TC
YEDITEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
MASTER'S PROGRAM IN PROSTHETIC DENTISTRY

EFFECT OF IMPLANT ANGULATIONSON THE ACCURACYOF MULTI-IMPLANTS IMPLANT LEVEL IMPRESSIONUSING DIFFERENT MATERIALS AND TECHNIQUES

MASTER THESIS

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ONAY

Bu tez Yeditepe Üniversitesi Lisansüstü Eğitim-Öğretim ve Sınav Yönetmeliğinin ilgili maddeleri uyarınca yukarıdaki jüri tarafından uygun görülmüş ve Enstitü Yönetim Kurulu'nun 23..02..2018..... tarih ve 2018/04-05....... sayılı kararı ile onaylanmıştır.

Prof. Dr. Bayram YILMAZ

Sağlık Bilimleri Enstitüsü Müdürü

DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

08.02.2018

Abdulmounem Algellay

DEDICATION

Above all, I thank Allah the Almighty for His endowments to me; one of which is paving my way to achieve such study. I dedicate my work to every single person who has helped me and supported me endlessly; as such, my dear family and sincere teachers. Moreover, I allot this work to everyone who has helped me in order to complete this project, at the top of the list is my supervisor.

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LIST OF SYMBOLS AND ABBREVIATIONS

°c	Centigrade/ unit of temprature on Celius scale
2D	Two dimension
3D	Three dimension
ANOVA	Analysis of variance
cm	Centimetre
min	Minute
mm	Millimetre
PEC	Indirect snap-on technique with polyether
PEO	Direct splinted technique with polyether
PVSC	Indirect snap-on technique with polyvinyl siloxane
PVSO	Direct splinted technique with polyvinyl siloxane
STL	Stereolithography
X-axis	The first axis in the three-dimensional Cartesian coordinates
Y-axis	The second axis in the three-dimensional Cartesian coordinates
Z-axis	The third axis in the three-dimensional Cartesian coordinates
µm	Micrometre

ABSTRACT

Algellay A. M. (2018). Effect of implant angulations on the accuracy of multi-implants implant level using different Materials and techniques. Yeditepe University, Institute of Health Science, Department of prosthodontics, MSc thesis, İstanbul.

This study aimed to evaluate the effect of implant angulation on the accuracy of multi implant impression using different material and techniques. A master model with four internal connection implants was prepared. With two implants placed anteriorly in canine region with 0°, and two implants placed posteriorly in the first molar region with 30°, which simulating the protocol of all on four. 40 impression were performed on the master model using two different techniques (direct splinted and indirect snap-on) and two different material (polyvinyl siloxane and polyether). Models where divided into four groups (n=10). Models where scanned with 3D shap scanner. STL file where anaylzed and measurements where performed using 3D design program (Rhinoceros 0.5), to measure the discrepancies between the master model and the produced model. analysis of variance (ANOVA) according to Kruskal–Wallis was used. The Mann–Whitney U-test was applied for paired group comparisons (*P*=0.05). The results revealed that a significant difference between the groups related to three-dimensional discrepancies (*P*=0.003), with higher discrepancy related to indirect snap-on technique with polyether (0.072 ±0.062) mm. The best results was with direct splinted technique with polyvinyl siloxane (0.032 ±0.020) mm and the indirect snap-on technique with polyvinyl siloxane showed a mean of 0.031(±0.042) mm. polyvinyl siloxane showed better accuracy than polyether where a significant differences in 3D and Z axis were found (*P*=0.002, *P*=0.000). we concluded that Implant angulation affected the impression accuracy, and a better result could be reached with polyvinyl siloxane material regardless of the technique.

Key words: angulated implant, impression accuracy, polyvinyl siloxane, polyether, indirect snap-on technique

ABSTRACT (Turkish)

Algellay A. M. (2018). İmplantaçılarının farklı materyal ve teknikler kullanarak çoklu implantlar implant seviyesinin ölçülerinin hassasiyetine etkisi. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Protetikdis tedavisi Bölümü, Yüksek Lisans Tezi, İstanbul.

Çalışmamızın amacı farklı implant açılarının farklı materyal ve teknikler kullanarak çoklu implant ölçülerinin hassasiyetine etkisini değerlendirmek. Ana modele yerleştirilmiş dört adet iç bağlantılı implant hazırlanmıştır. Ikiimplantanteriora, kaninbolgesine 0° ile yerlestirilmistir, iki implant da posteriora 30 ° all on fourprotokülüne göre yerleştirilmiştir. Ana modelin üzerinden 40 ölçü 2 farklı teknik(direkt splintili ve indirektgeçmeli) ve 2 farklı materyal (polivinilsiloksan ve polieter) kullanarak alındı. Modeller 4 farklı gruba bölünmüştür (n=10). Modeller 3D sharp tarayıcısı ile taranmıştır. STL dosyaları 3D tasarım programlarını kullanarak (Rhinoceros0.5) analiz edilmiştir ve ana model / üretilen model arasındaki tutarsızlıkları ölçmek içinKruskal-Wallis'e göre değişkenlerin analizi ANOVA kullanılmıştır. Eşleştirilmiş grup karşılaştırmaları için Mann-Whitney U-testi uygulanmıştır (P=0.05).Sonuçlar, gruplar arasındaki önemli ölçüdeki farklılıkların, üç boyutlu tutarsızlıklarla ilgili olduğunu ortaya koymuş (P=0.003), ve daha büyük bir tutarsızlığın ise polieterleindirekgeçmeli tekniğinden ötürü olduğu görülmüştür (0.072 ±0.062 mm). En iyi sonuç, polivinilsiloksan (0.032 ± 0.020) mm ile direkt splintli teknik ve polivinilsiloksan ile indirektgeçmeli tekniği ortalama (0.031 ± 0.042) mm olarak gözlemlenmiştir.Polivinilsiloksanın, 3D ve Z ekseninde anlamlı farklılıklar bulunan polieterden daha iyi doğruluk derecesine sahip olduğu gözlemlenmiştir (P=0.002, P=0.000). Implant açılarının ölçü model doğruluğunu etkilediği ve tekniğe bağlı olmadan polivinilsiloksan materyal ile daha iyi bir sonuca ulaşabileceği belirlenmiştir.

Anahtar kelimeler: açılı implant, ölçülerin hassasiyeti, polivinilsiloksan, polieter, indirektgeçmeli tekniği.

1.BACKGROUND and PURPOSE

Dental implants have become the treatment of choice in many situations where missing teeth require functional and esthetic replacements. Reproduction of the position and orientation of intraoral implants by means of an accurate impression in the definitive cast is the first step in achieving a passively fitting multi-implant supported prosthesis, to decrease the mechanical and biological complication of the prosthesis.

The accuracy of multi-implant impression have been reported to be affected by many factors like; the impression technique, impression material, implant number, implant angulation, level of impression, type of connection, stone model pouring procedure, machine tolerance of implant component.

While most of the performed in vitro studies investigated how to increase the impression accuracy in ideal situations, with straight implants, whereas fewer investigations evaluated the effect of angulated implants on the final precision of the impression, this study will focus on assessing the impression accuracy in the presence of angulated implant

The subject of the thesis will be the effect of implant angulation on the accuracy of implant impression with different technique and impression material. Where the purpose of our study is to investigate impression accuracy of mutli-implant impression in case of four internal connection implants placed simulating the clinical situation of all on four protocol. With two posterior implants positioned with 30° angulation, and two anterior parallel straight implants. Using two different technqiue (direct splinted and indirect snap-on technqiue) and two material (polyvinyl siloxane and polyether). To evalute the effect of the three factor: implant angulation, technique and impression material type on the outcome accuray of the impression.The results of this study will help to decide which technique is more favourable in case of angulated implants in the clinic, as well to show the degree of implant angulation effect on the production of accurate position of the implants on the definitive cast, which in order will help to improve the outcome in the clinical cases in term of passive fit prosthesis and long term successful prognosis.

2-INTRODUCTION

2.1. General Information

Oral rehabilitation of partially and completely edentulous patients with dental implants nowadays is routine treatment modality and clinical studies have reported the longitudinal success of this treatment modality. Osseointegrated implants have provided alternative treatments to conventional prostheses and achieved predictable long-term successful results. Longitudinal studies showed an implant success rate of 96-99% in the mandible and 80- 90% in the maxilla, for a period up to 15 years. Optimization of this success is directly related to the fabrication of passively fitting implant superstructures (1).

2.1.1. Edentulous

Demographic changes in the population around the world in the recent years showed an increase in life expectancy and the number of old age population. A previous survey in the united stated showed that in patients aged 45-54, around 31.3% have mandibular free-end edentulism, and 13.6% have free-end edentulism in the maxillary arch(2).While a survey was done in Australia between 2004 and 2006 reported that the percentage of edentulous people aged 65-74 years was 20% (3).A cross-sectional survey in turkey reported that 48.0% of elderly aged 65 - 74 years were edentate, while just 12.4% of the population had functional dentition(4).In the united states of America, the percentage of completely edentulous patients is about 10% of the total population and is expected to increase in the following years as the life expectancy also increases.with that in mind, it becomes clear that the need for prosthodontic treatment including dental implants for partially and completely edentulous patients will increase.

2.1.2. Osseointegration

Osseointegration is defined as “the apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening connective tissue”(5).Branemark developed the initial concept of osseointegration and observed under a light microscope, the inseparable connection between the titanium chambers and surrounding bone tissue that had incorporated itself into the thin spaces within the titanium.

This concept was then applied to dentistry and was used to restore a range of cases from single tooth sites to fully edentulous arches. Various studies have reported the survival rates of implants to range from 87.89% to 100% during follow-up periods of 5 to 29 years. These values along with the average prosthesis survival rate of 86% to 100% during the same time period, make implants a viable option for replacing the missing dentition(6). In order to preserve the connection between the implant and surrounding bone, it is important to have proper stress distribution as any uncontrolled load transferred to the implant fixtures can lead to a marginal bone loss. It is also vital that there is a direct connection between the implant and bone, without any intervening fibrotic layer that can cause micromotion and disrupt the contact. Additionally, shock-absorbing materials such as acrylic resin have been recommended to provide shock protection to the implants(7).

Loss of osseointegration is a major concern when planning and restoring implants. According to Branemark, osseointegrated implants can be lost through three possible mechanisms: soft tissue encapsulation of the implant during initial healing, repeated overloading of the implant, a gradual apical migration of the marginal bone level. To avoid these complications, it is important to have an atraumatic surgical technique to avoid overheating or traumatizing the hard and soft tissue as well as thorough assessment and adjustment of the restoration's occlusion(8).

Where the implants are ankylosed to the bone and no periodontal ligament are found between the implant and bone interface, leading to implants lack of mobility. Hence, they cannot accommodate distortions or misfit at the implant-abutment interface(7). Although absolute passive fit of implant fixed complete dental prostheses is not yet attainable, it is still unclear what degree of prosthesis misfit will lead to biologic or technical complications (9). Screw loosening and/or fracture, implant fractures and prosthetic components strain and fracture have been related to prosthesis misfit.

The clinical fit of an implant prosthesis at the implant-abutment junction is directly dependent on the accuracy of impression technique and cast fabrication. Hence, an accurate implant impression is mandatory, to provide an accurate definitive cast, which is the milestone in the fabrication of an accurately fitting prosthesis. The advancement incomputer-assisted design/computer-assisted manufacturing technology increased the precision of fit of implant prostheses through improving the framework fabrication procedures accuracy.

The accuracy of implant impressions plays a significant role and serve as a starting point in the process of producing good working casts (10). Several factors influence the accuracy of a final cast for the fabrication of an implant prosthesis, such as, the impression technique used, the implant connection type, splinting or surface treatment of impression copings, the type of impression material used, the impression type, implant angulations and number, the depth of implant position, the dimensional stability of the gypsum used to fabricate the cast, the die system used and the length of the impression copings(11–16).

Nowadays we consider that the clinical fit of an implant prosthesis at the implant-abutment junction is directly dependent on the accuracy of impression technique (17), and the fabrication of a precise definitive cast that exactly transfers its intraoral position for the long-term stability of the implant prosthesis (11).

