Available online at www.sciencedirect.com

SciVerse ScienceDirect

British Journal of Oral and Maxillofacial Surgery 53 (2015) 741–747

BRITISH Journal of Oral and Maxillofacial Surgery

www.bjoms.com

Biomechanical loading test on reconstructed mandibles with fibular, iliac crest or scapula graft: a comparative study

Isabella Grohmann[a,*], Stefan Raith[b], Thomas Mücke[c], Herbert Stimmer[d], Nils Rohleder[c], Marco R. Kesting[c], Frank Hölzle[e], Timm Steiner[e]

[a] *Department of urology, Technische Universität München, Ismaningerstrasse 22, 81675 München, Germany*
[b] *Department of Dental Materials and Biomaterials Research, RWTH Aachen University Hospital, Pauwelstrasse 30, 52074 Aachen, Germany*
[c] *Department of oral and maxillofacial surgery, Technische Universität München, Ismaningerstrasse 22, 81675 München, Germany*
[d] *Department of radiology, Technische Universität München, Ismaningerstrasse 22, 81675 München, Germany*
[e] *Department of oral and maxillofacial surgery, University hospital of RWTH Aachen, Pauwelstrasse 30, 52074 Aachen, Germany*

Accepted 24 May 2015
Available online 16 June 2015

Abstract

Advantages and disadavantages of the three most commonly-used bone grafts for mandibular reconstruction are widely known, but biomechanical experimental studies are rare. We have done loading tests on cadaveric mandibles reconstructed with fibular, iliac crest, and scapular grafts using 3 different osteosynthesis systems to detect and compare their primary stability. Loading tests were done on mandibles with grafts from the fibula and iliac crest and published previously. A 4.5 cm paramedian L-type defect was reconstructed with scapula using 2 monocortical non-locking plates, 2 monocortical locking plates, or a single bicortical locking plate/fracture gap in 18 human cadaveric mandibles. These were loaded on to the "Mandibulator" test bench and the movement of fragments in 3 dimensions was assessed and quantified by a PONTOS® optical measurement system. Comparison of the osteosynthesis groups showed that the miniplate was significantly superior to the 6-hole TriLock® plate for both fibular and iliac crest grafts. The fibular graft gave greater stability than the iliac crest and scapular grafts for all 3 osteosynthesis systems. All bony specimens offered sufficient resistance to mechanical stress within the recognised range of biting forces after mandibular reconstruction, independently of the choice of bone graft and osteosynthesis system used. Anatomical and surgical advantages need to be taken into account when choosing a graft. Stability can be maximised with a fibular graft, and further optimised by enlarging the binding area by using the "double barrel" method. Computer simulated experiments could segregate factors that biased results, such as morphological differences among cadavers.

Keywords: Comparative study; Mandible; Osteosynthesis; Biomechanics; Iliac crest

Introduction

Since microvascular bone graft transfers were introduced in 1970, new possibilities in reconstructive surgery have arisen.[1] Microsurgical transfer of flaps has become the gold standard of surgical treatment after resection of tumours of the mandible.[2] The most common and most investigated transplants are the fibular flap, the iliac crest flap, and the scapular free flap. Hidalgo first reconstructed a mandible using a fibular free flap in1989,[3] since when its suitability (particularly for extensive bony defects over half the size of the mandible) has been confirmed.[4–6] Up to two skin paddles can be taken in addition to the segment of bone, which allows simultaneous closure of soft tissue defects.[3,4,6] However, in some cases, such as segmental mandibulectomy or hemimandibulectomy, the iliac crest flap with the deep circumflex iliac artery (DCIA) as its vascular pedicle is thought to be superior to the fibular flap, as its natural curvature better mimics the shape of the mandible, and it sometimes

* Corresponding author at: Possartstrasse 3, 81679 München, Germany.
E-mail address: bella.grohmann@gmail.com (I. Grohmann).

http://dx.doi.org/10.1016/j.bjoms.2015.05.022

even supersedes the need for osteotomy.[7–9] As Sanders and Mayou showed, a corresponding skin layer supplied by the myocutaneous vessels of the DCIA can be harvested in addition to the bony segment, which allows both extraoral and intraoral reconstruction[1,10,11] Because so much bone is available, osseointegrated dental implants can successfully be inserted so that the patient can chew satisfactorily.[1,9]

