Passive fit of CAD/CAM implant supported screw-retained metal frameworks based on actual versus screwmented ones based on virtual implant position: A randomized in vitro study

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Method Article

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Abstract

CAD/CAM (computer aided design/ computer aided manufacturing) constructed screw retained implant supported frameworks give solutions for the problems arising from the lost wax technique by improving accuracy, adaptation and passive fit of the final restoration. However, concerns about the passive fit of a pre-implant insertion CAD/CAM constructed framework still exists due to the expected errors in imaging, registration, surgical guide construction, adaptation and hence transferring the planned position intra-orally.

Introduction

II. Introduction:

The adoption of digital workflow in implant restorations gives fast, accurate and predictable results in both surgical and prosthetic phases. Nowadays, computer guided implant surgery has been introduced as an efficient alternative to conventional implant placement. CAD/CAM allows the integration of the 3D data gained from computerized tomography, optical scanning and implant planning software. These tools will determine the planned implant sites, path of insertion, allow for abutment customization, and enhance the possibility of obtaining passively fitting final implant prosthesis (Colombo et al., 2017)

However, computer guided implant placement protocol still has its limitations including CBCT and data acquisition, software planning, surgical guide design and fabrication, intraoral positioning and insertion of the guide. Starting from CBCT related factors which may be due to metallic artifacts, patient movement, Voxel size, quality of x ray machine. Also using of intra oral scanners to gain 3D models for data alignment may be complicated due to movements of objects, presence of saliva, occlusal registration challenges((Rutkunas et al., 2020)Improper implant planning due to inaccurate data acquisition will complicate the following steps of surgical guide designing and fabrication, while 3D printing technology accuracy will affect the final product of surgical guide. The 3D printed guide should fit its digital design, the mismatching manifestations will appear intraorally upon seating of surgical guide. Also, the additional cost and the time needed to produce devices by current 3D printing technology. Although the utilization of a digitally constructed template allows for predictable results because implant placement plans can be performed in the surgery, there is an error range which is larger in vertical implant position more than horizontal one. This happens during placement of the implant deeper or shallower than the planned implant position.

Surgical template support and stability is assumed to have an important effect on the accuracy of implant placement. In completely edentulous arches, surgical templates are totally tissue supported, while in
partially edentulous arches, stents may be totally tooth supported or partially supported by the soft tissues. When surgery is performed by using tooth supported surgical template, the superior suitability of stents can result in very accurate outcomes. (Moon et al., 2016) found that guided implant placement supported by adjacent teeth were more accurate than the ones without support at the most distal portion for distal extension cases due to the vertical movement of a stent distally. However, insertion problems because of the remaining teeth and tissue undercuts during the installation of the removable surgical guides can cause lack of conformity of the guide and postoperative errors. The factors involved in the positioning errors in computer-guided implant surgery include errors in data fusion due to limitations in CT resolution and metal scattering, lack of conformity of the guide due to teeth misalignment, difficulties in selecting anchor pin positions for stent fixation in edentulous patients, limitations in patient mouth opening, drop out of metal sleeves, and stent fractures. Limitations in mouth opening and inadequate inter arch space is a substantial condition that jeopardize proper seating of surgical template. In 2007, Hans Joachim et al reported that the utilization of surgical template is accurate but limited due to insufficient. intermaxillary distance in some cases.

When considering accurate implant placement and the patient costs and operators’ efforts in guide preparation, Other factors should be considered which cannot modified using computer guided stents. These factors include bone quality, time of surgery and type of the used implant. To conclude the difficulties of using computer guided surgery technique, the errors in computer-guided implant surgery are in the clinically acceptable range, however they can cause complications when there is vital anatomical landmark proximity such as maxillary sinus and inferior alveolar nerve. So for more accurate guided surgery, the abovementioned limitations of the guided surgery need to be precisely identified and avoided. (Moon et al., 2016)

(Bover-Ramos et al., 2018)" study analyzed 8 invtro studies, 4 cadaver studies and 22 clinical studies. The conclusion of this meta-analysis was that implant placement with fully guided technique showed greater accuracy than half guided technique. The coronal horizontal deviation was 1.00 mm for fully guided while half guided technique showed 1.4 mm deviation. Concerning apical horizontal deviation, the value was 1.9 and 1.2 for fully guided and half guided techniques respectively. Whilst, the angular deviation was 3.13 mm and 4.13 mm for fully guided and half guided implant placement techniques respectively.

The clinical trial of(Van Assche et al., 2010) suggested that flapless implant placement can be a useful procedure provided that accurate and reliable 3D CT-based image data and a dedicated implant planning software had been used. Performing flapless implant surgery protocol has a substantial influence on postoperative pain and discomfort. (Fortin et al., 2006) compared in his study compared the postoperative pain experienced following implant placement using a computer guided flapless surgical procedure and an
open-flap procedure. The results of this study showed a reduced postoperative pain, shortened duration and reduced need for pain killer intake related to the flapless group.