2.1.3. Passive fit

In order to have the best chance of long-term osseointegration, it is vital to achieving apassive fit between the prosthesis framework and the supporting implants. The passive fit is considered a prerequisite to maintaining the bone-implant interface as the prosthesis framework should produce no strain on the supporting implant components and the surrounding hard tissue when external forces are absent. Jemt further described the passive fit as a level of adaptation that will not cause any long-term clinical complications(7).The passive fit of an implant prosthesis is considered a significant factor in its long-term success(18). The contact of all fitting surfaces is thought to minimize the uncontrolled stresses and strains within the implant components, the prosthesis and surrounding bone in the absence of an applied external load (19). Furthermore, because of the precise fit of implant components and the rigid connection of the implant to the bone, small discrepancies can lead to stress applied to the implants when the framework is screwed (20). Several investigators have described the effect of accurately fitted complete-arch fixed implant prosthesis on long-term success.Misfit increases the risk of biological and mechanical failures such as occlusal discrepancies screw or abutment loosening, fracture of the prosthetic components, implant fractures and loss of osteointegration(9,11).

2.1.3.1 acceptable level of fit for implant prosthesis

Several authors have published on the acceptable level of fit for implant prostheses, with a range of values reported including 0.010mm,0.100mm, and 0.150 mmaccording to Branemark, Ma, and Jemt respectively(7,21,22). Most of the reported acceptable levels of fit have been found to be hypothetical and empirical in origin.

In a previous studies it has been stated that absolute passive fit is not achievable due to possible errors during the prosthesis fabrication(23,24). Wee reported on the clinical and laboratory factors that affect the accuracy and distortion of implant prostheses. He reported a “distortion equation” includes multiple components that may be clinically insignificant on their own but when accumulated, can result in the final distortion of the prosthesis. Errors can be introduced since the impression-making procedure depends on the impression technique or material, mandibular flexure, and the machining tolerance between the impression copings and the abutment or implant platforms. Additional errors can be made during master cast fabrication and the machining tolerance between the impression copings and the abutment or implant replicas. Conventional framework fabrication could also add more discrepanciesto the equation(24).

In order to minimize the effects of distortion, multiple authors have suggested different techniques to verify and maintain accuracy. Fabrication of a verification jig to confirm the accuracy of the master cast relative to the patient’s mouth has been recommended in the literature as a step that should be done prior to fabricating the metal framework. The impression copings should be verified with the analogs and the abutments prior to the appointment to ensure a good fit between the components. While the absolute passive fit is reported to be unachievable. Although there are no quantitative guidelines for evaluating misfit, it would be viable for the clinician to evaluate the implant framework fit using a variety of accepted clinical techniques. Acceptable fit could be considered as relative judgments, made during the clinical procedure by the dentist. until Future investigation decide the ranges of fit that do not affect the long-term success of Implant supported prostheses(25).

2.1.3.2. Complications of misfit

Misalignment of prostheses to the implants will result in internal stresses being formedwithin the prosthesis, implants, and surrounding bone. These stresses although not visually detectable, can lead to loss of osseointegration of the implant. Furthermore, if mutual congruency of the implant and prosthesis is not possible, a high amount of stress concentration can occur at the implants, particularly if the framework is forcibly tightened. The accumulation of stress can lead to microfractures within the bone with a possible shift towards marginal bone loss or it can lead to fracture of the implant itself(26).

2.2. Factors Influence The Accuracy Of Implant Impressions

2.2.1. Impression technique

Different ways have been used to produce the best impression for multi-implant cases, still the best technique is not clear yet, but the technique which will be considered the best for each case would be the one could be done in shortest time, in the easiest way, providing less discomfort for the patient and the most important to provide the highest accuracy could be done(20).Nowadays there are three techniques for implant impression:

- Direct impressiontechnique (open tray or pick up impression technique).
- Indirect impression technique(close tray or transfer impression technique).
- Digital impression technique.

2.2.1.1. Direct impression technique

In direct impression technique the implant coping is attached onto the implant and tighten with screw which is longer than the coping in order to make it able to show through the tray when seating the tray during the impression, after the set of the impression material the screw is loosed in order to be able to pick up the coping within the impression material. The implant analog then attached to the impression coping using the same screw. Then the impression is ready to be poured (1,16,27–29).

The direct impression technique allows the pick up of the impression coping within the impression material which to avoid the placement of the coping back into its space within the impression material, which might lead to misfit and increase the margin of error (27). On the other hand, the replacement of implant analog on the impression coping while it's in the impression material might lead to rotational stress which could lead to a real mistake and permanent deformation in the impression (30).

2.2.1.1.A. Splinting vs. Non-splinting

With direct impression technique, many authors had advised splinting the impression coping together before making the impression. In order to increase the accuracy and avoid the distortion, particularly while fastening the implant analogs to its related coping. Which have been reported to might lead to rotational distortion(31,32).Many materialshave been used as splinting material like light-curing composite resin, impression plaster, orthodontic wire, acrylic resin and auto polymerizing acrylic resin(20,33). The most commonly used material as splint is auto polymerizing acrylic resin.The dimensional shrinkage of resin is one of the main drawback points which need to be considered. Mojon et al. investigated the shrinkage behavior of acrylic resin, and reported that total shrinkage about 6.5% - 7.9% and around 80% of the total shrinkage occurs within the first 17 min(34). Some authors had stated that such shrinkage might lead to distortion of the impression coping position within the impression material (35). Splint material should be of the samethickness, otherwise it might show different shrinkage behavior and even lead to less accurate results(18).

Martinez et al. compared direct technique without splint, and direct technique with two splint material, sectioned acrylic resin splint and customized metal bar with plaster. The result of this study showed that splinted technique provided better accuracy(32).Papaspyridakos et al. made a clinical study to investigate this effect in the clinic, 13 edentulous arches were included where both splinted and the non-splinted direct impression was applied for each arch. The results showed significantly better results with splinted technique(9). Stimmelmayr et al. reported same results with mean discrepancies from the original model to the stone casts were 0.124 (±0.034)mm for the indirect technique, 0.116 (±0.046)mm for the direct technique, and 0.080 (±0.025)mm for the direct splinted technique(36).

In systemic review which reviewed 22 studies related to this factor, concluded that the splinted impression technique was more accurate than the non-splinted conventional impression techniques for both partially and completely edentulous patients(17).

2.2.1.2. Indirect impression technique

The Indirect impression technique or the close tray technique uses a taper-shaped coping which tightened on the implant for impression. After the set of impression material this coping stay attached to the implant after removing the impression from the mouth, then the coping is detached from the implant and connected to the implant analog. Then the whole assembly is replaced into indentation left on the set impression which was created by the impression coping during taking the impression, care should be taken to replace the coping exactly with its position(37,38).

There are clinical situations which force the clinician to use the indirect technique like in case of limited mouth opening, too posterior position of implants which make it difficult to manipulate with long copings of direct technique and in patients with an exaggerated gag reflex, when the impression has to be removed as quickly as possible(1,32). The main advantage of the indirect technique is its simplicity, where it is easier to apply in the clinic and even no need for using the custom tray. Because of using stock tray the thickness of impression materials around the coping is more, that lead to more support and more stable impression(29,32,39,40).

2.2.1.2.A.Indirectsnap-on impression technique

In this technique, a plastic cap is attached on the top of the impression coping. While making the impression on the top of the transfer coping, the plastic cap remain inside the impression material, that makes snap-on technique similar to the direct technique in this aspect. This technique could be applied to abutment or implant level impression(32,39,40).The main advantage of this technique that it provides the simplicity of the indirect technique, and at the same time provide comparable accuracy to the direct technique(13).Lorenzoni et al. stated that the use of transfer cap with the indirect technique provides a higher accuracy for the impression. They reported that discrepancies in x-axis without the application of transfer cap was 3·4 (±0·7)mm as compared with the application of transfer cap 0·2 (±0·04)mm. Discrepancies in Z-axis without transfer cap were 0·28 (±0·03)mm, while with transfer cap 0·17 (±0·02)mm were found(41). Shim et al investigated indirect snap-on technique, concluded that indirect snap-on impression technique have the convenience of use because of the closed tray technique that is used, and their reproducibility is similar to that of direct impression technique (13).

2.2.1.3. Digital implant impression

Nowadays digital dental technology is increasing popularity for application in the different branches of dentistry and especially in implant dentistry. As a part of that trend, digital impressions have been one of the main significant factors in that change. However, the increasing popularity of these systems may have many dentists and laboratory technicians confused about their accuracy and reliability. It provides a cutting-edge technology that creates a virtual, computer-generated replica of the soft and hard tissues in the patient mouth using lasers and other optical scanning devices (42,43).

Since their first introduction back in 2007, many digital impression scanners have emerged in the market. There is two techniques of digital impression nowadays available for dental professionals to use (44,45). One type takes the images as digital photographs (Tero™, Lava™ C.O.S. And CEREC® Bluecam) that the software ‘stitches’ together, providing dental professionalswith a series of images; the second type takes images as digital video (3shape TRIOS®, 3M True Definition™ Scanner, CEREC® Omnicam And E4D NEVO™ Scanner).

Digital impression systems represent a viable alternative and provide many benefits and advantages for the dentist. This technology removes the need for the conventional impression materials, which definitely a source of discomfort for some patients, also could be done in a real short time compared to the conventional impression techniques. Another main attraction point for this method is that the ability to evaluate the digital impression easily and even modify it directly before sending to the technician, avoiding the need to repeat the impressions which is one of the main problem related to conventional techniques(46).

Regarding digital impressions for implant-supported prostheses, currently, there are a few studies investigated the accuracy and reliability of digital impression. Anderiessen el al. designed a clinical study to evaluate the applicability and accuracy of intraoral scans by using abutments designed for scanning in edentulous mandibles. Twenty five patient with previously fabricated bar overdenture prosthesis on the mandible supported by two implants, were included in the study and intraoral scanning was performed for the two implants after detaching the prosthesis, the old master models which have been used before to fabricate the patient's prosthesis were used as a reference model for the measurement. The result showed that Five of the 21 suitable scans demonstrated an inter-implant distance error > 0.100 mm. Three of the 25 intraoral scans showed interimplant angulations errors >0.4 degrees. Concluding that the error was too high and an acceptance to produce a well-fitting prosthesis(43). In coinciding with that result another in vitro study reported that the mean discrepancy related to digital impression was 0.064 mm compared to 0.022 mm in case of the conventional direct impression technique, and concluded that there was a significant difference between that two techniques (47).

In contrary, Moreno et al. reported a case in which a digital impression was used to fabricate the complete arch hybrid prosthesis over six implants, an acceptable prosthesis fit was reported(45). In conclusion, digital implant impressions are gaining increasing popularity, however, further investigations are needed to evaluate the clinical accuracy of digital versus conventional implant impression techniques.

2.2.1.5. ComparisonBetween Different Techniques

Many studies had been designed to compare the accuracy of different techniques particularly between direct and indirect technique, according to the evidence available 34 studies were done.Where 18 studies advocated the direct open tray technique (20,27,32,39,48–59). On the other hand, 12 studies concluded that there was no difference in the accuracy of both techniques(60). While just two studies reported better results with indirect close tray technique(24). Furthermore,Papaspyridakos stated the same result in his systemic review; that the direct impression technique was more accurate than the indirect impression technique particularly for full edentulous cases.

2.2.2. Impression material

A number of ideal properties for impression materials can be identified. These include accuracy, elastic recovery, dimensional stability, flow, Flexibility, workability, hydrophilicity, a long shelf-life, patient comfort, and economics(20,24).Impression materials vary considerably in relation to these Ideal properties, and these differences may provide a basis for the selection of specific materials in specific clinical situations. Some impression materials properties, such as rigidity and dimensional stability, can affect the accuracy of the implant impression. When the pick up implant impression technique is applied, the impression material should be rigid adequately to hold the copings tightly and to avoid accidental distortion when the implant analogous are connected, in order to have minimal positional distortion between the implant replicas when compared with its intraoral position(60).

Although no impression material has recognized to provide perfect accuracy, four type of elastomeric materials had been used polysulfide, condensation silicone, addition silicone (polyvinyl siloxane), and polyether. From point view of dimensional stability, the greatest dimensional discrepancy was observed with condensation silicones, with more than 0.5% discrepancy.Furthermore, polysulfide showed about 0.2% which consider being clinically relevant(61). On the other hand polyether show better properties that help to hold the impression copings accurately, and it has high primary shear resistance, dimensional stability and high resistance to permanent deformation, making it an acceptable impression material for implant-supported prosthesis(41). Moreover, Polyvinyl siloxane impression materials have shown a good outcome of their great dimensional stability, superior recovery from deformation, and precise reproduction of details (16).

