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Flapped versus flapless surgery and delayed versus immediate loading for a four mini implant mandibular overdenture: a RCT on post-surgical symptoms and short-term clinical outcomes

Running title: Post-surgical outcomes of mini implant overdenture treatment

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ClinicalTrials.Gov ID: NCT04760457 – Title: Mandibular overdentures retained by mini implants: a clinical trial comparing different surgical and loading protocols (SMIS)

AUTHOR CONTRIBUTIONS

Cláudio Rodrigues Leles: Conceptualization (Lead); Data curation (Lead); Formal analysis (Lead); Funding acquisition (Lead); Investigation (Lead); Methodology (Lead); Project administration (Lead); Resources (Lead); Supervision (Lead); Writing – original draft (Lead); Writing – review & editing (Lead). **Marcella Silva de Paula:** Investigation (Equal); Methodology (Equal); Project administration (Equal); Supervision (Equal); Writing – review & editing (Supporting). **Thalita Fernandes Fleury Curado:** Data curation (Equal); Investigation (Equal); Project administration (Equal); Supervision (Equal); Writing – review & editing (Supporting). **Jésio Rodrigues Silva:** Data curation (Equal); Investigation (Equal); Methodology (Supporting); Supervision (Equal); Writing – review & editing (Supporting). **José Luiz Rodrigues Leles:** Conceptualization (Equal); Investigation (Equal); Methodology (Equal); Supervision (Equal); Writing – original draft (Supporting). **Gerald McKenna:** Conceptualization (Equal); Formal analysis (Equal); Investigation (Supporting); Methodology (Equal); Validation (Equal); Writing – review & editing (Equal). **Martin Schimmel:** Conceptualization (Equal); Funding acquisition (Equal); Methodology (Equal); Validation (Equal); Writing – review & editing (Equal).

ABSTRACT

Objective: This factorial randomized clinical trial tested the effects of the surgical approach (flapped – FPS versus flapless – FLS surgery) and loading protocol (delayed – DL versus immediate – IL) for treatment with a four mini implant mandibular overdenture.

Material and Methods: A total of 296 one-piece titanium-zirconium mini implants were inserted in 74 patients (IL/FLS=17; IL/FPS=18; DL/FLS=20; DL/FPS=19). Outcomes included patient's perceived surgical burdens, clinical time, implant survival, and post-surgical symptoms and complications, assessed immediately after surgery, in the 7-day and 6-week follow-ups.

Results: Perceived surgical burdens were relatively low, higher for females, and no difference was found between flapped and flapless surgery. Surgical time was lower for flapless surgery. Overall symptoms were mild after 24 hours, and higher for females. Less symptoms were recorded for the flapless surgery compared to the flapped for the delayed loading patients, and flapless surgery was associated with lower risk of bleeding. No early implant failure was observed until the 6-week follow-up. Delayed was associated with discontinuous use of the prosthesis and poor function. Lower complaint rates were observed for immediate loading regardless of the surgery protocol.

Conclusions: Mini implants for mandibular overdenture is a feasible option regardless of surgical access and loading protocol, with high safety and predictable survival rates, and low incidence of post-insertion complications. Flapless surgery requires less clinical time and result in easier intraoral prosthetic incorporation of attachments compared to flapped surgeries. Immediate loading did not increase the risk of early implant failure when satisfactory primary stability was achieved.

INTRODUCTION

Improving patient experience with surgical interventions should be part of any plan to improve the overall quality of care [Fregene et al., 2017]. Many surgical interventions have been introduced in healthcare settings to improve patient safety, reduce morbidity and the incidence of adverse events including structural and process interventions, clinical safety measures, and team training [Howell et al., 2014]. Although dental implant treatment primarily aims to achieve effective osseointegration and successful prosthetic rehabilitation to restore function, aesthetics, and comfort throughout patient's life, the need to provide a better surgical experience for patients should also be considered. Reducing the burden of surgical harm is a highly desirable aspect of implant surgery which can result in reduced surgical burden, immediate post-operative symptoms, and patient discomfort during healing.

Implant placement surgery has been considered a less unpleasant experience than a tooth extraction, with less postsurgical pain and limitation of daily activities [Reissmann et al., 2015; AlQutub, 2021]. Pain reported by patients during and after implant surgery is usually mild and gradually decreases with time, but this may be influenced by factors such as operator experience, patients' gender, surgical difficulty, and pain levels experienced at immediately after surgery [Al-Khabbaz et al., 2007]. Whilst some specific factors can influence the pain intensity and discomfort level on an individual basis, in general more conservative interventions will reduce the risk of adverse effects and postoperative burden. More straightforward and conservative implant procedures may be preferable to patients than more extensive and invasive options, assuming that they are equally effective and carry comparable costs [Pommer et al., 2014]. Moreover, there is evidence that more conservative and less invasive surgical protocols result in favorable outcomes in several clinical presentations.

The loading of the implants in immediate or early periods may improve patient satisfaction and adherence to treatment. Particularly, the use of implants with reduced diameters have been recommended as viable and safe alternatives to standard-diameter implants aiming to avoid the burdens of bone augmentation procedures for atrophic ridges [Ma et al., 2019]. The use of reduced-diameter implants (or mini implants) for implant-retained overdentures has been demonstrated as suitable for insertion in narrow ridges, are less invasive, more straightforward, less costly, and require less surgical time compared to standard-diameter implants [de Souza et al., 2015]. This treatment protocol could be especially advantageous for older and frail patients who would benefit from more conservative and less burdensome treatments [Della Vechia et al., 2018].

Several clinical studies reported the successful use of mini implants for mandibular overdentures with data on implant survival, functional improvement, patient satisfaction, and positive quality of life impacts [Goiato et al., 2018]. However, there is still limited evidence on the comparative effectiveness of different treatment protocols using mini implants for overdenture applications. Therefore, this study aimed to test the effects of different surgical and loading

protocols on the short-term outcomes following the use of four mini implants for mandibular overdenture retention. Outcome assessment was focused on surgical burdens in addition to clinical and patient-centered measures of post-surgical outcomes. The study's hypotheses were that combined flapped surgery and delayed loading (control interventions) have higher surgical burdens and worse post-insertion outcomes compared to combined flapless and immediate loading (test interventions). The study also assessed differences in the combined use of flapped/flapless and delayed/immediate approaches on surgical outcomes.