According (de Araújo et al., 2015), the passive fit of implant supported prosthetics is defined as a stress-free, simultaneous, circumferential contact at the implant-prosthesis interface before functional loading. Unlike the natural teeth which can move in their sockets about 100 microns, the implant has limited range of movement around 10 microns (Bisayan and Yunus, 2014) The challenge of achieving passive fit for screw retained multi-unit implant prosthesis is considered the main item in delivering durable and accurate prosthesis, in addition to maintaining successful osseointegration. The distortion equation includes the many clinical and laboratory procedures which include impression procedure, master cast fabrication, wax pattern fabrication, framework fabrication, definitive prosthesis fabrication and definitive prosthesis delivery. Passive fit can be achieved if the summation of this distortion equation was zero. To achieve passive fit or a strain-free superstructure, a framework should, theoretically, induce absolute zero strain on the supporting implant components and the surrounding bone in the absence of an applied external load. (Sahin and Çehreli, 2001) The only method for determining the actual amount of superstructure passivity in vivo is the analysis of the strains on each implant abutment and/or component of the prosthesis after cementation or screw-fixation.

According to (Buzayan and Yunus, 2014), any misfit of the framework of osseointegrated implants is considered as a source for internal stress in the prosthetic framework, the implants and its surrounding bone. (Kan et al., 1999) claimed that the difficulty the level of misfit, at which adverse effects appear, might be difficult to determine. This level is very complex and probably depends upon such factors as bone quality, length and diameter of implants, and implant surface characteristics. Secondly, it is hard to be measured clinically. (Sahin and Çehreli, 2001) However, there were some trials that quantified tolerable misfit. Branemark reported that the misfit should be not more than 10 microns, while Klinberg and Murray stated that 30 µm gap at the implant–abutment interface will be acceptable if it is not including more than 10 % of the circumference. (Buzayan and Yunus, 2014) Jemt stated that a misfit around 150 microns will be acceptable. (Jemt et al., 1996) In addition, Jemt stated that the clinician can gain other 150 microns when screwing extra one half turn only in the systems that have thread pitch of the abutment screw is 300 µm, such as Nobel Biocare prosthetic screw. It was finally claimed that absolute passive fit is not possible (Sahin and Çehreli, 2001)

(Buzayan and Yunus, 2014) stated that adaptational misfit of the implant supported superstructure have unfavorable results on both mechanical and biological aspects. (Manzella et al., 2013) stated that misfit between implants and frameworks should be carefully considered as the stress induced by misfit was comparable to that induced by occlusal stresses. Two terms should be understood to analyze the biological and mechanical consideration of prosthetic misfit. First term is called mechanical tolerance or
machining tolerance which defined as the difference in rest positions (horizontal shift) between the components when these components are held in place by their respective fastening screws. Kim et al found that the mechanical tolerance is $31.1 \pm 15.5 \, \mu m$ between the abutment and the impression coping and the value of $30.4 \pm 15.6 \, \mu m$ between the impression coping and the abutment replica. The combination of the two values will result in more than 61 microns of machining tolerance for single abutment. The another term is called biological tolerance which is according to (Buzayan and Yunus, 2014), the capability of the bone surrounding the implants to withstand and tolerate the stresses distributed along the implant-bone interface, without any further clinical complications. Michaels et al stated that there was no significant clinical, histomorphometric, or radiographic proof of implant- osseointegration failure, although bone remodeling happens. Jemt and Book could not find a relation between this misfit and the observed marginal bone loss around the implants, although the presence of three-dimensional distortions ranged between 91 and 111 µm. (Buzayan and Yunus, 2014)

Mechanical complications may include prosthetic screw loosening, fracture or locking in abutment screw. Insufficient passive fit results in vertical gap that affects the distance between implant prosthetic platform and prosthesis margin. (de Araújo et al., 2015) On the other hand, pain, marginal bone loss and even loss of osseointegration are considered common biological complications resulting from prosthetic misfit. The factors that contribute to prosthesis misfit include distortion of impressions, plaster models and metal castings. The complications were reported concerning the soft tissues. The risk of screw related complications was more significant based on two clinical studies. However, there is insufficient evidence that links between implant prosthetic misfit and clinical prognosis of the prosthesis (Katsoulis et al., 2017)

Plaque accumulation was not correlated to misfit values. Neither vertical (> 1 mm) nor horizontal marginal gaps ($\leq 275 \, \mu m$), nor static strains ($\leq 533 \, \mu m/m$) due to screw tightening were found to have a negative effect on initial osseointegration or peri-implant bone stability over time in humans (Katsoulis et al., 2017)