Although,none of the available impression material has 100% elastic recovery, and for all types of impression materials, the greater the depth of the Undercut, the greater the deformation of the impression material. Polyvinyl siloxane impression materials reported to have the best elastic recovery at over 99% elastic recovery with a specific test undercut(1,16). This property, along with excellent dimensional stability make it the best choice for a second pour (49,62). Although varied outcomes have been reported, the majority of studies appear to conclude that the least amount of dimensional discrepancy occurs with addition silicones (0.06%) and polyethers (0.1%)(24,61). Therefore, a strongsuggestion of this two materials to be the materials of choice for multiple implant screw-retained impression procedure.

2.2.2.1. Polyvinyl siloxane

Addition silicone was introduced as a dental impression material in the 1970s. It is also known as polyvinyl siloxane (polysiloxane is the generic chemical expression for silicone resins). It is similar in many aspects to condensation silicone unless it has greater dimensional stability(63). Also, it has been reported that temperatureaffects the setting time of this material. The set material is less rigid than polyether. Adverse soft-tissue responses have been noticed(64).One of the disadvantages of this material that the setting reaction is affected by latex particles in the used gloves in the dental office. The problem is most apparent if a hand-mixed putty is used. Addition silicones are hydrophobic in nature, although surfactants have been added to some formulation, in order to provide hydrophilic nature, providing wettability similar to polyether. Even more, this material expands when coming in contact with moisture and water resembling the polyether at this point. Addition silicone is generally provided as a two-viscosity system, although monophase formulations are also available. Pouring should be delayed up to 4 hours in order to get rid of some of the earlier byproducts. If this is not considered, a generalized porosity of the cast surface caused by gas from the impression material might be noticed. Although Newer products have been developed which contain "scavengers" that prevent the escape of gas at the polymer-cast interface, make it able to be poured immediately(65).

2.2.2.2. Polyether

Polyether impression material was developed in Germany in the 1960s, it has a polymerization mechanism different from the other elastomers. Where no volatile by-productsare produced, that leads to better dimensional stability. Moreover, its polymerization shrinkage is considered low compared with most room temperature cured polymer systems(5). However, accurate casts can be produced when the material is poured more than a day after the impression has been made because of the high dimensional stability of polyether. Another advantage of polyether is its short setting time in the mouth (about 5 minutes).In addition When comparing torque resistance of impression materials, it has been stated that polyether material showed the highest torque values, which might be more favorable for the open tray impression manipulation(49). For these reasons, thepolyether is used recommended by many authors. On the other hand, polyether has certain disadvantages. The high stiffness of the set material is the main disadvantage, which makes it hard to separate a stone cast from the impression. Whereas shrinkage of impression materials over time have been observed, because of the continuous polymerization and loss of by-product(65). Polyether material shows different behavior that it swells Over time because of water sorption. Thus, in order to get the best accuracy from polyether, it should be poured withinan hour after impression procedure unless it is stored dry(24).

2.2.2.3. Comparison between impression material (polyether vs. polyvinyl siloxane)

Many studies had been designed to investigate the effect of impression material type on the accuracy of multiple implant impression (1,12,20,25,35,41,48–50,66–72). Most of the results were consistent and reported that both polyether and polyvinyl siloxane material could provide accurate comparable results. Holst et al. investigated the effect of impression materials on the end accuracy of the prepared models, where 4 implants with internal connection where placed on a control model, 4 experimental groups with four different material medium consistency polyether and 3 different type of polyvinyl siloxane. Concluded that Although polyether materials are considered the gold standard material for implant impressions in multi-implant screw retained cases, polyvinyl siloxane materials have equal precision(25). In agreement of that Aguilar et al. evaluated this effect where a control model with 5 implants was prepared and 2 groups of polyether and polyvinyl siloxane material was produced through direct technique impressions over the control model. The comparison of the produced models of both groups showed that there was no significant difference(66). Moreover, inconsistent with previous outcomes Papaspyridakos et al. reported in the conclusion of a systemic review that implant impressions accuracy of is not influenced by the impression material whether polyether or polyvinyl siloxane were used, for both completely and partially edentulous cases(17).

Controversially Moreira et al. stated in the conclusion of their respectful systemic review that regardless of the technique used, more accurate outcomes could be reached with the use of polyether as impression material, followed by polyvinyl siloxane(73). In addition Comparing torque resistance of impression materials, it has been reported that polyether material showed the highest torque values, make it more suitable for direct non-splinted technique (49).

2.2.3. Implant angulations and number

Implant angulations effect on the accuracy of implants impression has been investigated in many studies,Kim et al. had reported that presence of angulated implant will lead to more distortion in the implant impression(39). Papaspyridakos reported in a systemic review that angulated implants greater than 20 degrees will lead to less accurate impressions(74). Assuncao et al. compared accuracy of impression technique and material related to 4 different angulations 90,80,75,65 degree, metal matrix with four implants was prepared as control model and different techniques and material was used, as a result they concluded that the less angulated the implant was the more accurate was the impression provided, the greatest dispersion occurred in implants at 65°(9).

On the other hand, some authors found that there was no significant difference between angulated and straight implant effect on impression accuracy. Gillianet al. investigated the implant angulations effect by comparing the accuracy of close and open tray technique in case of angulated implants, a model with six implants with different angulations 0°,15°,30° was prepared and 12 experimental casts were prepared with each technique. The result showed that there was no difference in the accuracy between the different angulated implants in both groups(17). Wee investigated the accuracy of impression techniques in a clinical study, were open and close tray technique was applied to same 11 implant site and verification framework was prepared to compare the fit resulted from both techniques, were microcomputed tomography scanning and two blind examiners used to assess the framework fit. he reported that no difference was found between close and open impression techniques accuracy related to implants had less than 10° of angulations(24).

2.2.3. Other Factors Affecting The Impression Accuracy

2.2.3.1. Connection levels (implant level and abutment level)

Effect of connection-level on the accuracy of implant impression still no clear and enough evidence related to this factor. Alikhasi et al. investigated the effect of implant impression level on the accuracy of impression, where two implantswere placed on control model and three-techniques where applied implant level (direct and indirect technique) and abutment level, dimensional discrepancy was assessed in the three groups. The author reported that the implant level technique produced greater accuracy in representing the three-dimensional positions(75). In controversy same research group investigated the same factor but with full arch and four implant model with situation simulating the all on 4 protocol, where posterior implant where positioned with 45° and straight parallel anterior two implants, four group where designed two groups included implant level with direct and indirect technique, other two groups included abutment level with direct and indirect techniques. Outcomes of this study showed that impression level could influence the impression accuracy, as abutment level impression provided better accuracy in representing three-dimensional positions of angulated implants in the impressions made with additional silicone impression material(76).

2.2.3.2. Impression coping type and modification

Different techniques have been used to improve the stability of the impression copings inside the impression material in order to increase the accuracy of the outcomes. Those techniques included roughening of the external surface of the coping, using an adhesive layer and adding an extension on the top of the coping. Liou et al. evaluated the effect of coping modification by airborne- particle abrasion and using adhesive, he reported that the impression coping modification provide better results(72). Moreover,Vigoloinvestigated the same modification but the same conclusion could not be reached(30). Further studies advocated that to compensate for the inaccuracy of subgingival positioned implants impression, a 4-mm piece of the impression copings could be added on the impression copings, which will lead to more accurate outcomes. Still, there is not enough evidence related to the effectiveness of such modification(40).

2.2.3.3. Implant connection type

Maintaining the stability of the implant-prosthesis interface depends on the shape and geometry of the implant-abutment connection (77). Many systems have been clinically employed in implant-abutment connection include external hexagon, internal hexagon and taper joints.

2.2.3.3.A. The external connection system

Provide an anti-rotation mechanism, easier retrievability, and compatibility among different systems(17).However, the main drawbacks of the external hex are micro-movements, higher center of rotation leading to lower resistance for rotational and lateral movements and a micro gap leading to bone resorption. Furthermore, during impression taking, external connection implants can accommodate a larger degree of divergence than internal connection systems due to the limited height of the external hex(78).

2.2.3.3.B. The internal connection system

This system provides more simplicity and reliability in abutment connection, suited for one stage implant installation, another main attraction point is higher stability and anti-rotation because of a wider area of connection and suited for single tooth restoration, even because of lower center of rotation it could provide better resistance to lateral load and higher stress distribution. However it has thinned out the wall of the fixture at the connection part make it more prone to fracture, and even it might show some difficulties to adjust divergence in case of extremely angulated implants(30,52).

2.2.3.3.C. Conical connection

Have advantages of better sealing capabilities in closing the micro-gap on top of those in an internal hex system.

Considerable uncertainty regarding the effect of connection type on impression could be reported, where regarding internal connection, the impression coping has an intimate fit with the implant which may make it more difficult to withdraw the copings, leading to a higher degree of distortion(52,79). That coincides with a recent in vitro study showed that the impression with draws in case of internal connection implants is likely to make more stress between the impression copings and implants, which in order will lead to more stress on the impression material than from external hexagon implants(80). This stress may hypothetically produce permanent distortion of impression material or displacement of the impression copings within the impression material. Furthermore, under the presence of implant angulations, this may be exacerbated. The removal of rigidly splinted internal connection impression copings may not be possible when the angulations of the implants are extreme. Hence in cases of internal-hex implant systems, the more the angulations then the harder it is to remove the impression(30). On the other hand due to the limited height of the external hex, external connection implants can accommodate a larger degree of divergence than internal connection systems (76,78).On the contrary, a recent study suggested that internal connection implants provide more accurate implant impressions compared to external connection implants(81).

2.2.3.4. The depth of the implant placement:

In some situation because of esthetic consideration and bone availability, it became a must to place dental implants more subgingivally, which make the impression coping needed to be positioned more subgingivally, that reduce the surface of the impression coping exposed to impression material will recording the impression. In the end, this might have a direct effect on the coping stability and accuracy of the impression(32).

Lee et al. evaluated the effect of subgingival depth of implant position on the accuracy of the multi-implant impression. The authors used five parallel implants and two types of impression materials (polyether and polyvinyl siloxane). One implant was inserted 4 mm below the surface of the model while another implant was placed 2 mm depth. The author reported in the outcome of this study that there was no effect of implant depth on the dimensional accuracy of putty and light-body combination of polyvinyl siloxane Impressions, either vertically or horizontally. While in case of medium-body polyether impressions, the deeper implants exhibited a significantly less accurate impression horizontally(40). Too few studies were available to draw any conclusions.

2.3.Other Factor Affecting Fit For Implant Prostheses

2.3.1.Pouring techniques

In regards to pouring techniques, a few in vitro and 2 clinical studies have shown that the double pouring technique results in better outcomes (9,20,74,82). The double pouring technique is different than the conventional pouring technique in the following manner. After connection of the implant analogs to the impression copings, low expansion (0.09%) type IV die stone is mixed. First the stone is mixed manually with distilled water for 15 seconds to aid the incorporation of the water and then under vacuum and an initial pour of stone up to the middle of the analogs is carried out. All of the stone mixes are vibrated before and during the pouring. After 30 minutes the second pour of vacuum-mixed die stone is done. This double pouring technique minimizes the volumetric expansion of the stone and has been shown to lead to more accurate die casts (82).

2.3.2. Machining tolerance

In regards to the machining tolerance and its effect on accuracy measurements, it has been shown that paired prosthetic components may be rotationally displaced during connection to their respective parts(83). This displacement cannot be controlled by the clinician and lies within the range of the inherent machining tolerance(21). Hence, errors occur during connection of impression copings to the implants intraorally and to the implant analogs in the laboratory, respectively. For instance, Ma reported that the machining tolerance of the first generation Branemark components was larger than the currently used components and ranged from 33 to 100 μm(21). The machining tolerance differs between different implant systems and is an unknown variable in the accuracy measurements. Kim et al. studied the machining tolerance of the implant components and found a machining tolerance of 31.1 ± 15.5 μm between the abutment and the impression coping and the value of 30.4 ± 15.6 μm between the impression coping and the abutment replica. These two values combined will give more than 61μmof machining tolerance for the single abutment(84).

