A COMPARISON OF PASSIVE FIT BETWEEN CONVENTIONAL AND DIGITAL IMPRESSION TECHNIQUES FOR AN ALL-ON-6 MAXILLARY FRAMEWORK

(AN IN-VITRO STUDY)

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Aim: The aim of this study was to compare the passive fit of full arch superstructure using conventional impression versus digital impression using extraoral scanner.

Methodology: Six implants were installed in the epoxy edentulous cast using a trial denture base setup of teeth. All implants were installed using a dental surveyor to ensure parallelism of all 6 implants, installed in central, canine, and second premolar areas bilaterally. Two frameworks were fabricated; in group 1 casted conventional framework using a conventional open tray impression, while in group 2 milled framework was fabricated using a digital impression, and in each group, 5 frameworks were fabricated.

In Group 1: Five Splinted open tray conventional Impressions were carried out for all of the six installed implants; each impression was poured in a conventional manner to fabricate a master cast. This master cast was used for the fabrication of a casted superstructure framework.

In Group 2: Scan bodies were screwed to the installed implants, and five digital impressions using an extra-oral scanner will be carried out. The STL files of the five impressions were used to fabricate 5 milled frameworks using Exocad software.

The passive fit of all frameworks fabricated in the two groups was evaluated using the Sheffield test (one screw test) and was assessed as passive or non-passive, and gap distance was measured using a stereomicroscope when all implants screws were fully tightened, and when only the most distal implant was tightened.

Results: All frameworks were considered passive using the one-screw test. There was a statistical difference in mean gap value between milled and casted groups when all implants were fully tightened, while when only the most distant screw was tightened, casted frameworks showed less passive fit than the milled group. The casted frameworks show higher significant gap distance (61.74 microns) when all implants are fully tightened, and (146.30 microns) when only implant A is fully tightened. So, the milled group is more passive than the casted one.

Conclusions: When evaluating the passive fit of implant-supported full-arch maxillary framework fabricated using conventional and digital techniques, the milled group is more passive than the casted one when all implants are fully tightened and when implant (A) is fully tightened.

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Introduction:

Rehabilitation of the edentulous maxilla has been more challenging when compared to the mandible due to vertical and horizontal alveolar bone resorption and compromised bone quality, especially in the posterior region of the maxillary arch, where bone grafting is often indicated due to maxillary sinus pneumatization.

Although All-on-four concept for edentulous mandible reported high success rate, ***Browaeys et al. (2015)*** showed significantly lower implant success after 1 year in maxilla (56%) compared with the mandible (90%) when implants were immediately loaded with an All-on-4 full-arch screw-retained prosthetic bridge. Moreover, the oral hygiene of the hybrid all-on-four fixed restoration is challenging due to the presence of extensive prosthetic flanges which induce more plaque accumulation.

As an alternative to the conventional all-on-four implant concept, ***(Agliardi et al., 2014)*** reported that six implants could be considered a predictable and cost- and time-effective option for the immediate restoration of the edentulous maxilla, avoiding bone grafting procedures.

The accuracy of the impression is considered the main factor influencing the structures' fit, is affected by impression material, impression technique, implant angulation, and the number of implants. An optimal fit of the implant-fixed prosthesis is required for its long-term success. An accurate implant impression is an integral prerequisite for obtaining an accurate master cast which is the key for fabricating an accurately fitting prosthesis.

Splinting of the impression copings prior to impression-making produces a more accurate definitive cast than non-splinting for both partially and completely edentulous patients.

Moreover, it has been stated that there is no difference in accuracy between open-tray and closed-tray impressions for partially edentulous patients; however, open-tray impressions were found to be more accurate than closed-tray impressions for patients with complete edentulism.

The passive fit of implant-supported prostheses to the underlying structures is fundamental for the success and survival of the Osseo-integrated prosthesis. Any misfit of the framework to the Osseo-integrated implants, clinically detectable or not, is believed to induce internal stresses in the prosthesis' framework, the implants, and the bone surrounding the implant.

Any incorrect framework may lead to mechanical complications such as screw loosening or fracture and biological complications, which could compromise the bone-implant interface and the homogeneity of the occlusal load.

While the absolute passive fit of the restoration is virtually impossible, various measures have been introduced to enhance the fit of the prosthesis. Clinical and laboratory methods of passivity assessment have been published in the literature, but they all have their limitations.