MATERIALS AND METHODS

Study design and setting

This manuscript reports on the surgical outcomes of a randomized clinical trial which tested the effectiveness of a mandibular overdenture retained by four mini implants and a conventional maxillary complete denture in edentate patients. The study had a 2×2 factorial design combining two surgical approaches and two loading protocols. Therefore, we estimated the effect of each factor on the response variable and the effects of interactions between factors on the response variables [Montgomery et al., 2003]. The tested factors were the surgical approach – flapped surgery (FPS) or flapless surgery (FLS), and the loading protocol – immediate (IL) or delayed (DL), resulting in a factorial experiment with two main factors and four treatment combinations in total: IL/FLS (Group I); IL/FPS (Group II); DL/FLS (Group III); DL/FPS (Group IV). This report was produced according to the guidelines of the CONSORT 2010 statement for reporting randomized clinical [Schulz et al., 2010].

The study was conducted at the School of Dentistry, Federal University of Goias, Brazil. The research protocol was approved by the local Ethical Research Committee (CAAE: 24833219.4.0000.5083) and was registered at ClinicalTrial.gov before initiating patient recruitment (NCT04760457).

Population and sample

Study patients were recruited from an existing pool of edentate adults referred for complete denture treatment to the School of Dentistry of the Federal University of Goias, Brazil. The patients were not charged any treatment costs as part of this study.

The target population comprised edentulous patients wearing either clinically acceptable conventional complete dentures or requiring a new set of complete dentures. Eligible patients for the implant phase of the study were those patients with a minimum 3-month period of denture usage. They were initially evaluated

through a clinical assessment, panoramic radiograph (OPG), and cone-beam computed tomography (CBCT) exam. The inclusion criteria for the study were: (1) no contraindications for implant surgery (including uncontrolled systemic diseases); (2) sufficient bone height in the interforaminal area for an implant length of at least 10 mm; (3) and ridge width of 5.4 mm for implant insertion, as considered the minimum width to account for inaccuracy related to flapless procedures. All study patients were provided with a patient information sheet and provided written consent to take part in the study.

The exclusion criteria for the study included: individuals who disagreed with being randomly allocated to the treatment study groups, those with signs of untreated temporomandibular disorders or uncontrolled systemic or oral conditions requiring additional treatment, participants unable to understand and answer the questionnaires used in the study, and unable to attend the scheduled post-treatment appointments for longitudinal data collection. Excluded subjects were referred for appropriate care in other clinics of the School of Dentistry.

Implant treatment planning

The implant surgery planning was performed using CBCT images of the anterior mandible obtained with a limited Field of View (FOV) and standard protocols for minimizing radiation exposure. Two 2 mm gutta-percha points were inserted in the fitting surface of the mandibular denture at the canine position, bilaterally to serve as reference landmarks for the surgical planning. The mandibular denture was duplicated to be used as a surgical guide to assist in surgical placement of the implants [Oh & Saglik, 2008].

The surgical planning for the four mini implants was performed on the basis that the implants must be at least 7 mm anterior to the mental foramen bilaterally. The remaining anterior space should be distributed equally between implants, with a minimum 5 mm distance between implants. As a general rule, the four mini implants should be evenly distributed along the interforaminal region to reduce the cantilever and provide optimal load distribution. In anatomically non-optimal situations, the distal mini implants shall be placed starting 5mm anterior to the mental foramen.

For surgery planning, the tomographic sections were obtained in Dicom format and imported directly into the coDiagnostiX™ 10.5 software (Dental Wings GmbH). The gutta-percha landmarks were used as reference points to guide the position of the most distal implant in relation to the mental foramen, particularly for the flapless surgeries. In addition, surgical planning using the CoDiagnostiX software assisted the visualization of the optimal three dimensional position of the mini implants, and selection of implant length, according to bone volume and morphology. All surgeries were conducted free-hand.

Implant surgery

All implant surgeries were performed by the same surgeon (JLRL). Surgeries were carried out under local infiltrative anesthesia, and surgical access was performed according to the protocol of the randomized groups. The mini implants were inserted through the mucosal tissues without reflecting a flap for the flapless surgery. In contrast, a crestal incision was performed using a 15C disposable scalpel blade for the flapped surgery, followed by full elevation of a mucoperiosteal flap and closure using non resorbable sutures which were removed after seven days.

In cases with limited attached mucosa width, a careful incision using a buccally displaced flap was performed in the flapped groups, and a lingual displacement of the keratinized tissue was adopted in the flapless groups in order to obtain minimal width of attached mucosa in the lingual aspect of the mini implants.

The mini implant used in this study is shown in Figure 1. This was a one-piece mini implant (Straumann® Mini Implant System, Institut Straumann AG, Switzerland) with an amorphous diamond-like carbon (ADLC) coating for the prosthetic connection combined with titanium housings with female PEEK matrix inserts (Straumann® Optiloc® Retentive System, Institut Straumann AG, Switzerland). The mini implant has an apically tapered implant body design and was composed of a high strength titanium-zirconium alloy (Roxolid®) and a sandblasted, large grit, acid-etched implant surface (SLA®). The mini implants are available with length options of 10 mm, 12 mm, and 14 mm and were used in according with the patient's anatomical situation.

The two most distally-sited implants were prepared first, and then the other two anteriors were inserted toward the midline, using the surgical guide. Implant site preparation was performed using the needle drill (Institut Straumann AG, Switzerland), followed by the 2.2 mm BLT Pilot Drill (Institut Straumann AG, Switzerland). All implants were placed parallel with the help of paralleling posts (Institut Straumann AG, Switzerland). The paralleling post was also used to measure the gingival height when raising a tissue flap (flapped surgeries) or when performing the tissue punch in the flapless technique, by considering the 2.2 mm side of the paralleling post as a reference, which represented the gingiva height/machined part of the mini implant.

