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Axiographic results of CAD/CAM-assisted microvascular, fibular free flap reconstruction of the mandible: A prospective study of 21 consecutive cases

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ABSTRACT

Virtual planning and guided reconstruction of the mandible following ablative surgery have become standard procedures in reconstructive surgery. Many advantages regarding operation time, morphology, bony fit, and consolidation have been described, but analyses of the functional outcome of virtually planned mandibular reconstructions are lacking. We prospectively analyzed 21 consecutive cases of mandibular reconstructions using CAD/CAM-assisted microvascular, fibular free flaps in operations between July 2014 and January 2016 at a single center. Axiographic measurements were performed preoperatively and at 10 days and 3 months postoperatively and were correlated with clinical findings. Uni- and multivariate regression analyses were performed to determine the association between possible predictor variables on functional outcomes. Overall, no statistical differences between the t1 and t3 measurements were seen in the analyzed variables. The univariate analysis showed a significant influence of indication and pre- and postoperative irradiation only on mouth opening ($p = 0.018$, $p = 0.026$, and $p = 0.049$). Timing, the number of osteotomies, and the incidence of wound healing disturbances had no significant influence on postoperative function ($p = 0.753$, $p = 0.69$ and $p = 0.776$). In particular, cases without malignancy or preoperative irradiation benefitted from the integration of the CAD/CAM technique and showed good functional outcomes.

1. Introduction

Since the first successful transfers in the past century, bony reconstruction of the resected mandible with the various available free flaps, such as the fibula, iliac crest, and scapula flap, has evolved to become a key step in oral rehabilitation after ablative surgery (Hidalgo, 1989; Cordeiro et al., 1999; Cornelius et al., 2016). Preoperative planning, simulation, and production of cutting guides, produced by maxillofacial technicians in the laboratory, were significantly facilitated by the introduction of computer-aided design and computer-aided manufacturing (CAD/CAM) technology (Cutting et al., 1986). Virtual planning and guided resection with customized cutting guides has significantly facilitated complex three-dimensional reconstruction, especially of the mandible, in the last years after extensive development in the fields of software programs, virtual reproducibility, and real accuracy by others. With regard to postoperative aesthetics, morphology, and function, the fibular free flap raised as osteomyocutaneous, osteocutaneous, or osseous flaps with or without simultaneous dental implants for oromandibular reconstruction can be considered the work horse of microvascular head and neck surgery. The integration of CAD/CAM technology in the pre- and intraoperative workflow has been shown to shorten the operation time and hospital stay and to improve bony consolidation, symmetry, and morphology (Sieira Gil

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et al., 2015; Tarsitano et al., 2016b; Weitz, et al., 2016). The interoperator variability caused by surgeon experience can be minimized, and even younger colleagues can become accustomed and trained to undertaking the complex reconstruction by first planning the procedure (Avraham et al., 2014). Moreover, oral and dental rehabilitation might be accelerated because preoperative planning facilitates interdisciplinary dialogue with members of the prosthodontics department and allows exact positioning of implants with satisfactory outcomes (Hanken et al., 2015a).

On the other hand, the preoperative planning time is increased, and intraoperative adaptation to changes in resection or reconstruction is difficult to implement in cases that have been virtually planned (Moro et al., 2009; Avraham et al., 2014). Associated costs are a frequently discussed aspect of CAD/CAM-assisted reconstructions. However, due to ongoing research and development, the introduction of the modern technology can be supplied at a considerably less expense than earlier.

Although the above-mentioned advantages and disadvantages have previously been described, analyses of the functional outcome of virtually planned mandibular reconstructions are still lacking. We consider function as the key factor for sufficient and satisfying oral rehabilitation and hygiene, because the simple act of opening the mouth represents the condition sine qua non for the success of the ambitious goal following ablative surgery.

2. Materials and methods

2.1. Ethical statement and patient recruitment

All clinical investigations and procedures were conducted according to the principles expressed in the Declaration of Helsinki. Written patient consent was obtained. Ethical approval for the prospective study was granted by the Ethical Committee of the Technische Universität München (Approval No. 342/14).

Any patient between July 2014 and January 2016 who underwent a CAD/CAM-assisted reconstruction of the mandible by means of the microvascular fibula free flap after ablative surgery at our department was included in the prospective study. This involved all patients presenting with oral squamous cell carcinoma (OSCC), therapy-resistant osteoradionecrosis (ORN) of the mandible, medication-related osteonecrosis of the jaw (MRONJ), or chronic osteomyelitis (OM).