Materials and methods:

Epoxy Resin Master Cast Fabrication:

A duplicate of a readymade maxillary edentulous model was fabricated. Silicon mold was fabricated and Epoxy resin material[1] was mixed following manufacturer's instructions and poured inside the silicon mold to fabricate the master cast. Epoxy resin master cast was left to dry for 24 hours.

This epoxy resin model was used to simulate a clinical condition.

Denture Fabrication:

An impression was made for the epoxy resin master cast using medium consistency addition silicone material[2] using a custom-made tray. A trial denture base with teeth setup following a conventional manner was fabricated on the epoxy model. Then a complete denture was fabricated following the conventional steps.

Set up of the teeth was used to fabricate a surgical stent to guide for implant installation at central incisor, canine and second premolar areas bilaterally.

Implant Installation:

Pilot drill was used to drill holes corresponding to the site of implant installation using the trial denture base, implant direct[3] drilling kit was used to drill holes were inside the epoxy resin model in the areas of central incisor, canine and second premolars bilaterally.

six dummy implants[3] were installed in the drilled osteotomies using the dental surveyor by connecting the implant driver to the dental surveyor hock and the implant were placed in the implant driver and using the surveyor's arm, all implants were installed in their prepared sites using soft mix of clear acrylic resin[4].

The six implants were installed parallel to each other, the cast was left until the complete setting of the soft acrylic resin.

Each implant was named starting from the right side A, B, C, D, E, and F.

In this study, using the same master cast, 2 groups of frameworks were fabricated following different impression techniques.

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[1] Egy king epoxy, Egypt

[2] Zhermack elite, Italy.

[3] Implant Direct, USA.

[4] Henry Schein, Spain.

Group 1: casted cobalt chromium frameworks using conventional open tray impression technique, Group 2: milled titanium frameworks using extra oral scanner and computer aided milling technology.

- Group 1: Casted Framework Fabrication:
  Six open tray impression transfers[5] having square geometry were attached to the six implants respectively. All torqued according to the manufacturer's instructions.

  All six implants were connected using dental floss multiple times around each open tray transfer and the subsequent one and were splinted together using flowable composite[6].

Stock plastic tray was checked for proper seating with no rocking. A hole was made corresponding to each implant and the open tray transfer was checked to be showing through the tray.

The impression was made using Poly vinyl siloxane putty and light consistencies[7] by one-step impression technique for the open tray impression. Material was left to set according to the manufacturer's instructions.

After setting of the material, Open tray transfers were unscrewed, and the impression was removed, and properly checked if there is any separation between the impression material and the tray, and also the impression material was checked to be covering all aspects of the cast, in addition to that, no movement of the open tray transfers inside the impression material was assured.

Implant analogues[8] were attached to the transfers and whole impression was poured immediately using dental plaster and left for complete setting.

Group 1 Casted Framework Fabrication:

Open tray transfers were unscrewed and non-hexed Ti-bases[9] were fastened to the analogues. Waxing up of the framework was done so that entire metal core is sculpted in wax at the precise shape and size to produce a pattern connecting all the implants forming a bar which was then invested and casted into cobalt chromium alloy[10].

The same steps were followed to fabricate 5 frameworks.

Group 2 Milled Framework Fabrication:

Six PEEK scan bodies[11] were attached to the six implants A, B, C, D, E and F respectively, on the same model.

An extra-oral scanner[12] and software was used to scan the full cast.

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[5] Implant Direct, USA.
[6] 3M, USA.
[7] Zhermack elite, Italy
[8] Implant Direct, USA
[9] Implant direct non-hexed Ti-bases, USA
[10] AE Alloys™, USA
[11] Direct PEEK scan bodies, USA.
[12] Medit T310 Extra-Oral Scanner

The scans were performed following the manufacturer's instruction for the scan strategy. The cast was placed on the movable part of extra oral scanner which corrects the scanning triangle and perform the accurate scanning. The scanning was repeated 5 times to generate 5 scans for the same master cast to generate STL files.

Framework Fabrication:

The STL files were exported from the scanner software, and using Exocad software, a standard bar was designed using bar module which allowed fast and accurate shaping of the bar, covering all implants and having cylindrical holes for the bar was designed to fit into non-hexed Ti-bases[13].

Same designing steps were followed to generate five frameworks using the milling machine[14].