A minimum of 35 Ncm insertion torque was planned for all implants, regardless of implant loading protocol (immediate or delayed). Final implant positioning was achieved with a handpiece at a maximum speed of 15 rpm or manually. Delayed loading was performed in all cases when a patient randomized to the immediate loading group and any one of the mini implants did not achieve the minimum 35 Ncm torque (per-protocol analysis – or "as delivered").

For the delayed loading protocol group, a 6-week healing period was observed. The fitting surface of the mandibular denture was relieved to prevent any loading on the mini implant. Where required, a chairside soft reline was used during this healing period. However, the material was relieved to prevent any loading on the mini implants.

The existing mandibular denture was converted into an implant retained overdenture by following these steps: (1) placement of the white mounting collars on each Optiloc® (Institut Straumann AG, Switzerland) to block out the area surrounding the attachment; (2) placement of the matrix housing with the retention insert (yellow, medium) onto each abutment, leaving the white mounting collar beneath it; (3) preparation of the lower complete denture to create a minimum space of 1 mm around the housings to allow for sufficient thickness of the self-polymerizing resin (Duralay, Reliance Dental); (4) seating the denture in position to check if the denture base is seated passively in occlusion without touching the matrix housing; (5) incorporation of the matrix housings in the denture with self-curing PMMA resin. All prosthodontic procedures were performed by the same prosthodontist (CRL).

Outcomes

This study assessed direct measures of treatment outcomes which included both objectively and subjectively measured endpoints. Primary outcomes were selected according to the treatment stage: patient's perceived burdens related to surgery (immediate stage), post-surgical level of oral symptoms (7-day follow-up), and patient complaints and discomfort (6-week follow-up). Secondary outcomes included clinical time, the incidence of surgical complications, consumption of analgesics, implant survival and success, and the number of unscheduled visits during the follow-up period. The definition and methods for outcome assessment are described as follows, according to the treatment stage.

- Implant surgery

Surgical burdens

Treatment burden is defined as the workload and impact of treatment regimens on function and well-being [Demain et al., 2015]. The "Burdens in Oral Surgery Questionnaire – BiOS-Q" was used for the assessment of the surgical burdens since it is considered a reliable and valid tool for the evaluation of the patient-based process-related quality of care in oral surgery [Reissmann et al., 2013]. The questionnaire was translated and adapted into Brazilian Portuguese and the internal consistency of the instrument was measured after data collection.

The questionnaire consists of 16 items, including all aspects of the surgery, from the patient's perspective, focused on their perceptions of pain, burdens, and unpleasantness. Responses for each item are assessed using a visual analogue scale (VAS) ranging from 0 – no expression of the attribute (e.g. not unpleasant at all), to 100 – maximum expression (e.g. very unpleasant).

Based on the clinical aspects and internal consistency of the scale, the 16 items were combined into three different domains of clinical aspects of the surgery namely anesthesia (7 items), bone and soft tissue manipulation (5 items), and side effects (4 items) [Reissmann et al., 2013]. Summary data for all the BiOS-Q items and each specific domain were calculated for the four study groups.

Clinical time

The duration of the surgery appointment was measured (in minutes) with a digital chronometer, and the following time points were registered: from anesthesia until osteotomy, from osteotomy until implant insertion, and for prosthodontic procedures. The four study groups' overall clinical times for surgical and prosthodontic procedures were calculated, including the prosthodontic procedures for the immediate and delayed loading protocols.

Surgical complications

Any complications associated with the surgical and prosthetic procedures and the devices used were recorded in the patients' records and incidence rates calculated.

- Immediate 7-day follow-up

Oral symptoms

Patients recorded their symptoms using a seven-day daily diary from the day of the surgery until 7-day follow-up, which was returned in the 7-day recall visit. They rated their perception of the following items: 1) pain in the surgical area, (2) pain when chewing, (3) bleeding in the surgical area, (4) swelling, and (5) overall discomfort [Mundt et al., 2017; de Resende et al., 2021]. Responses were rated on a visual analogue scale (VAS) from 0 to 100 mm according to their individual perception, every day from 24h to 7 days after surgery.

Consumption of analgesics

Immediately after the surgery, a 750mg paracetamol tablet was administered to all participants. Then, they received a sheet containing several numbered individual paracetamol tablet capsules. They were informed to take one capsule for each 6-hour in the first two days, and continue analgesics at every 6 hours if the pain persisted. They also registered the day and time they took the medication. The sheet was returned in the 7-day follow-up visit, and the total number of tablets taken was registered.

Number of unscheduled visits

The frequency and reasons for post-surgery visits during the first week were recorded, when requested by the patient due to complaints including difficulties in using the overdenture, injury to the surgical area, or other issues.

- Healing stage outcomes (6-week follow-up)

Short-term implant survival and success

The condition of the implants was assessed at the 6-week follow-up for both immediate and delayed loaded groups and rated as success, satisfactory survival, compromised survival, or failure according to the ICOI Pisa Implant Quality of Health criteria [Misch et al., 2008]. During this period, as no implant-loading was performed in the delayed-loaded groups, the 6-week assessment aimed to differentiate the overall experience between groups as to how the immediate-loaded groups could feel and perceive the advantage of additional retention for the dentures provided by the implants.

Patient complaints

A specifically tailored questionnaire containing 7 items was administered at the 6-week follow-up to assess the levels of pain, discomfort, and prosthesis use experienced by the patient during the 6-week healing period after implant insertion. They were asked to rate the level of discomfort on a 0–100 continuous scale representing the best possible condition (score 0) and the worst possible condition (score 100). The specific aspects assessed were: (1) overall discomfort; (2) frequency of mandibular prosthesis use (reversed scores); (3) difficulty inserting and removing de mandibular prosthesis; (4) difficulty cleaning the region around the implants; (5) injuries due to the prosthesis use; (6) difficulty chewing; and (7) difficulty talking.

Number of unscheduled visits

The frequency and reasons for non-programmed visits during the healing period were recorded, when requested by the patient due to complaints related to the use of the mandibular prosthesis.

Sample size calculation

A sample size calculation was undertaken and based on a power estimation of the main effects and interactions in factorial ANOVA for the combinations of the experimental conditions, considering the treatment outcome “patient-perceived burdens in surgery” measured at the patient-level, and the following parameters: number of subgroups = 4; df = 3 (number of groups minus 1); the number of covariates = 2; power = 0.80; alpha (type I error rate) = 0.05; Effect size= 0.40 large (assuming a large difference between the presumable “worst” and “best”

protocols). This resulted in a minimum total sample of 73 participants. The G*Power Version 3.1.9.4 software was used for sample size calculation [Faul et al., 2009].