2.3.3. Method framework fabrication

The lost wax casting technique was for years the gold stander for the framework fabrication, although among the drawbacks of such a technique, the difficulty of obtaining one-piece castings with a good precision of fit on the implants.More importantly the variability in precision and accuracy among different dental technicians(85).

To improve the fit of implant frameworks,several methods have been developed. In general, that could be divided into two categories: addition of fit refinement steps or elimination of fabrication steps. The first category includes sectioning and soldering/ laser welding, spark erosion with an electric discharge machine (EDM), and bonding the framework to prefabricated cylinders. The second category includes computer-aided design/computer-assisted manufacturing (CAD/CAM) and other rapid prototyping technologies. The potential for CAD/CAM to enhance the accuracy is based on omitting certain fabrication steps, such as waxing, investing, and casting(86).

Torsello et al. evaluated the marginal fit of multi-implant prosthesis fabricated with five different technique. He reported that the mean values for the microgap were

78 µm for lost wax technique frameworks, 33 µm for cast titanium sovra structures laser welded to titanium copyings, 21 µm for the Proceras implant bridge, 18 µm for the Cresco TiSystemt and 27 µm for the CAM structsure. Concluded that The computer-aided procedures showed a greater precision compared with the traditional casting methods or with the use of prefabricated titanium copings(87).

2.4. Methodology Of Accuracy Assessment

The diverse results from some previous in vitro studies may be partially explained by the differences in methodology of accuracy measurements, by the machining tolerance of components, and by improvements in dental materials. In regards to the methodology of accuracy assessment and its effect on accuracy measurements, several methods have been employed to measure and quantify the 3D discrepancies on the X, Y and Z-axis between the implant casts produced with different impression techniques including computerized coordinate measuring machine, 3D photogrammetry, traveling microscope, computerized tomography (CT) scan and recently optical scanning and digitization (16).

Several studies indirectly assessed the implant impression accuracy by evaluating the fit and/or distortion of fabricated frameworks on the resultant casts with strain gauges and compared the fit and/or distortion of the frameworks on the reference master cast(88–90). Other studies indirectly assessed the implant impression accuracy by evaluating the fit of frameworks with microscopes (29,82,91). Lastly, other studies evaluated the accuracy of the implant impressions by measuring inter-implant distances of the working casts in relation to a reference control cast(18,24,30,33,35,92,93).However, with the advent of 3-D measurement devices, a 2-D assessment of the accuracy cannot be accepted today for scientific purposes. Optical scanning and dedicated software for superimposition of the scanning datasets is currently an efficient and precise technique to measure and compare the 3-D discrepancies at the microscopic level between different groups and thus seems to be the recommended technique for future investigations (94).

3.MATERIALS AND METHODS

3.1.Material

Table 1. Table summarize the used materials and devices in this study

	Materials and devices	Manufacturing details
1	Zinc oxide eugenol	Cavex Outline, Cavex, Holland
2	Additional silicon impression material	Express XtPenta Putty Soft, Express Xt Light Body Quick, 3M ESPE, Germany
3	Implants	4.3*10 internal conical hybrid connection, implance, turkey
4	Parallelometer	Bego, Bremen, Germany
5	Light polymerizing resin	Nova-Tray Light Curing Tray, President Dental, Germany
6	Base plate wax	Cavex Ste Up Regular Wax, Cavex, Holland
7	Alginate impression	Zhermack, Tropicalgin, Italy
8	Metal impression tray	GC America, Metal Impression Trays, USA
9	Vibrator	Whip mix corporation, louisville, USA
10	Impression copings for indirect snap-on technique	BICT45S Hex Impression Coping Transfer, Implance, Turkey
11	Implant system ratchet	Ratchet With Torque, Implance, Turkey
12	Polyether adhesive material	PE, ImpregumPenta Soft; 3M ESPE, USA
13	Polyvinyl siloxane adhesive material	Universal Tray Adhesive, Zhermack, Italy
14	Polyether impression material	MonophaseImpregumpenta Soft, 3MEspe, Germany
15	Auto mixing machine	Pentamix, 3M ESPE, Germany
16	Garant dispenser	GarantDispenser, 3m ESPE, Germany
17	Disposable 10ml plastic syringe	Disposable 10ml Syringe, Agar Scientific, United Kingdom
18	Implant analogs	BFLA Implant Analog, Implance, Turkey
19	Impression copings for direct technique	BICP45S hex Impression Coping Transfer, Implance, Turkey
20	Prefabricated acrylic resin bar	Prefabricated Resin Bar, Bego, Germany
21	Diamond disc	Diamond Disc, Mend Tech Inc, USA
22	Cold acrylic resin	Pattern Resin Ls Acrylic For Patterns, GC, USA
23	Dental stone type IV	Type Four Dental Stone, Dentona, Germany
24	Stone vacuum mixer	Smartmix Smart-Mix, Amanngirr-Bach Gmbh, Pforzheim, Germany
25	O-ring abutments	BORA60, O-Rings Abutments, Implance, Turkey
26	3D scanning machine	3Shape 3E Lab Scanner, Copenhagen, Denmark

3.2.Method

3.2.1. Mastermodel fabrication

A master model simulating an upper jaw for an edentulous patient fabricated with epoxy resin (Epoxy Resin, Torrdental, Turkey), where an impression for the upper jaw for an edentulous patient was made with zinc oxide eugenol(Table 1.1) in order to fabricate a complete prosthesis, the produced model was duplicated using additional silicon impression material(Table 1.2), then the model was fabricated with epoxy resin.

On the master model four implants(Table 1.3)were placed in the canine and first molar region on each side, to simulate the clinical situation of all on four technique(76,95,96)(Figure1).Two anterior implants in the canine region were placed parallel to each other and perpendicular to the occlusal plane, the angle of these two implants were considered 0°, as they are parallel to the perpendicular axis on the occlusal plane. While the two posterior implants were positioned in an angulated position distally with 30°to the perpendicular axis on the occlusal plane.Parallelometer (Table 1.4) was used to place the implants in canines and first molar regions with the exact accurate angle required(1)(Figure 2).

Two metal reference pieces were inserted in the midline of the palate of the model, one positioned posterior to the last implants while the other reference was placed near to the incisive foramina area. Where will be used as reference points for measurement(49,62,69,76)(Figure 3).In order to standardize the impression trays positioning and the pressure while making the impression for the control model throughout the study three grooves; one anterior near to the midline area and two posterior related to premolar region; were made on the model with 3-mm deep and 6-mm width and height(Figure 4)(38).

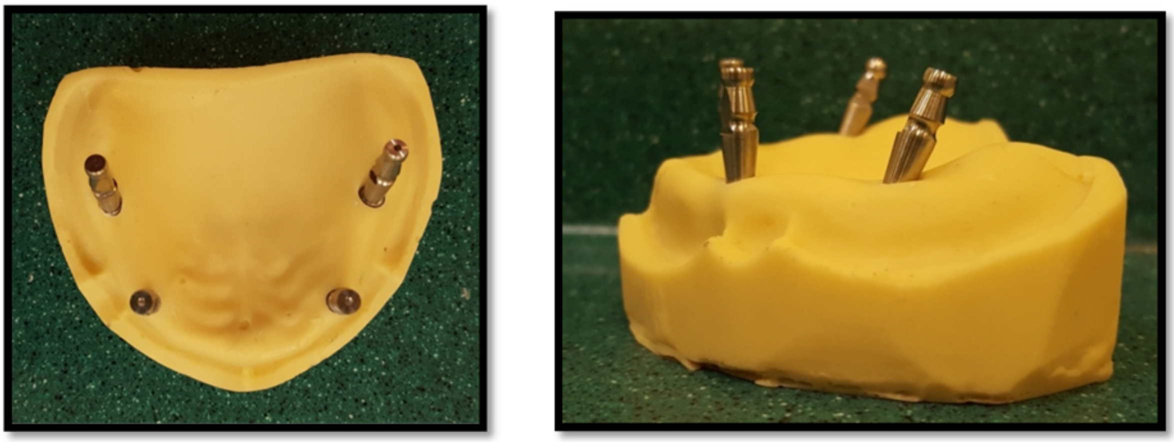

Figure 1.master model with four implant in place.

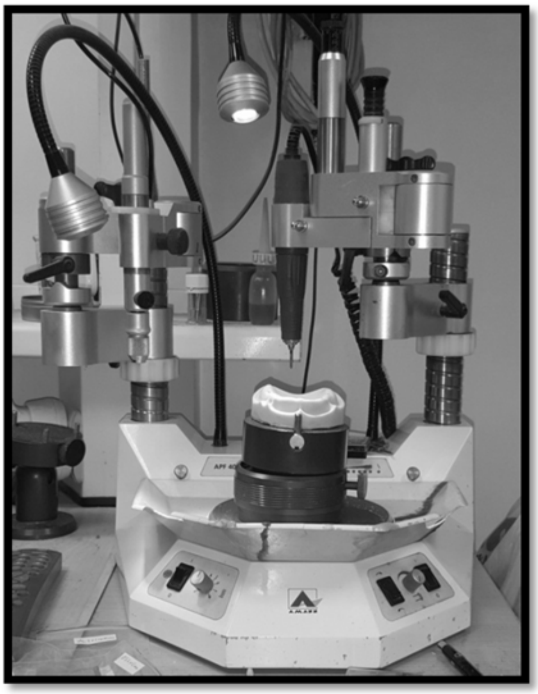

Figure 2.Parallelometer.

Figure 3.Master model with two metal reference pieces.

Figure 4.Master model with three grooves on the side.

3.2.2. Custom trays fabrication

Custom trays of light polymerizing resin(Table 1.5) for the direct and indirect technique were manufactured. After attaching the impression coping a three layer of baseplate wax (Table 1.6) applied over the impression coping to cover the undercuts and to provide 3mm space for impression materials (Figure 5a). An alginate impression (Table 1.7) was made using a readymade metal tray (Table 1.8) extended with wax to cover the periphery of the model (Figure 5b). This procedure was done for both direct and indirect copings. The stone was poured on a vibrator (Table 1.9) to minimize the entrapment of air bubbles, and then it was allowed to set for 30 min. On those two models, 20 trays for direct technique and 20 trays for the indirect technique was fabricated. Care was taken to make sure that trays extend over the prepared three grooves in the cast to ensure the fit of the trays accurately while making the impressions. Holes were opened over the corresponded implant analogs for the direct technique's trays (Figure 6).

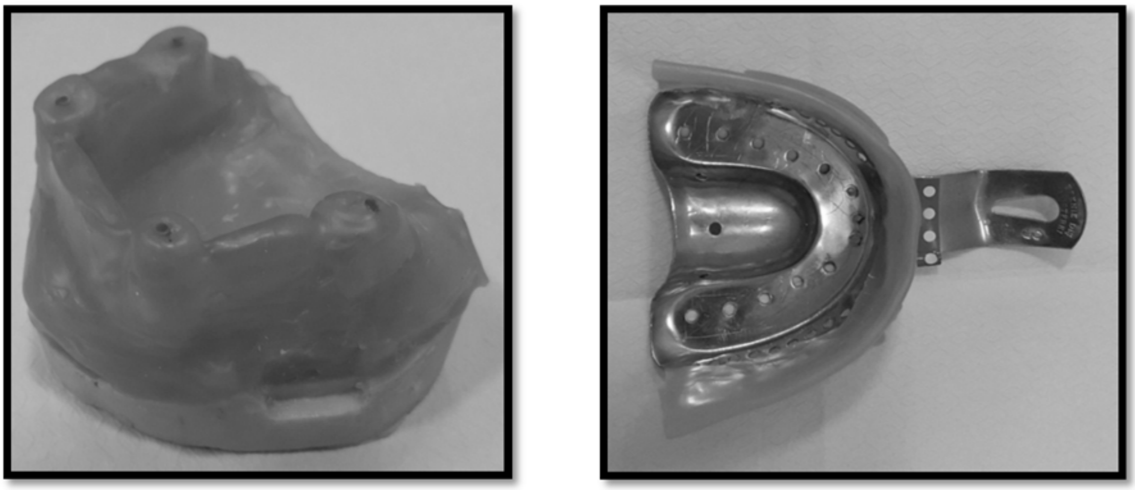

Figure 5. (A) a three layer of base plate wax over the master model. (B) a ready-made metal tray extended with wax to cover the periphery of the model.

