profile height (1.5 mm), comparable length (Fig. 1), and screws with identical diameter (2.0 mm).

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Fig. 1. The three different locking plates assessed (from top to bottom: Stryker, Synthes, Medartis).

2. Material and methods

For fixation, 2.0-mm screws (10-mm length) and six-hole plates made of titanium alloy with a central ridge (1.5-mm profile height) were applied. Three different systems were compared, namely, those manufactured by Synthes, Stryker, and Medartis. In each system, the standard 1.5-mm profile plate was chosen for assessment. The geometrical differences of the plates assessed are listed in Table 1. The prices of one plate with six matching screws are shown in Table 2.

Four-point bending tests were performed on the different screw/plate designs to compare their initial stability and failure limits under realistic loading conditions.

2.1. Specimen preparation

Artificial bone blocks (Solid Foam 30pcf, Sawbones; Pacific Research Laboratories, USA) measuring 130 × 40 × 22 mm were used to support the plate and transfer the load from the testing setup to the implants. The plates were fixed to the bone following the surgical procedure. First, holes were drilled according to the plate type on a milling machine tool (±0.01 mm). Once the six holes were drilled, the artificial bone was cut in its central part to reduce its width to 10 mm (Fig. 2). This thickness represents the mandible cross-sectional area. Based on this initial cut, the bone fracture was created by cracking the material with a chisel. Finally, plates were attached to the bone using six screws (2.0 mm).

2.2. Screws and plates

2.2.1. Synthes

The 2.0-mm locking system by Synthes has self-taping and self-drilling screws with conical double threads beneath the screw head (Fig. 3). These threads engage and lock into the threaded plate holes (Figs. 4a, 4b, and 5).

Table 1
Geometric measurements of the assessed mandibular reconstruction plates.

Manufacturer	Length (mm)	Length of central ridge (mm)[a]	Distance between holes (mm)[a]
Synthes	52.7	11.5	5.4
Stryker	50.2	8.2	5.3
Medartis	60.3	15.1	6.0

[a] Distance from whole edge to whole edge.

Table 2
Prices (in Euros) of tested mandibular reconstruction plates.

Manufacturer	Price CHF	Price difference (%)
Synthes	575.85	+71.5
Stryker	335.80	–
Medartis	379.25	+12.9

Prices are for one plate with six screws, and do not include shipping or VAT.
CHF = Swiss francs; VAT = Value added tax.

2.2.2. Stryker

The 2.0-mm locking screw by Stryker also has conical double threads beneath the screw head (Fig. 6). The plate hole consists of a single thin vertical thread (Fig. 7a,b). When tightening the screw, a deformation of this metal lip/thread occurs, resulting in a rigid connection between two metallic parts (Fig. 8). Stryker highlights the fact that their screws can be applied with an angulation of up to 10°.

2.2.3. Medartis

The locking system by Medartis (MODUS TriLock) consists of screws with spherical three-point wedged, conical head (Fig. 9). This design allows locking screws to be fixed in the plate (Fig. 10a,b) within a freely selectable range (±15°). The spherical

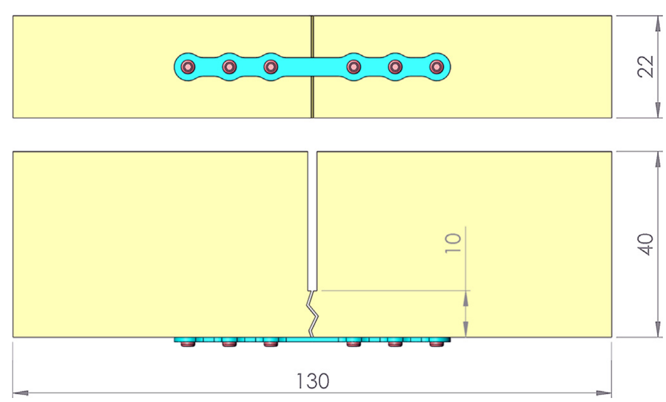

Fig. 2. Schematic representation of the plate fixed on the artificial bone using six screws. The fracture was aligned with the center of the plate.

Fig. 3. 2.0 Synthes: 10 mm self-taping and self-drilling screws with conical double threads beneath the screw head.