Randomization

A computer-based random number generator assigned participants to the treatment groups. To prevent an imbalance between groups, participants were stratified according to gender. Block randomization was used to randomly assign participants to sets of different sizes, although with multiples of the number of treatments taken into account (1:1:1:1 allocation ratio). The sequences were concealed in opaque, consecutively numbered envelopes for each block. Two separate envelopes were obtained for each participant, corresponding to the assignment of the surgery protocol (flapped vs. flapless) and loading protocol (immediate vs. delayed).

In addition, the allocation ratio in the following block was adjusted to minimize unbalanced treatment regimens delivered to prevent unequal group sizes due to deviation from the randomized protocol. Deviations from the randomized protocol occurred when a patient was randomized to the flapless group, and there was a need to raise a flap during the surgery, and when a patient was randomized to the immediate loading group and any of the mini implants did not achieve the minimum 35 Ncm torque, and the delayed loading was adopted.

To avoid selection bias and ensure adequate allocation concealment, the surgical protocol allocation was only disclosed immediately before local anesthesia. Similarly, the group assignment concerning the loading protocol was only revealed after the surgical procedures were complete. No blinding was adopted for participants, interventors, and outcome assessors, since the surgical and loading protocols differ markedly concerning the level of surgical invasiveness, active retention of the overdenture, and time points for data collection.

Data analysis

Descriptive statistics and bivariate tests for comparison of independent groups were used for initial analysis, according to the patterns of data distribution. Cronbach's Alpha was used to measure the internal consistency of the BIOS-Q instrument, considering that values above 0.70 indicate good reliability, and values between 0.60 – 0.70 indicate an acceptable level of reliability.

A Generalized Linear Model (GLM) regression was used to test the effect of independent variables (sex, age, study group, and other clinical features) on the post-surgical outcomes using the BIOS-Q instrument. Then, in order to take into account the correlation of within-subject data, the Generalized Estimating

Equations (GEE) regression was used to analyze the repeated-measured outcomes of the 7-day post-surgery diary in multiple regression models, considering the combined surgery/loading protocol groups and other independent variables. Odds-ratio (OR) and their 95% confidence intervals were used as the parameter estimates for the regression models. P-values lower than 0.05 were considered as statistically significant. The IBM-SPSS 24.0 software was used for all statistical analyses.

RESULTS

A total of 74 patients completed this study, thereof 48 (64.9%) were female, age range 34 - 79 years (mean = 64.1; SD = 8.0). The complete study flowchart is detailed in Figure 2. According to the randomized protocols, 36 and 38 participants were assigned to the flapped (48.6%) and flapless (51.4%) surgeries, respectively, and 36 and 38 to the delayed (48.6%) and immediate (51.4%) loading protocols, respectively. Figure 3 illustrates two cases of flapped and flapless surgeries and the clinical aspects observed on the day of the surgery, and in the 7-day and 6-week follow-ups.

Concerning deviations from the randomized protocols, there was a need to raise a flap in four cases (10.5%) assigned to the flapless surgery and delayed loading was performed in nine cases (23.7%) assigned to the immediate protocol, and adjustments in the allocation ratio of the following randomization blocks were performed to ensure balanced sample sizes across groups. Therefore, the final sample sizes were: IL/FLS = 17 (23.0%); IL/FPS = 18 (24.3%); DL/FLS = 20 (27.0%); DL/FPS = 19 (25.7%). The four groups were similar regarding gender ($p = 0.868$) and age ($p = 0.828$).

Implant surgery outcomes

The BIOS-Q instrument showed good reliability for all items ($\alpha = 0.86$), anesthesia ($\alpha = 0.81$), and bone/soft tissue manipulation ($\alpha = 0.76$), and acceptable reliability for side effects ($\alpha = 0.65$). Table 1 shows the summary data for the BIOS-Q scale and domains. Perceived burdens associated with surgery were relatively low – the overall median score was 15.1 (IQR = 26.1), and no difference was found between flapped and flapless surgery groups, as well as amongst the combined four study groups ($p > 0.05$). On the other hand, female patients reported higher surgical burdens concerning the overall scale ($p = 0.043$), and the bone/soft tissue manipulation domain ($p = 0.050$).

Table 1 also shows that surgery duration was significantly lower for flapless surgery ($p < 0.001$), with a mean difference of 40.5 (95% CI = 25 – 56) minutes. For immediately loaded cases, the duration of the pick-up procedure was also significantly lower for flapless surgeries (mean difference = 9.3 minutes; 95%CI

= 0.5 – 18; p = 0.039). Nevertheless, there was no effect of surgery duration on patient's perceived burdens concerning BIOS-Q scale and domains (p > 0.05).

Then, GLM regression tested the effect of clinical (surgery and loading protocols, and surgery duration) and demographic (gender and age) on the BIOS-Q measures. Only the effect of patient's gender remained significant, showing that female patients were more likely to perceive higher surgery burdens concerning the overall BIOS-Q scale (OR = 1.81; 95%CI = 1.08 – 3.03; p = 0.024), tissue manipulation (OR = 2.20; 95%CI = 1.20 – 4.05; p = 0.012), and side effects (OR = 2.01; 95%CI = 1.08 – 3.73; p = 0.027).

Finally, there were a small number of minor complications during the surgical procedures recorded for 22 patients (29.7%). The most common complication was the need to prepare more than one drilling bed for an implant during osteotomy in 18 patients (24.3%), due to poor primary implant stability, correction of implant angulation, need to improve implant distribution, fracture of the cortical bone walls during implant insertion, or a combination of these factors. Other relevant events were jaw dislocation (n=2), and episodes of hypotension (n=2). The incidence of multiple osteotomy site preparation was similar for flapped (29.7%) and flapless (18.9%) surgeries (p = 0.278).