Many strategies are reported to achieve passive fit such as laser welding, electric discharge machining, intraoral luting and soldering (Wee, Aquilino and Schneider, 2014). One of the most recent approaches to improve passive fit is CAD/CAM technology. Published studies proved that the precision of fit of CNC-milled prosthesis is comparable to the conventional casted frameworks (Jemt et al., 2003). The combination of pre surgical virtual implant planning, computer guided implant placement and CAD/CAM technology for prosthesis fabrication have been introduced as a solution of immediate restoration. In the study of (de Araújo et al., 2015), the fit accuracy of 3-unit, screw-retained, fixed dental prostheses (FDPs) fabricated by CAD/CAM of zirconia, CAD/CAM of Co-Cr, and conventionally fabricated of Co-Cr alloy was analyzed. (de Araújo et al., 2015) reported that CAD/CAM fabricated frameworks showed better vertical misfit values than other conventional fabrication techniques. Furthermore, (Abduo, 2014) stated that frameworks fabricated by CAD/CAM technology showed higher passive fit values more than laser welded
and one-piece casting frameworks. According to Karl, the vertical fit of CAD/CAM frameworks ranged from 1 to 27µm. (de Araújo et al., 2015)

Randy et al reported greater improvement in cement retained rather than screw retained frameworks. (Buzayan and Yunus, 2014) Taylor et al said that the potential of fit passivity of cement retained prosthesis due to presence of die spacer which provides 40 µm cement space. However, (AL-Meraikhi et al., 2018) et al concluded that implant supported CAD/CAM fabricated screw retained frameworks showed clinically acceptable misfit values. Nonetheless, no absolute passive fit is achieved.

According to Hebel and Gajjar, cementing the framework onto the abutments give better marginal fit and passivity, as the cement will fill the gap and small misalignments between frameworks and abutments. (de Araújo et al., 2015) Nonetheless, screw retained frameworks showed easier retrievability, maintenance and can be used with questionable inter arch space.

Baig et al showed that the combination between the passivity of cemented prosthesis and retrievability of screw retained prosthesis can be achieved by intraoral luting technique. The proposed technique uses a custom cast frame cemented to with prefabricated milled abutments to create a retrievable metal-resin fixed complete denture. The technique reduces potential misfit in cases of long span implant supported fixed bridges in addition to the ability of retrieval and repair.

McCracken et al used a screw-retained framework with cemented denture to eliminate visible screw-access holes for aesthetic reasons and to ensure the simultaneous ease of retrievability of the prosthesis. (Baig and Gunaseelan, 2012) Baig has luted immediately loaded provisional full-arch restorations intraorally through a single step. While Rodrigues have luted immediately loaded provisional full-arch restorations intraorally through multiple steps. (Baig and Gunaseelan, 2012) The clear limitation of this technique is the gross mis-angulated implant positions. It can be countered with angled or cast abutments, to an extent. The technique also demands accurate transfer of abutments from the laboratory casts to the implants orally.

Although presence of all these merits of CAD/CAM technology in implant supported prosthesis, it still has initial high cost, needs both clinician and laboratory technician who master this technique to get accurate and predictable results.

The material of fabrication is assumed to have an effect on prosthesis fit. Karl and Taylor stated that titanium, Zirconia and chromium cobalt alloy CAD/CAM frameworks exhibit better fit than screw retained or cement retained cast gold frameworks. (Katsoulis et al., 2017) Karl et al showed the change in CAD/CAM material had a minimal effect on fit of the framework. However, it is found that screw retained zirconia frameworks showed better fit than titanium framework.
Passive fit of frameworks can be evaluated by different clinical methods including visual inspection, finger pressure, radiographic assessment, screw resistance test, single screw test and disclosing materials.

One screw test is done by tightening the most distal screw and loosening the other screws at least one and half turns and then the discrepancies observed at the other terminal screw. The idea of this technique is if no vertical gap on opposite side is created when single screw placed in a distal abutment, the framework is considered to have clinically acceptable fit. Whereas, screw resistance test is done by starting with the implant closest to the midline, the screws are tightened one by one until the initial resistance is met at one of the screws. If that screw needs more than extra half a turn to achieve the optimum screw seating, the framework is considered to be misfit.

Radiographic evaluation is done by using bite wing x-ray to evaluate full seating of the restoration (Abduo, 2014) Turkyilmaz showed that single screw test which is known as “Sheffield test”, in combination with radiographic assessment is a suitable maneuver to assess the passive in long span frameworks. (Turkyilmaz and J., 2011)

Multiple in vitro methods to assess framework fit can be utilized to compare the relative accuracy of various fabrication techniques and materials. Such methods include; photo elastic, strain gauge analysis, finite element analysis, microscopic, photogrammetric, and coordinate measuring machine. However, (Kan et al., 1999) concluded that no test is reliable to check passive fit alone, it is better to use combination of these tests to verify passive fit.

