Journal of Cranio-Maxillo-Facial Surgery 42 (2014) 790–795

Contents lists available at ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

One vs. two piece customized implants to reconstruct mandibular continuity defects: A preliminary study in pig cadavers

Jutta Markwardt [a,*], Tony Weber [b], Niels Modler [b], Philipp Sembdner [c], Raoul Lesche [d], Matthias C. Schulz [a], Bernd Reitemeier [e]

[a] Department of Oral and Maxillofacial Surgery (Director: Prof. Dr. Dr. G. Lauer), University Hospital, Technische Universität Dresden, Fetscherstr. 74, 01307 Dresden, Germany
[b] Institute for Lightweight Construction and Plastics Engineering (Director: Prof. Dr. W. Hufenbach), Technische Universität Dresden, Germany
[c] Department of Design Engineering/CAD (Director: Prof. Dr. R. Stelzer), Technische Universität Dresden, Germany
[d] Fa. Hofmann und Engel, Produktentwicklung (Director: Dipl.-Ing. G. Engel), 01468 Boxdorf, Dresden, Germany
[e] Department of Prosthetic Dentistry (Director: Prof. Dr. M. Walter), University Hospital, Technische Universität Dresden, Germany

ARTICLE INFO

Article history:
Paper received 12 June 2013
Accepted 4 November 2013

Keywords:
Customized mandibular implant
Loss of continuity
Cadaver study
Bonding strength testing
Pig mandible

ABSTRACT

Objectives: The reconstruction of mandibular continuity defects by bridging plates often leads to complications. Customized mandibular implants might be an alternative option. In the present study, the stability at the bone–implant-interface of customized two-piece implants was compared to one-piece implants.
Methods: Thirty pig mandibles were randomly divided into three groups. One group (A) was left untreated and served as reference. In groups B and C, a continuity defect was created in the left mandibular side. The defects were reconstructed by customized pure titanium implants, manufactured using the LaserCUSING® technology. Group B received a one-piece implant; in group C a two-piece implant was inserted to reconstruct the continuity defect. The bonding strength was examined statically and dynamically under standardized conditions. Digital Image Correlation was used for distortion measurement. Different dynamic measurements were performed for orientation purposes.
Results: The highest bonding strength was measured for the reference group. The two-piece implant showed an increased bonding strength when compared to the one-piece design. In all pig mandibles treated with individual implants a fracture occurred on the non-operated side. This indicates a high primary stability of the bone–implant-interface.
Conclusion: The two-piece individual mandibular implant manufactured by LaserCUSING® technology should be further analyzed in future studies.

1. Introduction

The reconstruction of mandible continuity defects is still a challenge for oral and maxillofacial surgeons. Tumor therapy is the most frequent reason for continuity defects (Markwardt et al., 2007). In addition severe infections of the lower jaw or comminuted mandible fractures might cause extended defects, resulting in severe functional deficits of the orofacial system (Taylor, 2000). The dislocation of the remaining stumps of the mandible during mastication can lead to non-occlusion of the remaining teeth. Thus, the ingestion of solid food is hampered and can cause malnutrition (Reitemeier et al., 2012). Additionally, the position of the patient's tongue might be altered by mobility of the mandibular stumps. This alteration might cause a constriction of the upper airway causing dyspnea as well as a phonetic dysfunction. These conditions lead to a severe impaired esthetic–physiognomic function of the orofacial system. Furthermore, patients with continuity resections of the mandible suffer from a reduced social function and thus the quality of life is negatively influenced (Becker et al., 2012). Therefore, an effective rehabilitation of the defect would be desirable. At the moment, there is a significant failure rate for mandible reconstruction using bridging or reconstruction plates (Ueyama et al., 1996; van Minnen et al., 2002; Markwardt et al., 2007). The most frequent complications are plate fractures, infection with either intra- or extra-oral exposure of the plate and the loosening of screws (Blackwell et al., 1996; Markwardt et al., 2007; Ettl et al., 2010). Stable connection between the mandibular stumps and the

* Corresponding author. Tel.: +49 (0)351 458 3761; fax: +49 (0)351 458 5348.
E-mail address: jutta.markwardt@uniklinikum-dresden.de (J. Markwardt).

1010-5182/$ – see front matter © 2013 European Association for Cranio-Maxillo-Facial Surgery. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jcms.2013.11.013

bridging plate is essential to bear the load occurring during mastication (Curtis et al., 1999; Iwase et al., 2006; Hannam et al., 2010). Therefore, a customized implant replacing the resected part of the mandible and enabling a stable connection of the remaining stumps would be a promising approach to functional reconstruction. In order to reproduce such an implant the first requirement is a set of data depicting the mandible and, a computed tomography (CT) scan is essential along with technology being able to depict such a highly complex form. One technology able to meet these requirements is LaserCUSING®. Using this method, thin layers of titanium are being built up consecutively. Thus, it is possible to produce highly complex shapes (Gebhardt, 2003; Schöne et al., 2012). A pre-operative CT scan is necessary to determine the dimension and location of the tumor or comminuted fracture. A three-dimensional model of the mandible is created and the planned resection/cutting planes are specified by a maxillofacial surgeon. These cutting planes are crucial as they represent the dimensions of the customized implant. In order to precisely locate the cutting planes on the mandible during surgery, individual metallic cutting templates are created. Subsequently, the customized mandibular implant is created as a virtual computer model. This set of data is sent to the LaserCUSING® where the customized implant and the cutting templates are produced by laser sintering technology.