Compared with the fibular and the iliac crest flaps, the scapular flap is the third choice for mandibular reconstruction.[12] However, its suitability for extensive composite resection has been questioned. As it provides different flaps supplied by the same pedicle, it offers a great diversity of soft tissues such as skin and muscular components that make it suitable for defects that involve bony with particularly large areas of soft tissue.[12–15]

Numerous comparative studies have been published about the surgical and anatomical advantages and disadvantages, the donor side morbidity, the quality of life,[16] and the applicability of each bone graft depending on the size and type of the defect after resection of tumours.[1,14] In terms of biomechanics, however, we know of few if any experimental studies that have directly compared the biomechanical properties of the reconstructed mandible. There is also a lack of studies that investigate the primary stability after reconstruction.

The aim of the present study was to find out which transplant best withstands mechanical stress, as a lack of stability is responsible for the formation of pseudarthrosis.[17] Sufficient primary stability after mandibular reconstruction has been confirmed in previous experiments for the iliac crest and fibular grafts.[18,19] Similar biomechanical studies have also been made using cadaver mandibles reconstructed with scapular osseous flaps. Three different types of osteosynthesis were used in the former experiments, and we have compared primary stability for all 3 bone grafts.

Methods

Specimens of bone

Fifty-four human mandibles fixed in 2% 2-phenoxyethanol were collected from cadavers in accordance with the rules of the committee of ethics (Technische Universität München, Germany). They were divided into 3 groups with 18 mandibles in each.

A 4.5 cm paramedian discontinuity L-type defect as described by Jewer et al. was made in all mandibles lateral to tooth 43, and it was reconstructed with either human cadaver iliac crest, fibular, or scapular grafts 4.5 cm in size.[9] The bones were taken from different cadavers, and the mandibles and grafts were distributed randomly. Each of the 3 test groups was subdivided into 3 subgroups of 6 mandibles each in which 3 different plate systems for osteosynthesis (2 parallel lines of monocortical, 6-hole, conventional titanium miniplates 1.0 mm thick; 2 parallel lines of monocortical, 6-hole, titanium locking Plates 1.3 mm thick; or a single, bicortical, 4-hole, titanium locking Plate 1.5 mm thick/osteotomy gap). The exact descriptions of harvesting the bone and preparation of the specimens have been described previously.[18,19]

Mandibles reconstructed with fibula were prepared and tested earlier than the other two test groups, but were prepared and measured in exactly the same way. Each step was done by only one person for all 3 experiments to ensure standard conditions. One single torque screwdriver was used for all 3 experiments.

Measurements

All specimens of bone were continuously loaded on the biomechanical test bench called "Mandibulator" as described by Steiner et al. and Grohmann et al.,[18,20] It was constructed specially to investigate test specimens of mandible as it simulated the act of mastication, starting at a mechanical loading of 0 N and continuing until it failed.

Optical measurements were made with a PONTOS® 5 M (GOM®, Braunschweig, Germany), which continously detected all movements of the different parts of the specimens in all 6 dimensions of freedom under loading. The recorded data could be used to calculate the interfragmentary movement for each osteotomy gap.[18–20]

Statistical evaluation

The interfragmentary movements in both osteotomy gaps were summarised to yield one scalar stability factor and assessed at a loading level of 100 N. We compared specimens reconstructed with the same graft but using different methods of fixation, as well as specimens fixed by the same osteosynthesis system but with different grafts. We used the non-parametric Mann-Whitney *U* test to assess the significance of differences between the bone grafts.

Results

Comparison of osteosynthesis groups

For mandibles reconstructed with iliac crest graft, Grohmann et al. showed that the miniplate was superior to the 6-hole TriLock® plate and the 4-hole TriLock® plate from the point of view of interfragmentary stability and this was significant for the 4-hole TriLock® (p=0.037).[18] When mandibles were reconstructed with a fibular graft as Trainotti et al. showed, the miniplate offered significantly better stabilisation than the 6-hole TriLock® plate at a load of 300 N (p=0.037).[19] Our biomechanical tests on scapular grafts showed that fixation with the monocortical, 6-hole TriLock® plate provided better primary stability than fixation with the monocortical miniplate or the bicortical and thicker single 4-hole TriLock® plate. However, neither of the latter comparisons differed significantly (p=0.109 (monocortical paired miniplate vs. monocortical paired 6-hole TriLock plate), p=0.521 (monocortical paired miniplate vs. single bicortical 4-hole