Figure 6.Custom tray with extension over the prepared three grooves.

3.2.3. Impression making procedure

3.2.3.1. Impression with indirect snap-on technique

The impression copings(Table 1.10)for indirect technique(Snap-On Technique)were placed on the reference model and tightened with 10 Newton using ratchet(Table 1.11)(Figure 7).Then the plastic pieces were attached on the top of the impression copings(Figure 8).A new impression coping was used for each impression to avoid the effect of repeated use of those parts(97).

For making the impression procedure after making enough pores on the trays to allow escape of the excess impression materials, the custom trays were covered with a thin layer of an adhesive material (Figure 9).polyether adhesive material(Table 1.12) was used in case of polyether impressions, while polyvinyl Sloane adhesive material (Table 1.13) was used in case of polyvinyl siloxane impressions and allowed to dry according to manufacturer instruction which is 15 minutes in case of polyether adhesive and 2 minutes in case of polyvinyl siloxane.

Polyvinyl siloxane (Table 1.2) and polyether(Table 1.14)were being used to make the impressions. Auto mixing machine (Table 1.15)(Figure 10) was used to mix the impression materials to avoid inconsistency mixture and avoid air bubbleswhile making impressions. Garant Dispenser (Table 1.16) was used to mix the light body of polyvinyl siloxane and to introduce it on the model to cover the implant coping transfers and reference points with an adequate layer of light body materials in order to get an accurate impression. In case of polyether impressionplastic syringe(Table 1.17) was used to introduce the medium body consistency on the model to cover the implant coping transfers and referencepoints materials in order to get theaccurate impression. While seating the trays care was taken to assure the engage of the tray into the three guiding grooves on the master model (Figure 14), by wiping the excess immediately, to standardize the seating load for each impression, bilateral finger pressure was applied throughout the setting time. The impression material will be allowed to set according to manufacturer recommendation, all impressions were made in a temperature-controlled environment (23 ±1°c) with a relative humidity of 10% (18,49,62).

After the complete set of the impression material, the impression coping was unscrewed carefully, and the tray removed from the model in the same way, in anterior superior direction. Then the implant analogs (Table 1.18) were attached to the copings and screwed according to manufacture instruction.

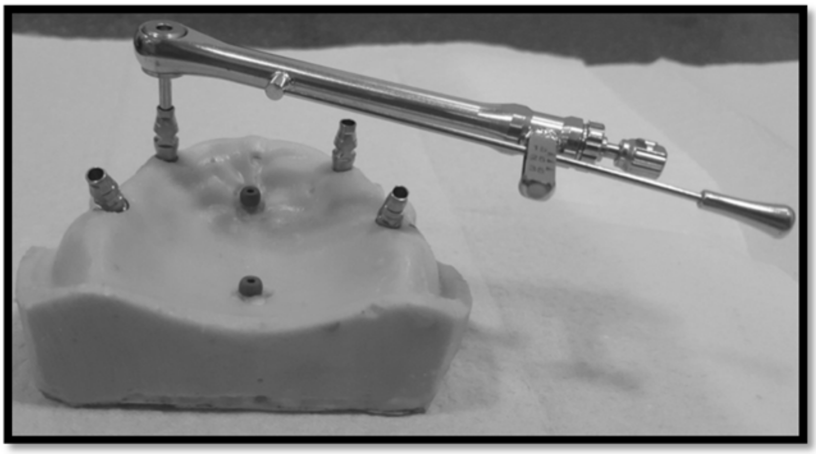

Figure 7. Tightening the impression coping with 10 Newton using ratchet (Ratchet With Torque, Implance, Turkey).

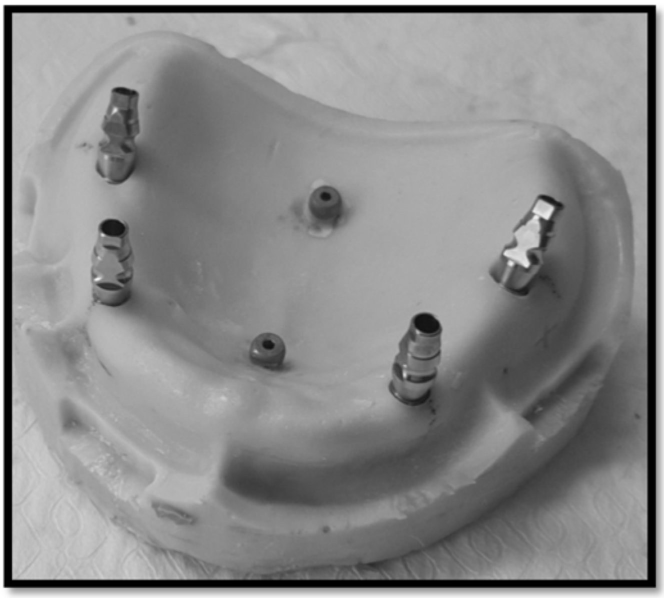

Figure 8. Plastic pieces attached on the top of the impression copings

Figure 9.Application of Polyether adhesive material and polyvinyl siloxane adhesive material.

Figure 10. Auto mixing machine.

3.2.3.2. Impression with direct splinted technique

The impression copings(Table 1.19) for direct technique were placed on the reference model and tightened with 10 Newton using ratchet(Table 1.11)(Figure 11).A new impression coping was used for each impression to avoid the effect of repeated use of those parts which have been reported to have an effect on the outcome accuracy(97).

Prefabricated acrylic resin bar (Table 1.20)was used to splint the impression coping, where the prefabricated bar was cut according to the distance between the impression coping with adiamond disc(Table 1.21), then was attached in each side using cold acrylic resin (Table 1.22) (Figure 12).Application of the cold acrylic resin was done in incremental manner, where a fine brush was dipped in the liquid of the acrylic resin to make it wet on the top and then the brush was slightly dipped into the powder in very delicate way to get some powder on the top of the brush which will start to polymerize in few seconds.Resinwas applied on the side of the prefabricated resin bar to join it with the impression coping, after finishing this step the model was left for 17 min before making the impression to make sure that most of the resin's polymerization shrinkage is finished(34).

For making the impression procedure after making enough pores on the trays to allow escape of the excess impression materials, the custom trays were covered with a thin layer of an adhesive material.Polyether adhesive material (Table 1.12) was used in case of polyether impressions. While polyvinyl siloxane adhesive material (Table 1.13)was used in case of polyvinyl siloxane impressions (Figure 9) and allowed to dry according to manufacturer instruction which is 15 minutes in case of polyether adhesive and 2 minutes in case of polyvinyl siloxane.

A polyvinylsiloxane(Table 1.2)and polyether (Table1.14) werebeing used to make the impressions. Auto mixing machine(Table 1.15)(Figure 10) was used to mix the impression materials to avoid inconsistency mixture and avoid air bubbles while making impressions. Garantdispenser (Table 1.16)was used to mix the light body of polyvinyl siloxane and to introduce it on the model to cover the implant coping transfers and referencepoints with an adequate layer of light body materials in order to get anaccurate impression. In case of polyether impression 10ml plastic syringe(Table 1.17) was used to introduce the medium body consistency on the model to cover the implant coping transfers and referencepoints materials in order to get theaccurate impression (Figure 13). A layer of base plate wax was placed over the opening of the trays to prevent theescape of the impression materials, and after seating the trays, the wax was removed carefully and impression coping located by removing the impression materials on the top. While seating the trays care was taken to assure the engage of the tray into the three guiding grooves on the master model (Figure 14), by wiping the excess immediately, to standardize the seating load for each impression, bilateral finger pressure was applied throughout the setting time.The impression material will be allowed to set according to manufacturer recommendation. All impressions were made in a temperature-controlled environment (23 ±1 °c) with a relative humidity of 10%(18,49,62).

After the complete set of the impression material, the impression coping was unscrewed carefully, and the tray removed from the model inthe same way, in anterior superior direction. Then the implant analogs (Table 1.18) were attached to the copings and screwed according to manufacture instruction.

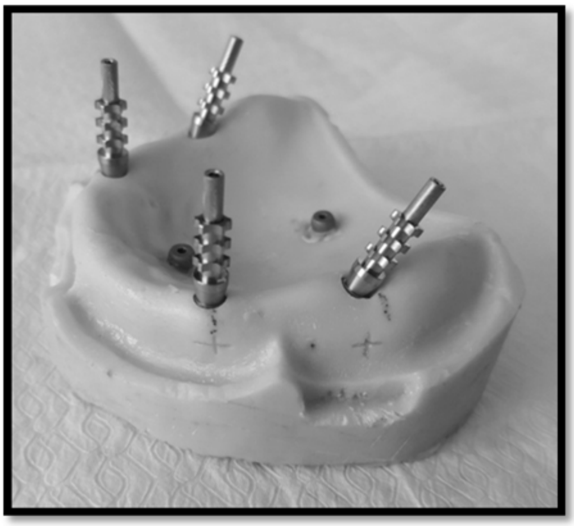

Figure 11. The impression copings (BICP45S hex impression coping transfer, Implance, Turkey) for direct technique placed in place.

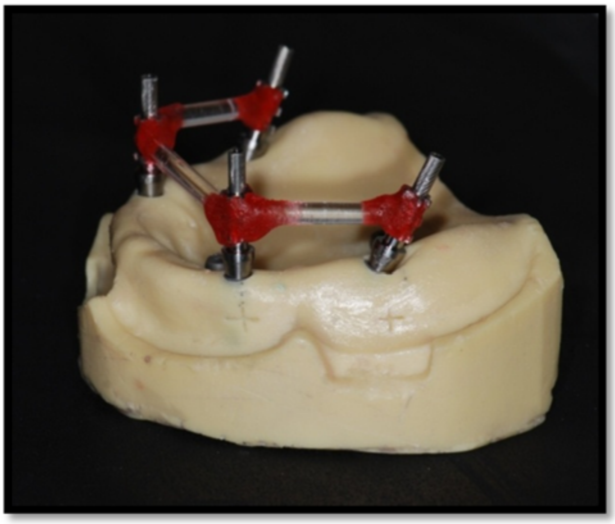

Figure 12. Prefabricated acrylic resin bar was used to splint the impression coping

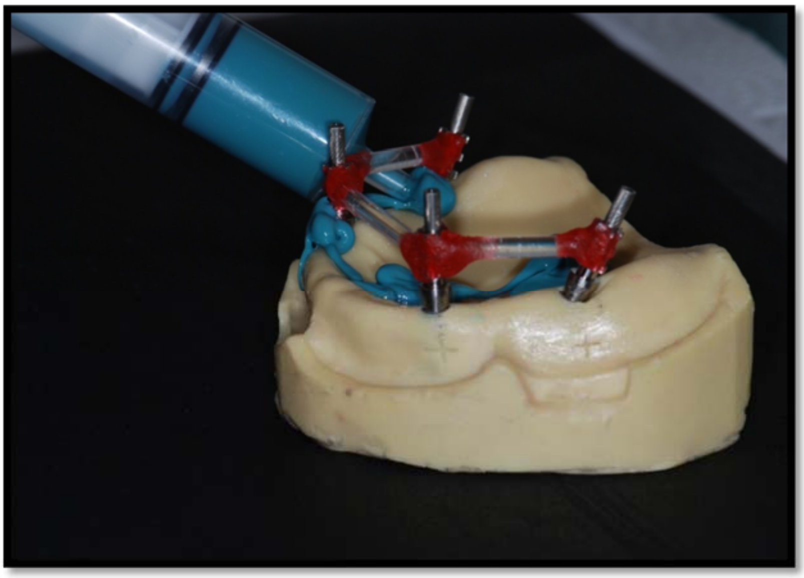

Figure 13. Introducing the polyether impression material around the impression copings Using a 10 ml plastic syringe.