Immediate 7-day follow-up

All participants completed the 7-day follow-up diary concerning oral symptoms. The changes in symptom levels throughout the first week, according to the study groups, are depicted in Figure 4. Overall symptoms were mild at the first day after surgery – mean (95%CI) overall scores were 3.3 (2.6 – 3.9) and 3.1 (2.5 – 3.8) for the flapped and flapless groups, respectively (p = 0.735). GEE crude regression estimates revealed higher overall symptom levels for female patients (OR = 2.0; 95%CI = 1.06 – 3.8; p = 0.032), and higher consumption of analgesics (OR = 1.08; 95%CI = 1.0 – 1.2; p = 0.042). Significantly less symptoms were recorded for the flapless surgery compared to the flapped for the delayed loading patients (OR = 0.41; 95%CI = 0.17 – 0.97; p = 0.044), as seen in Figure 4 (left). However, only the patient's gender was associated with the 7-day symptoms in the multivariate regression model (p = 0.014).

Figure 4 (right) also shows the changes in the specific symptoms alongside the first week. Based on a GEE regression model, the estimated marginal means (and their 95% confidence intervals) were calculated to account the effect of covariates (days after surgery). Mean values were 3.2 (2.6 – 3.7) for overall discomfort, 2.5 (2.0 – 3.0) for pain in the surgical area, 2.6 (2.1 – 3.2) for pain when chewing, which were the most relevant symptoms. Swelling [1.7 (1.4 – 2.1)] and bleeding [0.3 (0.15 – 0.5)] were significantly less common symptoms.

When each of the symptoms were modeled for the surgery and loading protocols in the regression analyses, the flapless surgery was associated with lower risk of bleeding (OR = 0.68; 95%CI = 0.49 – 0.93; p = 0.015). When the flapped/delayed group was considered as a reference, the flapped/immediate group showed lower risk of overall discomfort (OR = 0.22; 95%CI = 0.05 – 0.98; p =0.046), lower risk of pain when chewing (OR = 0.16; 95%CI = 0.04 – 0.66; p = 0.011), and less risk of bleeding in the flapless/delayed group (OR = 0.62; 95%CI = 0.40 – 0.98; p = 0.038).

The consumption of analgesics was similar across the four study groups (p = 0.617). No differences were found concerning the mean number of analgesics consumed by patients in the flapped (11.5 ± 4.7) and flapless (11.8 ± 3.1) groups (p = 0.713), and for the delayed (12.1 ± 4.0) and immediately loaded (11.2 ± 4.0) groups (p = 0.382).

The patients requested a small number of additional visits within the seven days after surgery. A total of four patients (5.4%) had one unscheduled visit before the 7-day follow-up due to difficulty using the lower denture and/or injury to the mucosa. Three out of the four cases were in the flapped and delayed loaded groups, however inter-group differences were not statistically significant.

Outcomes during the 6-week healing period

No early implant failure was observed until the 6-week follow-up and short-term survival rate was 100%. No signs of compromised survival were identified upon clinical and radiographic examination (periapical and panoramic exams).

Table 2 reports the levels of patient-reported complaints in the 6-week follow-up according to the combined surgery and loading protocol groups. Overall, there was a large variation in the levels of discomfort experienced by patients. The most relevant complaints were related to mucosal injuries, and difficulty of chewing, followed by overall oral discomfort. Significant group differences were observed for the frequency of denture use (p < 0.001), difficulty of chewing (p = 0.001), and difficult talking (p = 0.009). Patients who received delayed loading reported more discontinuous use of the mandibular prosthesis, irrespective of the surgery protocol. Similarly, patients who had delayed loading were more likely to report difficulty of chewing and talking when compared to immediately loaded patients (p < 0.05). Overall, lower complaint rates were observed for immediate loading patients regardless of the surgery protocol.

Concerning the occurrence of unscheduled visits between the 7-day and 6-week follow-up, there were a total of 20 visits by 16 (21.6%) patients – two patients had two visits, and one patient had three visits. No difference in the frequency of patients who required additional visits was observed between the study groups (p = 0.243). The reasons for those visits were for help to insert the overdenture

in the immediately loaded group (n = 3), relining with a soft material in the flapped/delayed group (n = 2), repair of a crack in the denture base (n = 1), and for adjustment/repair of the denture base (n = 18).

DISCUSSION

This study provides clinical evidence on short-term outcomes of treatment with a 4-mini implant mandibular overdenture for edentulous patients using a new 2.4mm one-piece titanium-zirconium mini implant with a miniaturized carbon-based coating attachment. Two surgical protocols (flapped and flapless) and two loading protocols (delayed and immediate) were tested, and findings revealed high early survival rates and low levels of post-surgical complications using all possible combinations of surgery and loading protocols. Moreover, findings suggest that a more conservative approach in surgical access (flapless) and the immediate adaptation of the overdenture is not inferior to the traditional delayed protocol and has the advantage of lower postoperative symptoms in the first week and less discomfort and functional impairment during the following healing period.

There is well-documented evidence on the use of narrow-diameter implants for load-bearing posterior regions and single-tooth non-load-bearing regions [Klein et al., 2014]. However, there is still a need for high-quality evidence from clinical studies about several aspects of using mini implants for overdenture applications [Bidra & Almas, 2013; Marcello-Machado et al., 2018]. Therefore, findings from this study support the successful use of mini implants for mandibular overdenture retention as reported in previous studies [Batisse et al., 2016; Batisse et al., 2017; Reissmann et al., 2018; Enkling et al., 2019; Enkling et al., 2020]. This study also confirmed the feasibility of the treatment protocol advocated by Kanazawa et al. who described the procedures for a flapless surgery with immediate loading of a 4-mini implant mandibular overdenture (Kanazawa et al., 2017).

Overall, the levels of perceived surgical burdens were mild, possibly due to the simplified procedures when using mini implants, even for open flap surgeries. Implant surgery has lower overall perceived burden during bone and soft tissue manipulation when compared to surgical tooth removal or apicectomy [Reissmann et al., 2015]. Furthermore, the placement of narrow-diameter implants is simpler and less invasive, and the entire procedure is also less time-consuming, which contributes to less discomfort during placement. Nevertheless, the burden of surgical pain and discomfort was substantially greater for female patients compared to males. There is support from the literature for gender differences in response to noxious stimuli, with females displaying greater sensitivity, and gender biases in pain treatment appear to exist, which are influenced by characteristics of both the patient and the provider [Bartley & Fillingim, 2013].