The 5 designs were exported into CAM files and milled using 5 axis CAD/CAM milling machine[15].

Measuring Passive Fit:

The frameworks for both groups were checked individually for passivity using the single screw test following the technique recommended by ***Sahin et al. (2001)***.

The technique involved screwing the most distal abutment of the each framework and check for possible lifting of the framework on the other side of the framework (Implant A) which if present, indicated lack of passivity of this framework. In case the framework remained stable in place, the middle screw was then placed, and so forth of the rest of the screws. Then, the screw was placed at B then C and so on until reaching F.

After placing screws one by one to ensure that the framework was passively seated, a final 180^o turn was performed to reach a torque of 10 Ncm for complete screw seating. In case one of the screws required more than 180 ^{o} to provide seating of the screw, the framework was considered misfit ***(Tepedino et al., 2017)***.

Detection of any gap by a probe and appropriate lighting was performed.

The stereomicroscope[16] was used to detect the gap distance at the buccal aspect for all six implants, and the gap distance was measured to indicate the level of passivity under two conditions, first when all screws were fully tightened, and when only implant A (the most distal from the right side was fully tightened).

The measurements were done using a zoom stereomicroscope with 3.0-megapixel CCD cameras[17] at a 125x PC-monitor magnification. Calibrated image software[18] was used to

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[13] Implant direct Ti-bases, USAb

[14] Maxidon Dental Milling Machine, USA

[15] CORiTEC 150i PRO, Germany

[16] SMZ-1500 Nikon, Japan

[17] Moticam 2300 Motic, Japan

[18] Motic Images plus 2.0, lesica software, Japan

measure the vertical gap between the edge of the framework and the implant surface, A trained and blinded investigator analyzed all the images captured and was asked to record 3 measurements at the buccal surface of the framework corresponding to each implant for each of the frameworks of the two groups.

The mean gap values of each implant were measured, tabulated and statistically analyzed.

Statistical analysis and methods:

Statistical analysis was performed with SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016. All quantitative data were explored for normality by using Shapiro Wilk and Kolmogorov Normality test and presented as means and standard deviation (SD) values, and independent t-test was used to compare between both groups.

Results were presented as normality test, comparison between group I (casted group) and Group II (milled group) when all implants were fully tightened, and implant A was fully tightened.

Results:

The milled framework is more passive than the casted one due to less gap distance than the casted one.

Discussion:

This study was classified as an in-vitro study, which is considered the lowest reliable evidence despite the fact, in vitro studies are always required to test intervention groups before being carried out on patients.

In the current in vitro study, epoxy resin cast was used, to ensure the best dimensional accuracy, as ***Gujjarlapudi et al. (2012)*** in a comparative study, compared physical properties of epoxy resin, resin-modified gypsum and conventional type-IV gypsum material, it was concluded that Epoxy resin exhibited superiority in dimensional accuracy, surface detail reproduction and transverse strength and is nearest to the standards of accurate die material.

Most reports recommended 6 to 12 in the maxilla to support an implant supported prosthesis ***Jemt et al. (2006).*** While 4 to 8 implants were recommended in the mandible ***Balshi et al. (2015).*** Our present study was carried out using 6 implants following ***Agliardi et al. (2014)*** who reported that six implants could be considered as a predictable and cost- and time-effective option.

In the current study, a dental surveyor was used to install the implants in the epoxy resin cast to ensure their parallelism, since ***Pande et al. (2014)*** mentioned that the dental surveyor is an instrument used to ensure parallelism of two or more surfaces of the teeth or other parts of the cast of a dental arch.

Implants were placed parallel to each other following ***Lin et al. (2018)*** who conducted a systematic review that stated no differences in clinical performance between implants that are placed in an axial position relative to the residual alveolar ridge when compared with implants that are intentionally tilted toward the distal aspect of edentulous jaws.

Open tray impression technique was used in the current study as ***Saini et al. (2018)*** concluded that open tray impression is more accurate than closed tray impression in edentulous patients.

Square impression coping was used as mentioned by ***Vigolo et al. (2004)*** who evaluated the accuracy of multiple internal connection implants and concluded that an improvement in accuracy of the definitive cast was achieved with splinted square impression copings.