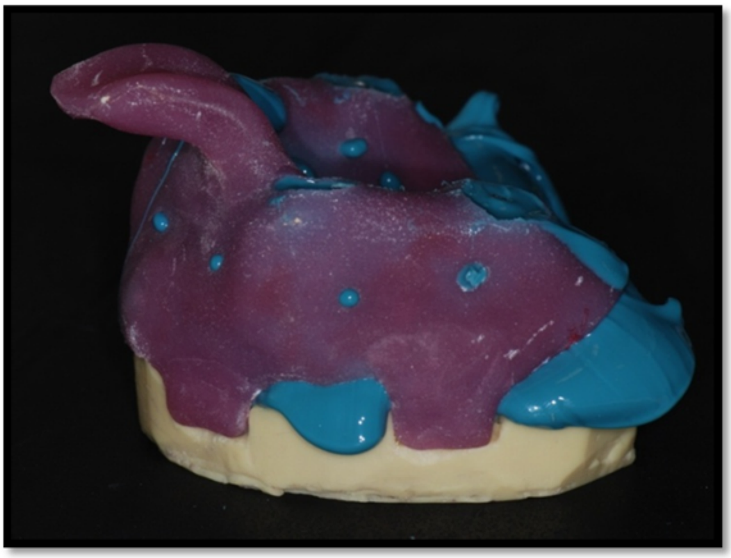

Figure 14. Engage of the tray into the three guiding grooves on the master model

3.2.4. Pouring of casts

The check was made for the whole impression that there was no discrepancy, air bubble, uncorrected set, loose impression coping and repeated if there is such mistake.all impression wastrimmed if there is any excess to be flushed with the trays margin, then boxed with wax (table 1.6) before pouring to provide 3 cm base(Figure 15). double mixing technique was used to decrease the effect of stone dimensional change (82). A dental stone type IV(table 1.23), which wasvacuum mixed(table 1.24) (Figure 16) with a powder/water ratio as recommended by the manufacturer's instructions was used to pour the casts.

The casts were allowed to set for 120 min as in the manufacturer'sinstructionsbefore impression were separated from the casts.The screws were loosed to separate the models of splinted-direct technique, while theseparation of models for thesnap-on technique was done directly with high care. The impression copings needed to be unscrewed from the implant analogs. Followed by trimming the edges for the models and labeling to prepare formeasurements. The same operator prepared all 40 model in all laboratory procedures. Prior to 3Dscanning, all the models werekept at room temperature for 24 hours(Figure 17).

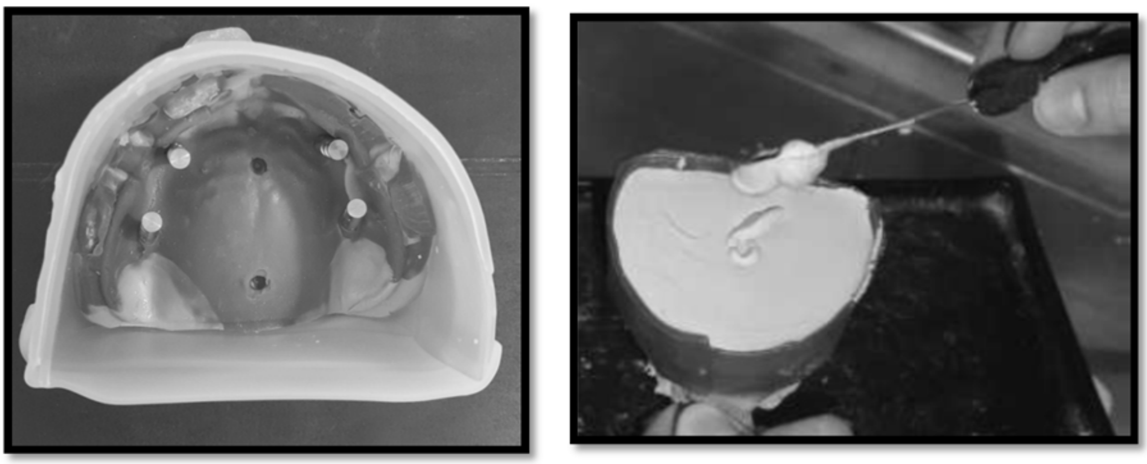

Figure 15. Boxing the impression with wax before pouring

Figure 16. Vacuum mixing machine.

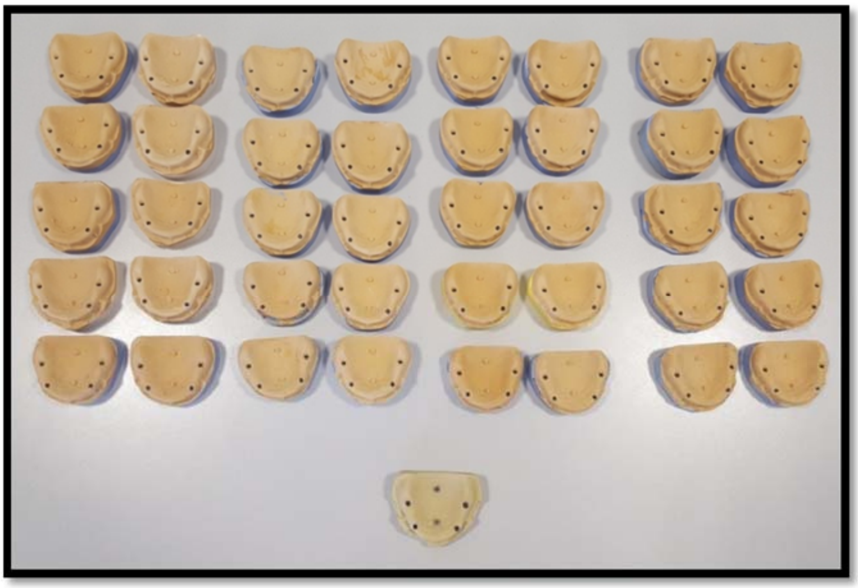

Figure 17.models of four groups ready for scanning.

3.2.5. Coding the casts

The 40 modelswere divided into 4 different group, with 10 model in each group. Where models produced from direct-splinted technique using polyether impression material were coded with PEO. Models produced from direct-splinted technique using polyvinyl siloxane were named with PVSO. While models produced from snap on indirect technique using polyether were named with PEC, and models produced from snap on indirect technique using polyvinyl siloxane were named PVSC. Each group was coded from 1 to 10 as summarized in (Table 2).

Table 2.Table Defining the four different group in the study.

Impression technique	Impression material	group
Indirect Snap On Technique	PolyvineylSiloxane	PVSC group (n=10)
	Polyether	PEC group (n=10)
Direct Splinted Technique	PolyvineylSiloxane	PVSO group (n=10)
	Polyether	PEO group (n=10)

Another code was made in order to make the operator who will make the measurement blind about the particular models, where MR1001 code continuing up to MR1040 was made according to special random table where files of 3D scanner, was coded according to this codes as shown in(Table 3).

Table 3.Coding of the prepared models.

Group According To The Group		Coding For Measurement
PVSC	1	**MR1025**
	2	**MR1006**
	3	**MR1004**
	4	**MR1005**
	5	**MR1010**
	6	**MR1001**
	7	**MR1008**
	8	**MR1002**
	9	**MR1009**
	10	**MR1014**
PVSO	1	**MR1013**
	2	**MR1018**
	3	**MR1028**
	4	**MR1016**
	5	**MR1011**
	6	**MR1020**
	7	**MR1021**
	8	**MR1019**
	9	**MR1023**
	10	**MR1026**
PEC	1	**MR1015**
	2	**MR1007**
	3	**MR1027**
	4	**MR1029**
	5	**MR1024**
	6	**MR1030**
	7	**MR1032**
	8	**MR1017**
	9	**MR1022**
	10	**MR1003**
PEO	1	**MR1012**
	2	**MR1037**
	3	**MR1040**
	4	**MR1035**
	5	**MR1033**
	6	**MR1038**
	7	**MR1036**
	8	**MR1034**
	9	**MR1031**
	10	**MR1039**

3.2.6. Measurement protocol

The purpose of our measurement were to measure the distance in three dimensionsand x-y-z-axis between each implant, and the posterior reference point (Figure18) in the all 40 model and the control model, in order to calculate the absolute discrepancies in each model related to the control model. O-ring abutments(Table 1.25)were attached to the implants throughout the measurements on all the models, where the same piece was used for the same implant number within the whole measurements in order to avoid machined tolerance error. The reason to use an O-Ring abutment that a spherical shape was more helpful for our method.

First step 3D scanning: 3D scanning machine (table 1.26) with an accuracy of 7- 10 µm was used to scan all the 41 models provide an STL file (figure 19).The scanning procedure took a duration of 80 sec for each model. During the scanning procedure, all the models were coded in new codes as shown in (Table 3) in order to hide the model's related group on the next step of the measurement procedure.

The second step defining the centers: 3D computer graphics and computer-aided design application software (Rhinoceros 5.0 Version, Robert McNeel& Associates, USA) was used to perform the measurements of the distance in 3D dimension and x-y-zaxis. The related file was imported into the software, then a procedure of defining the centers of the four O-Rings and the reference points. The command (Sphere Command-Fit Points) which able the program to produce a sphere fit to the points of theselected object (about 8000 points selected automatically on therelated object). The head of the o-ring or the reference point piece were selected and the command was ordered to get a sphere related to that object(Figure20), then the center of that sphere was defined with a point. These steps were repeated 5 times for each head, in order to make the center of the defined centers. This technique has shown a great precision with 1µm related the implants centers and 3µm related to the reference point centers.that could be explained because of the not exactly circular shape of our reference piont.

Third step setting coordinate plans: coordinate plans were set for each model in order to be able to measure the distances in x, y, z axis, the first reference point was used to set the all three axis x, y, z in zero, second reference point was used to set x,z axis in zero, another reference point produced by the center of the surface connecting the four implants (figure 21), was used to set x-axis in zero. By this,all the 41 model will be set in the position on the world plane coordinates.

Fourth step measuring distance: to measure the distance between the selected mean centers, the (Evaluate pt Command) was used to evaluate the world plane coordinates of the selected center and displayed in X,Y,Z format, which inform the distance from the reference point in X,Y,Z direction. Next (Distance Command) was used to measure the distance in 3D dimension between different centers.

Four measurements were recorded for each implant in (3D, X, Y, Z) distance, and a total of sixteen measurements for each model was recorded. Data were collected and inserted into excel sheet. "absolute values of discrepancies" in each model was calculated by subtraction the recorded value on the model from the related value on the control model. All the values were recorded in absolute numbers.

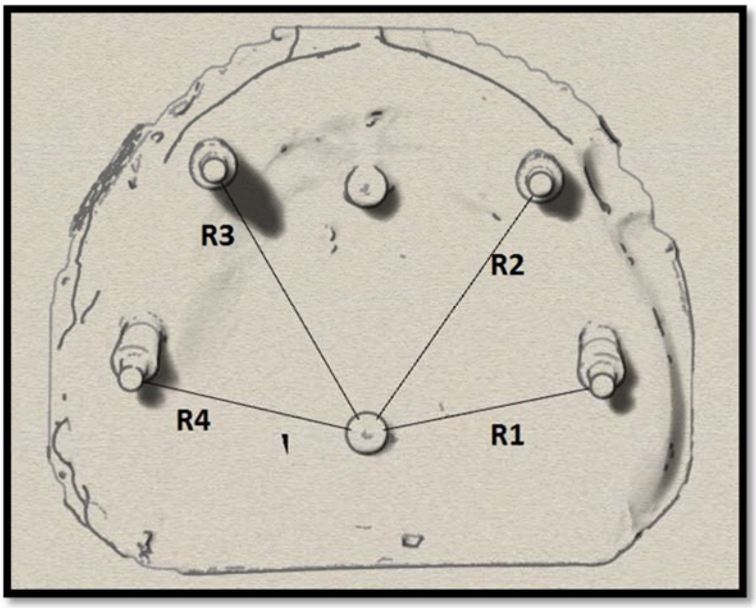

Figure 18. Measurement the distance in 3D dimension, x-y-z axis between each implant, and the posterior reference point