Hence, the aim of the study is to evaluate the passive fit of CAD/CAM screw retained frameworks that are constructed before and after implant placement.

Reagents

Equipment

Procedure

Resin model will be obtained from the patient. Primary impression using alginate impression material (Tropicalgin, Zhermack SpA – Badia Polesine (RO), Italy) will be used to obtain the diagnostic cast. A special tray is then fabricated and the secondary impression is made by using rubber base (medium consistency Elite HD+ Putty Soft Zhermack SpA –Badia Polesine (RO), Italy). impression material which will be poured twice to obtain 2 identical master casts, one for fabricating the denture and the other one for relating the scan appliance and later on the surgical template to the opposing dentition. This step is important to fabricate an interocclusal record that helps seating the scan appliance during imaging and the surgical guide during surgery. A facebow transfer and a centric relation record will be utilized to mount the
master casts on a semi adjustable articulator (Bioart). After trying the denture in the patient mouth, it will be processed in heat cured acrylic.

The denture will be then duplicated to fabricate the scan appliance. Then it will be modified to act an implant supported interim prosthesis.

The scan appliance is constructed through placing gutta percha in the six to eight widely separated points of the denture base. A triple scanning protocol will be followed. Three to four layers of wax is used to create a centric occlusion index at this stage to stabilize the appliance and opposing dentition during the CT scanning procedure (Planmeca, Helsiniki Finland). Besides, the cast with and without the seated scan appliance will be optically scanned using a bench top scanner (3Shape A/S, Holmens Kanal 7, 1060 Copenhagen K Denmark). Then, DICOM raw and the STL files will be imported into virtual planning software (Blue sky bio). After ensuring adequate bone height and width as dictated by the eligibility criteria, the optimum implant position will be determined and planned as such. The created virtual implant position will be utilized for designing the surgical guide, after which the guide will be printed using digital light processing (DLP).

Group I: Intervention group in which the edentulous area will be restored with 4 implants screwmented CAD/CAM frameworks constructed based on planned implant positions.

Group C: Control group: edentulous area will be restored with 4 implants conventional screw retained CAD/CAM frameworks constructed after implant placement

9. Intervention for each group

Surgical simulation:

Two mm twist drill, pilot drill and the final drill will be used for preparing the implant osteotomy according to manufacturing guidelines. The implants will be placed in the recipient site by means of a hand held driver. A torque driver set at 35 N cm will be used to evaluate primary stability of implant. The whole drilling will be carried out through the CAD/CAM guide.

For group I:

This group will be restored with implant supported screw-mented CAD/CAM frameworks using full digital workflow. All the procedures of prosthetic fabrication will be performed before surgical phase and will be done virtually. The STL files of the scanned model with the registered planned implant position in their relevant position on the cast will be exported to Exocad software (exocad GmbH) designing software), where the virtual design of the framework will be carried out based on the virtually placed implants. The virtual design will consist of metal frameworks to receive porcelain that will be build up in a conventional manner. STL file of the designed frameworks will be exported to 5 axis milling machine (CNC) (Roland, Roland DGA corporation Barranca Parkway, Irvine, California, USA) to convert the virtual design into milled cobalt chromium framework. The milled framework will be intraorally cemented using (RelyX U200 self-
etching resin cement) to the Ti bases which are attached to the implants using their abutment screws at 35 Ncm torque. Abutment screw channels will be packed with Teflon (plumbers ‘tape) to avoid cement from entering in it. The dental laboratory will deliver the fixed prosthesis with adequate cement space. Framework misfit will be managed by intraoral cutting and soldering using duralay resin. Laboratory welding will be carried out if needed and retried in model.

For group C:

Multi unit abutments will be screwed to the implants . scan bodies will be attached to the multi unit abutments . intraoral scanning (Medit I 500) will be done to scan the orientation and depth.

STL gained from intraoral scanning will be exported to Exocad. The framework will be designed and its height and contour will be adjusted.

The STL file will be exported for CAM: computer aided manufacturing for milling. Try in framework will be manufactured first to ensure that passive fit is achieved , then the final framework will be milled .Porcelain veneering will be then followed after ensuring a passive fit of the constructed prosthesis.

The optimized prosthesis would fit passively onto The final prosthesis will be then screwed to the multi unit abutments and tightened to 35 Ncm torque. Occlusal prematurity will be detected using articulator papers and grinded in centric, protrusive and lateral excursions. Finally, the screw-access channels will be filled with Teflon (plumber s’ tape) and sealed with composite resin (Cavex composite Cavex Holland BV RW Haarlem The Netherlands).

Troubleshooting

Time Taken

6 months

Anticipated Results

References