Short-term postoperative symptoms occurred within expected limits throughout the first week, with no major complications. There was also a low incidence of minor complications. However, although these events are usually transient and self-limiting, they are of major concern to many patients and often associated with non-adherence to implant treatment due to fear from surgery [Leles et al., 2011]. Negative post-surgical experiences also frequently leave patients with negative recollections of their recovery from surgery [Myles et al., 2000], and poor quality recovery frequently prolongs duration of suffering and functional limitation, both of which have significant implications for utilization of implants.

In this clinical scenario immediate loading appears to be comparable with the traditional delayed protocol. A randomized clinical trial comparing long-term outcomes of immediate and delayed loaded two-unsplinted implants for mandibular overdenture reported similar results concerning implant survival, radiographic bone level change, periimplant health, and prosthetic complications [Salman et al., 2019]. However, the procedure may result in additional costs due to the need for repeated relining, especially for flapped surgery patients [De Bruyn et al., 2014]. This study corroborates findings from previous studies about the feasibility of immediate loading of this mini implant system, which showed advantages when combined with the flapless surgery, resulting in lower postoperative symptoms and lower levels of pain and functional discomfort during the 6-week healing period. However, these better outcomes may be due to the advantage of experiencing the use of stable dentures during the 6-week healing period, which may account for more positive perceptions compared to the delayed-loaded groups. The immediate protocol also has the advantage of being less work-intense for relining and fewer visits for the patient during the healing period. Moreover, other factors such as the width of keratinized mucosa and anatomical features of the alveolar ridge may also have a relevant role on the health status of the supporting tissue around implants.

This study has strengths related to the focus on patient-centered outcomes and the study design. The treatment effects related to the surgical stage emphasized that the resulting benefits were detectable by the patients themselves in terms of perceived burdens associated with the surgical experience, the onset and persistence of symptoms, impacts on functional capacity, and the risk of complications and undesirable effects that affects comfort and well-being. In addition, the factorial design of the clinical trial allowed sufficient power to detect the effects of two distinct parameters that were tested simultaneously and their realistic interactions in the same population sample, thus creating a more efficient trial in terms of resources compared with separate trials for assessment of each parameter [Montgomery et al., 2003]. Such interactions between surgery and loading protocols may occur in a real-life scenario, since adopting a specific combined approach is part of the treatment decision process when choosing the best intervention protocol for the individual patient.

This study is limited to short term outcomes to provide evidence of the feasibility of different surgical and loading procedures. This is an important aspect of patient care but need to be considered with the context of achieving favorable results regarding patient oral comfort and function, and the need for implant/attachment systems with higher predictability on implant survival and retention performance in the long-term. Nevertheless, there is still limited information on the comparative effectiveness of different treatment approaches for using mini implants for edentulous patients, and this is a report limited to the short-term surgical outcomes of a novel mini implant system. Therefore, findings should be considered with caution. Future reports on this patient cohort with more extended follow-up periods and assessment of broader outcome sets are needed to confirm the effectiveness of these surgery and loading protocols.

Finally, although all the combined protocols resulted in favorable short-term outcomes, careful surgical planning may be essential for choosing the best alternative for the individual patient, considering specific clinical features and patient preferences.

CONCLUSIONS

Within the limits of this randomized clinical trial, the following conclusions can be drawn:

- Mini implants for retention of mandibular overdentures in the edentulous mandible are a feasible treatment option regardless of surgical access and loading protocol combinations.
- The mini implant system used in this study, using different combinations of surgical and loading protocols, resulted in low incidences of post-insertion complications.
- Flapless surgeries require less clinical time and result in easier intraoral prosthetic incorporation of attachments compared to flapped surgeries.
- Immediate loading did not increase the risk of early implant failure when satisfactory primary stability was achieved, and resulted in lesser symptoms, and better quality in patient-reported postoperative outcomes.
- Findings suggest that the combined flapless/immediate protocol is a feasible option for mandibular overdenture treatment with the mini implant system used in this study.

CONFLICT OF INTEREST

Cláudio Rodrigues Leles received a grant from the International Team for Implantology (ITI) to conduct this study (Grant 1447_2019) and received the mini implants, components, and instruments from Institut Straumann AG, Switzerland.

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FIGURE LEGENDS

Figure 1. Straumann® Optiloc® Retentive System. PEEK matrix inserts and titanium housing. The black abutment is coated by amorphous diamond-like carbon (ADLC). Straumann® Mini Implant made from the material Roxolid® with the SLA® surface, available in the endosteal diameter ø 2.4 mm, with length options of 10 mm, 12 mm and 14 mm.

Figure 2. Flowchart of the study.

Figure 3. Clinical and radiographic aspects of the surgery and follow-up visits using the flapped (A – F) and a flapless (G – L) approaches.

Figure 4. Changes in post-surgical symptoms based on the patient's diary recording from the day of the surgery until the 7-day follow-up. Left: changes in overall scores according to the four study groups. Right: Changes in the mean scores according to the recorded post-surgical symptoms.