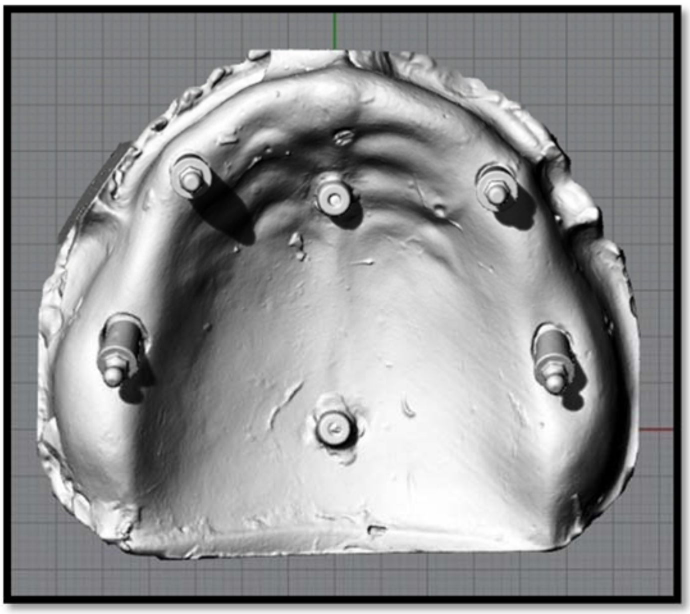

Figure 19. Scanned model with STL format

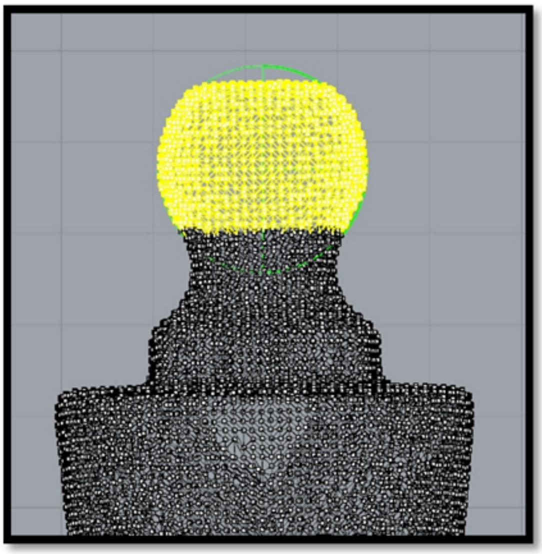

Figure 20.DefiningThe centers of the four O-Rings and the reference points. The command (Sphere Command- Fit Points)

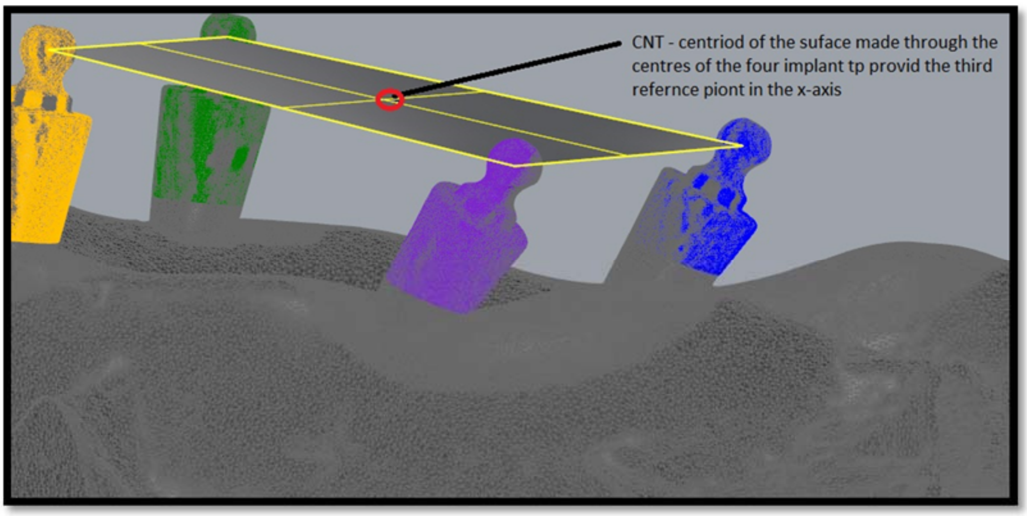

Figure 21. Reference point produced by the center of the surface connecting the four implants

3.2.7. Statistical Analysis

The normal distribution of the data has been check using Kolmogorov–Smirnov, also checking the graphics normal distribution plots. the data was non-normal distributed, which could be explained because the absolute values were used for analysis, that will lead to skew to the right from the normal distribution curve. The Wilcoxon rank sum test (Mann–Whitney U-test) was applied for paired group comparisons. The non-parametrical analysis of variance (ANOVA) according to Kruskal–Wallis was used in the case of several groups together. The level of statistical significance was set at 5%. Results were reported as mean (stander deviation). All statistical analyses were conducted with software (SPSS Statistics v17.0; SPSS, Inc).

3.2.7.1 Hypotheses

Null hypotheses

Main effects:

1. There is no significant difference between the four group PVSO, PVSC, PEO, PEC.
2. There is no significant difference in impression accuracy between direct splinted and indirect snap-on technique regardless of impression materials and implants angulations.
3. There is no significant difference in impression accuracy between polyether or polyvinyl siloxane impression material, regardless of impression techniques and implants angulations
4. There is no significant difference in impression accuracy between straight and angulated implants regardless of techniques and materials
5. There is no significant difference in impression accuracy between straight and angulated implants within same group

Interactions:

1. There is no significant interaction between the impression technique (direct splinted vs. indirect snap-on) and the impression material (polyether vs. polyvinyl siloxane).
2. There is no significant interaction between the impression technique (direct splinted vs. indirect snap-on) and implant angulations (straight and angulated).

3. There is no significant interaction between the type of impression material (polyether vs. polyvinyl siloxane) and implant angulations (straight and angulated).
4. There is no significant interaction between the impression technique (direct splinted vs. indirect snap-on), and type of impression material (polyether vs. polyvinyl siloxane) and implant angulations (straight and angulated).

Research hypotheses

Main effects:

1. There is significant difference between the four group PVSO, PVSC, PEO, PEC.
2. There is significant difference in impression accuracy between direct splinted and indirect snap-on technique regardless of impression materials and implants angulations.
3. There is significant difference in impression accuracy between polyether or polyvinyl siloxane impression material, regardless of impression techniques and implants angulations
4. There is significant difference in impression accuracy between straight and angulated implants regardless of techniques and materials
5. there is significant difference in impression accuracy between straight and angulated implants within same group

Interactions:

1. There is significant interaction between the impression technique (direct splinted vs. indirect snap-on) and the impression material (polyether vs. polyvinyl siloxane).
2. There is significant interaction between the impression technique (direct splinted vs. indirect snap-on) and implant angulations (straight and angulated).
3. There is significant interaction between the type of impression material (polyether vs. polyvinyl siloxane) and implant angulations (straight and angulated).
4. There is significant interaction between the impression technique (direct splinted vs. indirect snap-on), and type of impression material (polyether vs. polyvinyl siloxane) and implant angulations (straight and angulated).

4. RESULT

4.1. Comparing The Four Groups With The Means Of All Implants Discrepancies

The absolute values of discrepancies in three dimensional and the three coordinates X.Y.Z are presented as means (SD) in (Table 4) (Figure 22). Analysis of variance revealed that there was a significant difference between the groups related to three-dimensional discrepancies (*P*=0.003), with higher discrepancy related to PEC group with a mean (Sd) of 0.072 (±0.062) mm. The PVSC group showed a mean(SD) of 0.031(±0.042) mm. The PEO group had a mean(SD) with 0.043(±0.022) mm. The best result was shown in PVSO group with a mean (SD) of 0.032(±0.020) mm. In paired group comparisons (Table 4). The difference between PVSO group and PVSC group was not significant (*P*=0.862). Also, the difference between PVSO group and PEO group was not significant (*P*=0.294). But there was a significant difference between PVSO group and PEC group (*P*=0.001). Also, PVSC group and PEC was significantly different (*P* = 0.002).

Analysis of variance revealed that there was a significant difference between the groups related to the X-axis discrepancies (*P*=0.001) (Table 4). With the higher discrepancies related to PVSC groups and PEC group with a mean (SD) of 0.035(±0.018)mm and 0.034(±0.024) mm respectively. The PVSO group showed a mean(SD) of 0.022(±0.014)mm. The best result was shown in PEO group with a mean (SD) of 0.021(±0.021)mm. In paired group comparisons (Table 4). The differences between PVSO and PVSC was significant (*P*=0.007). The differences between PVSO and PEC group showed significant (*P*=0.012). The differences between PEO group and both PVSC group and PEC group were significant (*P*=0.002, *P*=0.003). While there was no significant difference between PVSO and PEO (*P*=0.328) which both showed the best results related to this axis.

Analysis of variance revealed that there was no significant difference between the groups related to the *Y*-axis discrepancies (*P*=0.673) (Table 3). With the higher discrepancies related to PEC groups with a mean (SD) of 0.072 (±0.079) mm. The PVSC group showed a mean(SD) of 0.047 (±0.048) mm. PVSO and PEO groups showed mean (SD) of 0.042(±0.030) and 0.052(±0.033) mm respectively.

Analysis of variance revealed that there was a significant difference between the groups related to the Z-axis discrepancies (P=0.000) (Table 4). With the higher discrepancies related to PEC groups and PEO group with a mean (SD) of 0.156(±0.094) and 0.138(±0.063)mm respectively. The PVSO group showed a mean(SD) of 0.088(±0.050) mm. The best result was shown in PVSC group with a mean (SD) of 0.081(±0.065)mm. In paired group comparisons (Table 5).the difference between PVSO group and PVSC group was not significant (P=0.336). there were significant differences between PVSO group and both PEO and PEC groups (P=0.001, P=0.001). Also, the differences were significant between PVSC group and both PEO and PEC groups (P=0.000, P=0.000).

Table 4. Means of the absolute values discrepancies in three dimensional and the three coordinates X.Y.Z distance inmm.

		Direct Splinted Technique		Indirect Snap-On Technique		
		PVS	**PE**	**PV**	**PE**	*P* value
3D	Mean	0.032	0.043	0.031	0.072	***0.003***
	SD	0.020	0.042	0.022	0.062	
	SEM	0.003	0.007	0.003	0.010	
	Median	0.030	0.034	0.026	0.050	
	Min	0.001	0.001	0.000	0.002	
	Max	0.072	0.244	0.086	0.238	
	Range	0.071	0.243	0.086	0.236	
	n	40	40	40	40	
X	Mean	0.022	0.021	0.035	0.034	***0.001***
	SD	0.014	0.018	0.021	0.024	
	SEM	0.002	0.003	0.003	0.004	
	Median	0.019	0.017	0.034	0.029	
	Min	0.000	0.000	0.002	0.003	
	Max	0.076	0.095	0.085	0.112	
	Range	0.076	0.095	0.083	0.109	
	n	40	40	40	40	
Y	Mean	0.042	0.052	0.047	0.072	0.673
	SD	0.030	0.048	0.033	0.079	
	SEM	0.005	0.008	0.005	0.012	
	Median	0.043	0.030	0.043	0.042	
	Min	0.002	0.000	0.000	0.000	
	Max	0.105	0.201	0.135	0.301	
	Range	0.103	0.201	0.135	0.301	
	n	40	40	40	40	
Z	Mean	0.088	0.138	0.081	0.156	***0.000***
	SD	0.050	0.065	0.063	0.094	
	SEM	0.008	0.010	0.010	0.015	
	Median	0.085	0.128	0.069	0.121	
	Min	0.005	0.044	0.002	0.018	
	Max	0.200	0.320	0.233	0.402	
	Range	0.195	0.276	0.231	0.384	
	n	40	40	40	40	

Table 5.paired group comparisons Mann–Whitney U-test

	3D	X	Y	Z
PVSO * PVSC	0.862	***0.007***	0.544	0.336
PVSO*PEO	0.294	0.328	0.544	***0.001***
PVSO*PEC	***0.001***	***0.012***	0.301	***0.001***
PVSC*PEO	0.179	***0.002***	0.751	***0.000***
PVSC*PEC	***0.002***	0.769	0.661	***0.000***
PEO*PEC	***0.034***	***0.003***	0.292	0.711