2.2. Surgery and postoperative measurements

The diagnosis was histologically confirmed in all patients prior to major surgery. In cases of malignancies, all patients received preoperative staging, ablative surgery in the common manner, and adjuvant therapy if indicated according to the current guidelines (Wolff et al., 2012). Postoperatively, all patients were kept under supervision for 1 night in the intensive care unit (ICU) and afterward were transferred to the ward or, if necessary, remained in the ICU. The postoperative regimen regarding antibiosis and anticoagulative therapy was as previously described (Mücke et al., 2015, Mücke et al., 2016).

We used the SAM Axioquick Ultrasonic Axiograph and the accompanying software program SAM Axioquick Recorder V1.2.7 (SAM® Präzisionstechnik GmbH; Gauting, Germany) for axiographic registration of the mandibular movements. Axiographic measurements were performed by the same person in all cases (C.K.) preoperatively (t1), 10 days postoperatively (t2), and 3 months postoperatively (t3) following explanation and simulation of the required movements.

2.3. Data analysis

Descriptive statistics for clinical characteristics are given as the means (mm) and relative change (%) ± standard deviation. The relative change between t1 and t3 measurements was calculated as follows: $\Delta = [(t3 - t1)/t1] \times 100\%$. Variables were compared with respect to mouth opening and latero- and protrusion by using the nonparametric Mann–Whitney *U* test.

Univariate linear regression analyses concerning mouth opening and latero- and protrusion were performed including the following possible predictors: OSCC vs. non-OSCC, pre- and postoperative irradiation (RTx), timing of reconstruction (primary vs. secondary), number of osteotomies, and the incidence of wound healing disturbances (WHDs). In instances of significant statistical findings, a complementary multivariate linear regression analysis and correlation analysis were conducted.

The data were analyzed with the “Standard Package for the Social Science” (SPSS for Mac, release 22.0.0, 2013; SPSS Inc., Chicago, IL, USA) and with the freeware “R Statistical Package” (R for Windows, release 3.2.0, 2015; R Foundation for Statistical Computing, Vienna, Austria). Figures were generated with SPSS and Microsoft® Office Excel (Microsoft® Excel for Mac, release 14.5.3, 2010; Microsoft Corporation; Redmond, WA, USA). All statistical tests were performed at a 0.05 significance level.

3. Results

3.1. General characteristics

Thirty-two consecutive microvascular fibula free flaps were performed in our department. In total, only 21 cases were included for further analyses, since 11 patients were excluded because of death or flap loss before measurement at 3 months postoperatively (t3) or because of noncompliance (Fig. 1).

The male/female distribution was 14/7 (66.67%/33.33%), and the mean age at the point of operation was 60.24 ± 5.71 years. The causes of mandibular reconstructions were OSCC in 10 cases (47.62%), ORN in 8 cases (38.09%), chronic OM in 2 cases (9.52%), and MRONJ in 1 case (4.77%). In 15 cases, patients had a history of preoperative irradiation (71.43%); however, the preoperative irradiation was not applied with a neoadjuvant intention. In 5 cases, patients underwent postoperative irradiation according to an oncologic adjuvant therapy regimen (23.81%). Fifteen patients underwent primary reconstruction of the mandible (71.43%) and 6 patients secondary reconstruction of the mandible (28.57%). The distribution of the number of osteotomies was as follows: 0 osteotomies (class 1; $n = 4$), 1 osteotomy (class 2; $n = 6$), 2 osteotomies (class 3; $n = 9$), 3 osteotomies (class IV; $n = 1$), and 4 osteotomies (class IV; $n = 1$) (Iizuka et al., 2005). An incidence of WHD was seen in 8 cases (38.01%).

3.2. Axiography

The overall results for mouth opening were 30.11 mm ± 11.45 at t1, 21.14 mm ± 7.26 at t2, and 26.26 mm ± 9.67 at t3. The reduction of the mouth opening between t1 and t2 was significant ($p < 0.001$) and between t1 and t3 was not significant ($p = 0.073$). The relative changes were between $\Delta t2 - t1$ −26.34% ± 19.77, $\Delta t3 - t2$ 19.08% ± 29.63, and $\Delta t3 - T1$ −7.41% ± 32.99. The overall results for protrusion were 7.2 mm ± 4.16 at t1, 4.81 mm ± 3.37 at t2, and 5.45 mm ± 3.39 at t3. The reduction of the protrusion between t1 and t2 was significant ($p < 0.007$) and between t1 and t3 was not significant ($p = 0.092$). The relative changes were between $\Delta t2 - t1$ −24.25% ± 37.69, $\Delta t3 - t2$ 16.80% ± 60.67, and $\Delta t3 - t1$ −5.86% ± 64.93.