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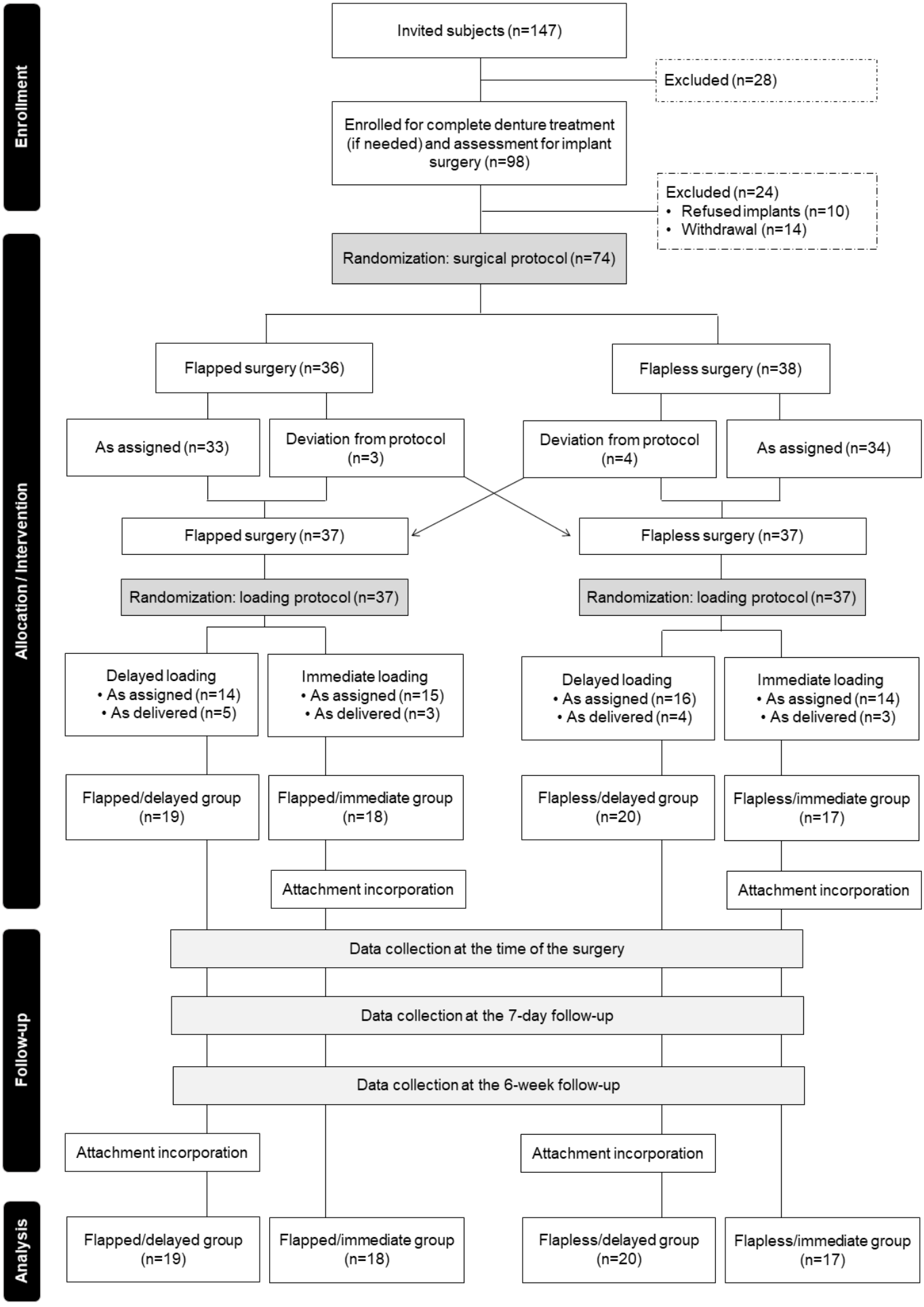

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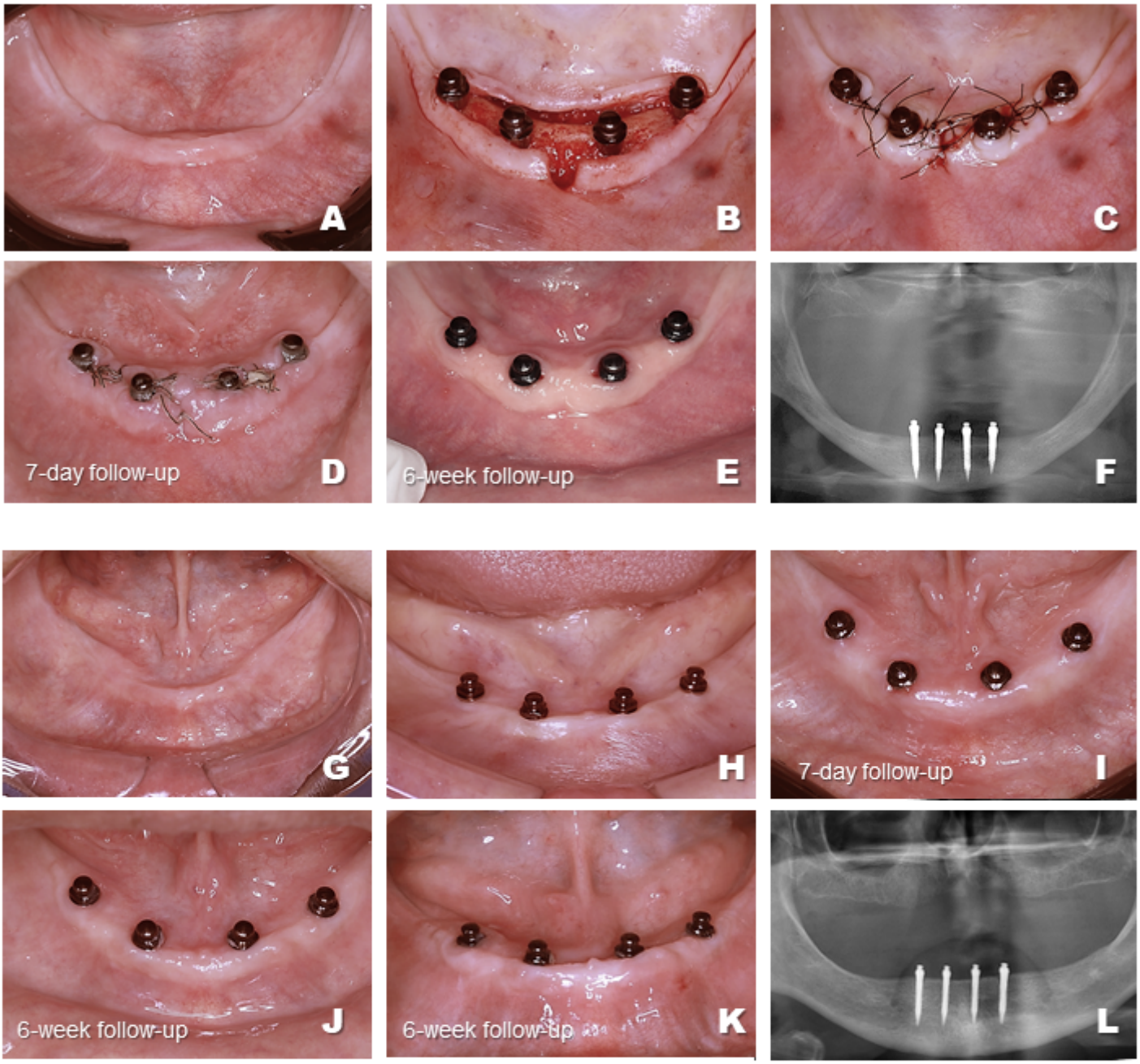