Poly vinyl siloxane material was used to record the open tray impression in the current study, following ***Kurella et al. (2020)*** who compared the accuracy and dimensional stability of High-rigid vinyl polysiloxane, polyvinyl siloxane, and polyether impression materials used in full arch implant-supported prosthesis either in splinted and non-splinted conditions, it was reported that polyether material showed less deviation from the reference model, followed by Poly Vinyl siloxane, and high rigid vinyl poly siloxane. Results proved that there was no statistically significant difference between them. All the three impression materials can be used for making full-arch implant-supported prostheses. In addition to that, Splinting resulted in more accurate results when compared to non-splinting.

These findings were assured by ***Alkhasi et al. (2015)*** who recommended that both closed tray and open tray techniques had acceptable results with the use of Polyvinyl siloxane, and ***Kaur et al. (2023)*** who pointed out that Poly vinyl siloxane was found equivalent in accuracy to rigid Poly ether for recording parallel or angulated implants.

Baig (2014) concluded in his systematic review that Poly Vinyl Siloxane and Poly Ether were the most accurate impression materials used for edentulous multiple-implant situations.

Splinted technique was followed in the present study, following ***Papasyyridakos et al. (2012)*** who compared between splinted and non-splinted technique in edentulous patients, and proved that the splinted technique generated more accurate master casts than the non-splinted technique for in edentulous jaws. These clinical implications demonstrate improved accuracy of splinted impression techniques compared with the non-splinted technique.

Flowable Composite resin material was used in splinting the impression copings following ***Kamrani et al. (2014)*** who compared the accuracy of impressions using 3 types of splinting materials: a pattern acrylic resin, an acrylic resin, and a dual-cured composite resin, their findings indicated that the composite resin demonstrated better accuracy than the other tested splinting materials.

Joseph et al. (2018) also evaluated positional accuracy in multiple implants using four different splinting materials in multiple implants, and reported that flowable composite as well as bite registration material can be recommended as a splinting material of choice for multiple implant cases.

Papsyrsidakos et al. (2016) compared the accuracy of digital and conventional implant impressions for edentulous patients and also compared between splinted and non-splinted conventional implant level impression technique showing that the splinted impression technique is more accurate.

Marques et al. (2021) in a Literature Review studying digital impressions recorded that the accuracy of digital impressions in implant dentistry depends on several aspects. The depth/angulation of the implant, the experience of the operator, the intra-oral scanner used, span of the scanned area and environmental conditions may influence the accuracy of digital impressions in implant dentistry. Also it was mentioned that scan body design and material, as well as scanning technique, have a major impact on the trueness and precision of digital impressions in implant dentistry.

Albanchez-González et al. (2022) identified certain factors that influence accuracy: the amount of visible scan body, distance and angulation between scan bodies, and operator experience.

In the following in vitro study, an extra-oral scanner (Medit T310) was used because intraoral scanners would result in progressive distortion that occurs when scanning large areas. Mainly intraoral scanners have a smaller measuring area, requiring the merging of more data set images, which results in a greater systematic error than extra oral scanners. For this reason, extra oral scanners may be preferred for more cases with large number of implants **(Güth et al., 2016).**

Different materials are used in scan body manufacturing, Currently, PEEK is the most popular material for commercially available scan bodies. As mentioned in a recent systematic review ***Mizumoto et al. (2018)***, the materials of a scan body could exert certain influence on scanning accuracy.

In the current vitro study, the scan body was made of peek material, small size and with extensional geometry following an in vitro study by ***Mizumoto et al. (2018)*** that indicated that the accuracy of digital impressions was affected by scan body geometry. It was proved that a shorter and simpler designed scan body might perform better in terms of scanning time and that scan bodies made of peek showed acceptable accuracy when compared to titanium scan bodies.

All screws were screwed according to the manufacturer’s instructions following ***Al Otaibi et al.(2014)*** who studied the effect of 2 torque values on the screw preload of implant supported prosthesis with passive fit or misfit, and he concluded that Increasing the torque value beyond the manufacturer's recommended amount and retorquing of the screws at 10 minutes after the initial torque did not necessarily lead to a significant increase in preload in full-arch implant-supported fixed prostheses, particularly under non-passively fitting frameworks.

Abduo et al. (2011) in a critical review assessing the fit of dental implant prosthesis mentioned that there are several methods for assessing passive fit of implant frameworks, clinical assessment methods including finger pressure, visual inspection, radiographs, tactile sensation, one screw test, screw resistance test and 3D photogrammetry.