In a previous cadaver study, customized implants were tested in the mandibles of adult domestic pigs. The results demonstrated the ability to produce customized mandibular implants resembling the resected mandible part.

The current interdisciplinary project focuses on the development of a customized mandibular implant to reconstruct continuity defects. The aim of the present cadaver study was to test the bonding strength between the mandibular stumps and customized mandibular titanium implants. It was hypothesized that two-piece mandibular implants show a higher bonding strength compared to those consisting of one piece.

2. Materials and methods

Thirty fresh cadaver mandibles of domestic pigs were used in the experimental setup. The study protocol was approved by the Commission for Animal Studies of the District Government Dresden, Germany (File No.: 21-9168.11-1/2010-25). The original weight of the animals was between 20 and 30 kg. First, the soft tissue was removed from all mandibles. A CT scan of each mandible was performed. The CT data was processed using an individually developed software and converted into a 3D model (STL = data format of CAD software for 3D systems). The data was arranged into a defined coordinate system. In order to design the shape for an identical mandibular implant by CAD technology, a mathematical surface description (STEP = Standard for exchange of product model CAD data) of the bone shape in the resection area was created by reverse planning. This was followed by the specification of the cutting planes for the defect area. The position, direction, length and diameter of the screws and dental implants were planned (Fig. 1a and b) using the specially designed “Kontito” software (Sembdner et al., 2012).

The data was sent to the manufacturer (Hofmann & Engel Boxdorf, Germany) and the customized mandibular implant was virtually developed. Fig. 2a and b shows an example of a computer model of a one-piece and two-piece mandibular implant. Following, pure titanium implants were created from these templates using a cusing machine (M2 cusing machine, Concept Laser, Lichtenfels, Germany). The cutting templates were virtually designed and transferred into titanium.

The pig mandibles were randomly divided into three groups of ten mandibles each.

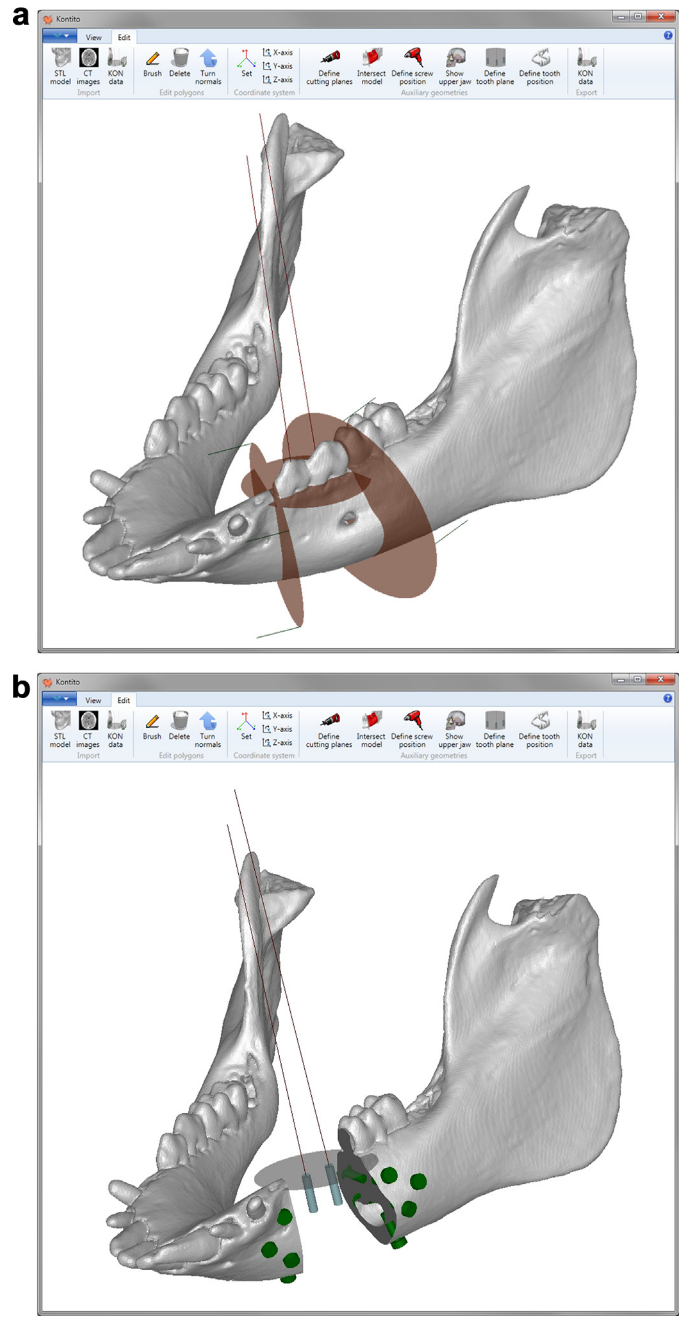

Fig. 1. a) Cutting planes at the mandible. b) Condition after removal of the planned resection with partially shown fixing screws and dental implant positions by means of the software “Kontito”.

2.1. Group A (reference)

The first group received no surgical intervention. Two mandibles showed damage in the area of the right mandibular angle and were therefore not included in the study. The remaining 8 mandibles were included in static testing.

2.2. Group B (one-piece reconstruction)

In the second group, a standardized defect simulating a continuity resection was created. A commercially available one-piece mandibular reconstruction plate was used for reconstruction.