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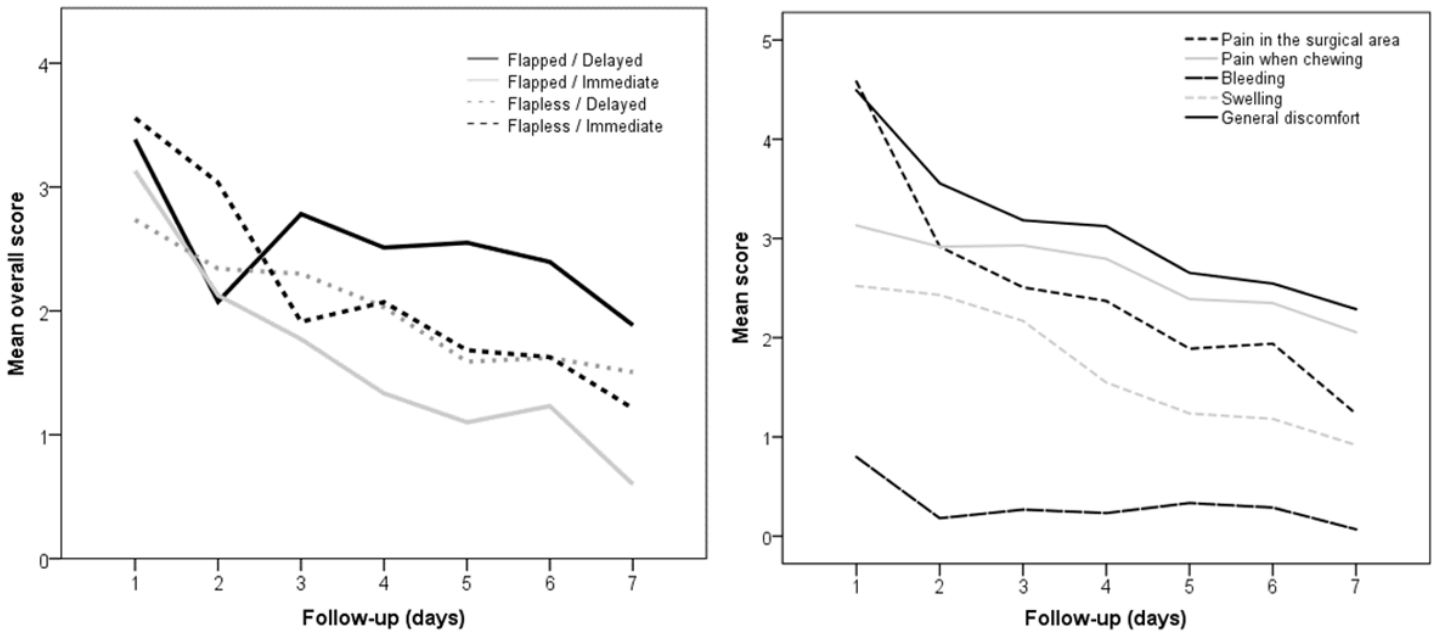

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Table 1. Summary data and between-group comparisons for the BIOS-Q scale and domain, and clinical time, according to the surgical protocols.

		Flapped (FPS)	Flapless (FLS)	All patients	p-value
BIOS-Q score – Median (IQR)	Overall scale	15.8 (28.2)	12.7 (25.6)	15.1 (26.1)	0.623*
	Anesthesia	19.9 (30.0)	17.1 (29.8)	17.4 (29.2)	0.800*
	Bone/soft tissue manipulation	10.8 (31.8)	8.9 (19.4)	9.8 (20.5)	0.374*
	Side effects	12.3 (29.4)	11.5 (28.6)	11.8 (27.7)	0.749*
Clinical time (minutes) – Mean (SD)	Surgery	112 (33)	71 (35)	91 (40)	<0.001**
	Prosthetics				
	Immediate loading (IL)	49 (13)	40 (12)	45 (13)	0.039**
	Delayed loading (DL)	47 (17)	46 (21)	47 (19)	0.929**

IQR – Interquartile range; SD – standard deviation

* Mann-Whitney test

** Independent t-test

Table 2. Levels of patient-reported complaints in the 6-week follow-up according to the combined surgery and loading protocol groups. Data are expressed as median (and interquartile range - IQR)

Combined surgery / loading protocols	Overall discomfort	Continuous use of the mandibular prosthesis	Difficulty inserting and removing	Mucosal injury due to prosthesis use	Difficult to chew	Difficult to talk
Flapped Delayed	45.0 (47.5)	87.0 (43.3)^{B}	5.5 (36.0)	39.0 (53.5)	58.0 (70.6)^{A}	41.5 (64.0)^{A}
Flapless Delayed	19.0 (49.0)	61.0 (94.0)^{B}	2.0 (8.0)	25.0 (39.0)	86.0 (77.0)^{A}	15.0 (51.0)^{A}
Flapped Immediate	9.0 (23.0)	99.0 (9.5)^{A}	42.5 (67.0)	21.5 (40.8)	5.0 (34.0)^{B}	2.5 (7.0)^{B}
Flapless Immediate	15.0 (55.0)	98.0 (5.5)^{A}	7.0 (42.0)	13.0 (40.5)	5.0 (32.0)^{B}	2.0 (5.0)^{B}
All patients	18.0 (48.0)	95.0 (33.3)	6.5 (41.5)	24.5 (42.5)	23.0 (81.0)	4.0 (30.0)
p-value*	0.144	<0.001	0.100	0.365	0.001	0.009

* Kruskal-Wallis test – Different letters indicate significant differences between groups.