It was reported that the Sheffield test or the one-screw test is an efficient test for clinical evaluation of framework fit. When one screw on the distal abutment is completely tightened without creating a gap between the other abutments and cylinders, the superstructure is said to have a clinically acceptable fit. This technique is especially effective for long-span frameworks, in which the vertical gap tends to be magnified at the opposite abutment. The vertical gap on the unscrewed abutments can be assessed with the aid of direct vision and an explorer ***(Abduo et al.,***

2011).

Although no single method has been universally accepted, limitations can be overcome by combining available fit-assessment methods. In the current study two methods were combined to assess the passive fit of the frameworks: one screw test (Sheffield test) and microscopy using stereomicroscope.

Discussion of the results:

One of the most crucial factors is achieving passive fit during prosthesis insertion. This is one of the key of success of dental implant-supported restorations, in addition to that passive fit reduces long term stresses subjected to the underlying implants and its superstructure ***(Jemt et al., 1996)***.

The misfit of implant supported restorations may lead to technical and biological complications. The most frequent technical complications was screw loosening and loss of retention of prosthetic components, while other complications also include chipping of the veneering ceramic and fractures of the framework. Biological complications such as mucositis or periimplantitis with crestal bone loss can be initiated by increased plaque accumulation and micro-movements at the implant-abutment connection; such complications can also be induced by the increased strains in surrounding tissues ***(Kan et al., 1999)***.

The achievement of absolute passive fit of a full arch implant-supported restoration is extremely difficult because of the presence of marginal discrepancies within the framework after various clinical and laboratory procedures ***(Paniz et al., 2013)***.

In the current study, the passive fit of two maxillary implant supported frameworks constructed using the conventional (Group 1) and the digital technique utilizing the milling technique (Group 2) was compared when all implants were fully tightened and when only one implant was tightened at one end (at implant A).

In Group 1 the framework was constructed using a conventional open tray impression and casting technique, a greater overall gap distance was present when compared to the Group 2 (milled group) when all of the six implants were fully tightened, the overall gap distance recorded for group 1 was 61.74±13.16 compared to 44.89±10.21 microns in group 2 which was not statistically significant (p=0.06). These values are considered to be clinically accepted. The literature reported that 10 to 150 µm are considered to be values for the acceptable vertical misfit. ***Brånemark et al. (1983)*** reported that 10 µm as the maximum marginal opening between prosthesis and abutments , and from 40 µm to 150 µm was considered to be an acceptable range ***(Jemt 1991; Yanase et al., 1994; Klineberg et al., 1985)***.

An explanation for the results of the present trial is that the conventional method will result in an accumulation of errors resulting from pouring of the impression, shrinkage of the stone, metal shrinkage, and casting errors, all these errors will eventually affect the passivity of the framework fabricated. This comes in agreement with ***Keith et al. (1999)***, ***Guichet et al. (2000)***

followed by, ***Takahashi et al. (2003)*** and ***Karl et al. (2004)*** who all reported that the conventional cast lost-wax technique, that is used to construct a casted full arch prosthesis will result in porosity, deformation, warpage which leads to loss of passivity. While on the other hand for the milled group a digital impression using an extra-oral scanner was used which eliminated the dimensional inaccuracies of any impression material and also the polymerization shrinkage resulting from pouring of the impression was avoided, in addition to all that the inaccuracies from the conventional steps of framework construction was eliminated due to the use of the milling CAD/CAM technology, in addition to that the milled framework will have a better fit and a larger number of contacts with the underlying implant than the cast framework ***(Fernández et al., 2014)*** which will result in a smaller gap distance for Group 2.

The achievement of passive fit for a full-arch implant-supported restoration, as a result of the many clinical and laboratory procedures involved, is extremely difficult to achieve, and marginal discrepancies will always be present ***(Michalakis et al., 2003; Carr et al,. 1993; Tan et al,. 1993)*** and this would explain that there was a statistically significant greater gap distance at implants A, B, C, and D in group 1 when all implants were fully tightened. While when only one implant at one end was tightened at implant A, there was a greater statistically significant gap distance at implants E, F and the overall gap distance for group 1.

Conclusion: From the results of the current study, we concluded that The digital impression technique utilizing the milling technology have resulted in smaller gap distance with better passive fit than the casted one. We concluded that absolute passive fit cannot be achieved regardless of the type of material and technique used.

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