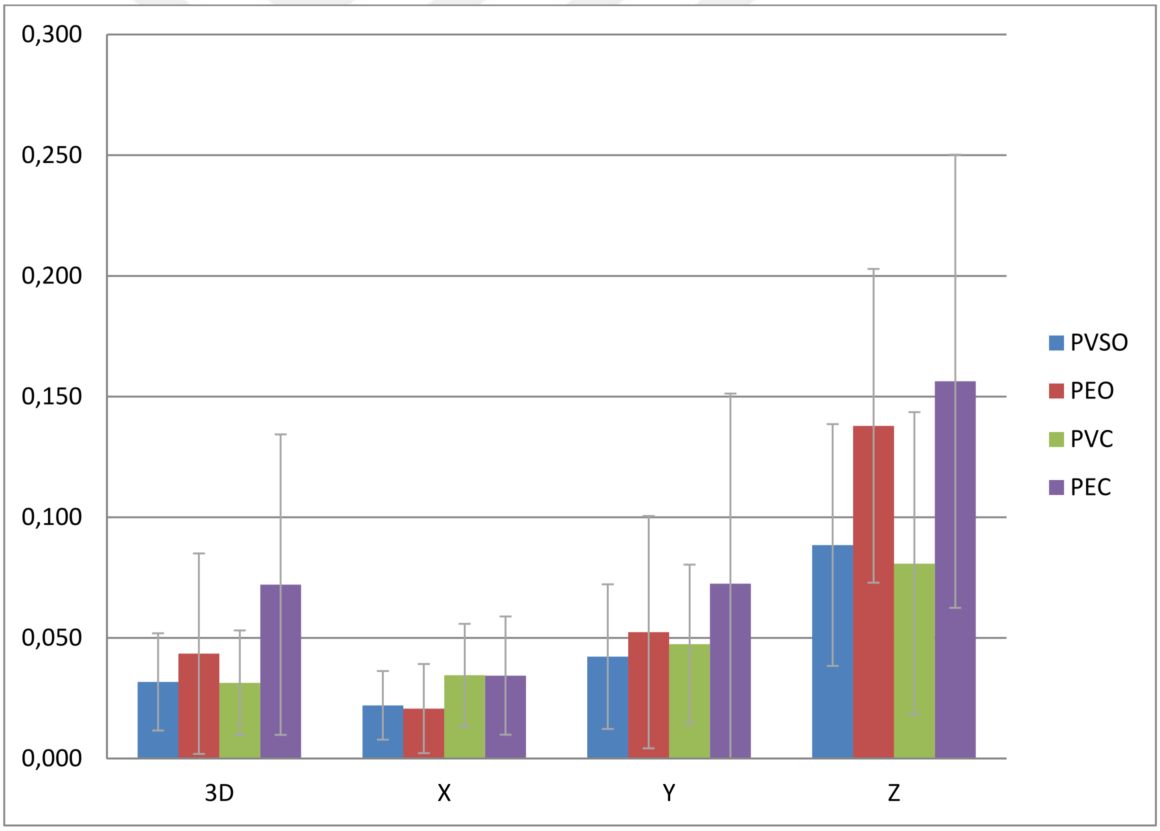

Figure 22. Means of the absolute values discrepancies in three dimensional and the three coordinates X.Y.Z in mm.

4.2. Comparing The Four Groups With Angulated Implants Discrepancies

The absolute values of discrepancies in three dimensional and the three coordinates X.Y.Z within angulated implants are presented as means (SD) in (Table 6) (Figure 23). Analysis of variance revealed that there was no significant difference between the groups related to three-dimensionaldiscrepancies, Y-axis and Z-axis (*P*=0.232,*P*=0.787, *P*=0.644). But a significant difference was found related to X-axis (*P*=0.020). In paired group comparisons (Table 7) the differences between PEO group and both PVSC and PEC groups were significant (*P*=0.010, *P*=0.017).

Table6.The mean absolute values of discrepanciesof angulated implants in three dimensional and the coordinates X.Y.Z distance inmm

	Direct Splinted Technique		**Indirect Snap-On Technique**			
	PVS	PE	PV	PE	*df*	*P* value
3D	0.034	0.032	0.029	0.058	3	0.232
SD	0.018	0.023	0.023	0.061		
X	0.023	0.018*	0.037*	0.033*	3	***0.020***
SD	0.016	0.026	0.015	0.024		
Y	0.052	0.062	0.049	0.080	3	0.787
SD	0.032	0.040	0.048	0.087		
Z	0.106	0.128	0.109	0.131	3	0.644
SD	0.051	0.071	0.053	0.084		

Table 7.paired group comparisons Mann–Whitney U-test

	3D	X	Y	Z
PVSO * PVSC	0.223	0.116	0.516	0.882
PVSO*PEO	0.425	0.163	0.534	0.245
PVSO*PEC	0.180	0.104	0.818	0.655
PVSC*PEO	0.417	***0.010***	0.387	0.337
PVSC*PEC	0.104	0.715	0.441	0.394
PEO*PEC	0.185	***0.017***	0.829	0.655

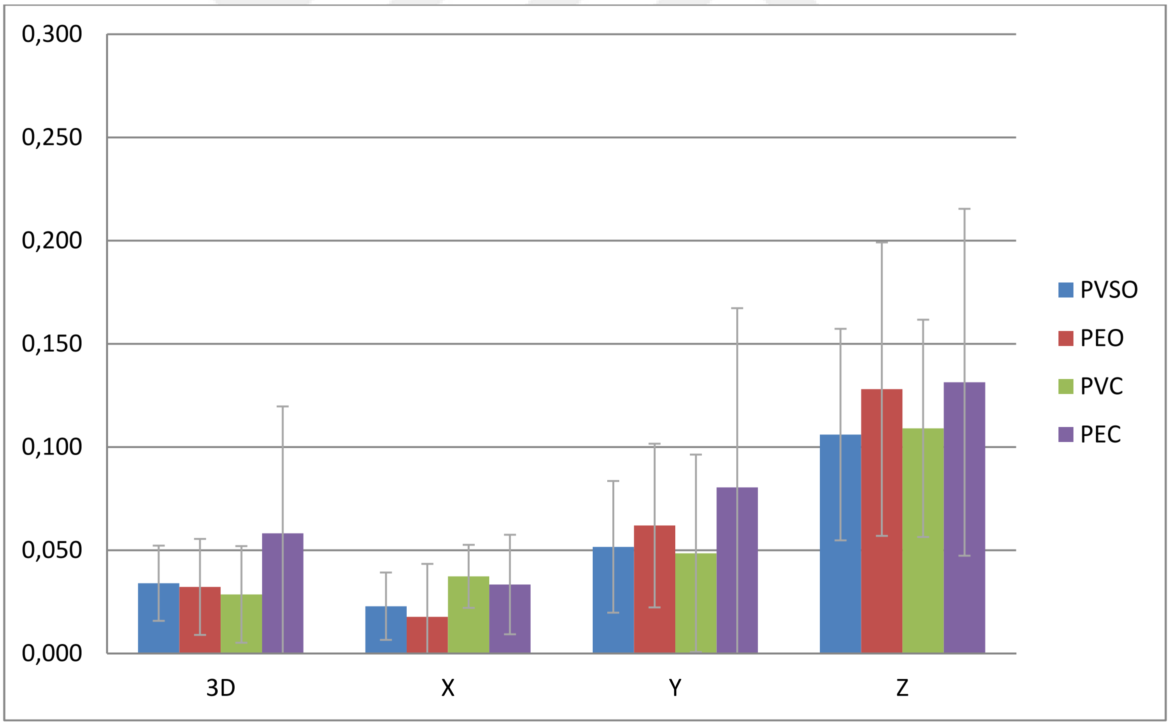

Figure 23.The mean absolute values of discrepanciesof angulated implants in three dimensional and the coordinates X.Y.Z distance inmm.

4.3. Comparing The Four Groups With Straight Implants Discrepancies

The absolute values of discrepancies in three dimensional and the three coordinates X.Y.Z within straight implants are presented as means (SD) in (Table 8) (Figure 24). Analysis of variance revealed that there was a significant difference between the groups related to three-dimensionaldiscrepancies,X-axis and Z-axis (*P*=0.003,*P*=0.046, *P*=0.000). While there was no significant in the Y-axis (*P*= 0.197). paired comparison between groups presented in (Table 9).

Table8.The mean absolute values of discrepanciesof straight implantsinthree dimensional and the coordinates X.Y.Z distance inmm.

	Direct Splinted Technique		**Indirect Snap-On Technique**			
	PVS	PE	PV	PE	*df*	P value
3D	0.029	0.055	0.034	0.086	3	***0.003***
SD	0.022	0.052	0.020	0.061		
X	0.021*	0.024	0.032*	0.035	3	***0.046***
SD	0.012	0.021	0.016	0.025		
Y	0.033	0.043	0.046	0.065	3	0.197
SD	0.025	0.048	0.026	0.071		
Z	0.071	0.148	0.053	0.181	3	***0.000***
SD	0.043	0.076	0.037	0.099		

Table 9.paired group comparisons Mann–Whitney U-test.

	3D	X	Y	Z
PVSO * PVSC	0.379	***0.026***	0.074	0.228
PVSO * PEO	0.062	0.957	0.839	***0.001***
PVSO * PEC	***0.001***	0.055	0.172	***0.000***
PVSC * PEO	0.185	0.051	0.144	***0.000***
PVSC * PEC	***0.006***	0.882	0.860	***0.000***
PEO * PEC	0.088	0.066	0.155	0.273

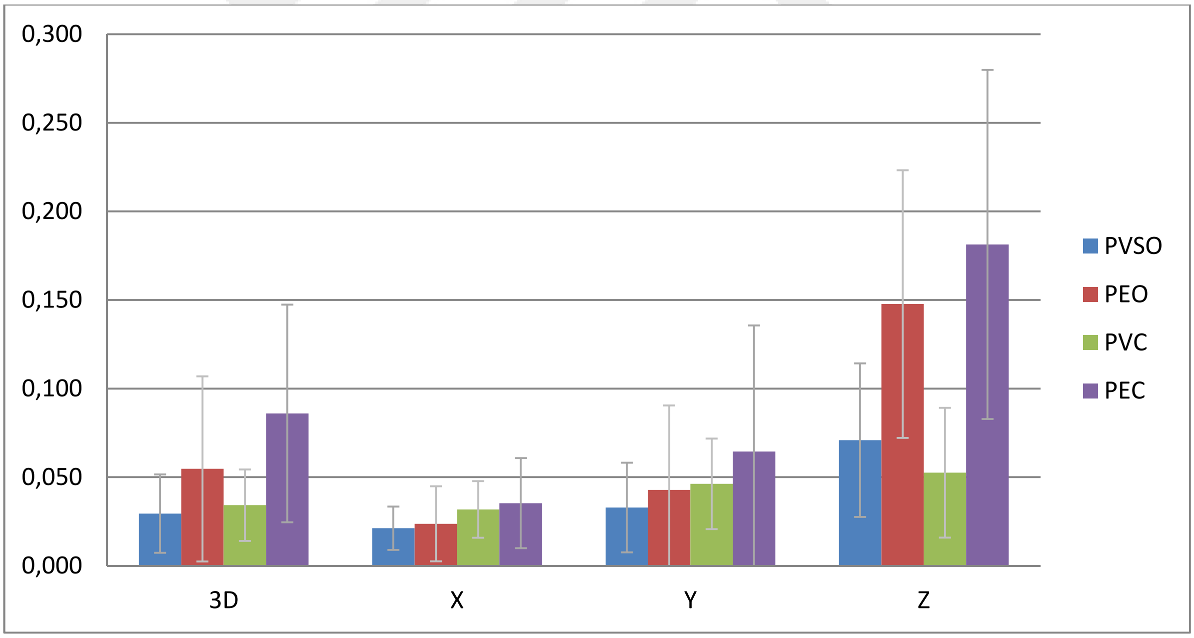

Figure 24.The mean absolute values of discrepancies of straight implants in three dimensional and the coordinates X.Y.Z distance in mm.

4.4. Comparing Angulated AndStraight Implants Discrepancies Within Same Group

The absolute values of discrepancies in three dimensional and the three coordinates X.Y.Z within straight and angulated implants are presented as means (SD) in (Table 10) (Figure 25). paired group comparisontest within angulated and straight implants within each group (Table 11) showed that there was a significant difference in the z-axis within PVSO (*P*=0.02). also a significant difference in z-axis within PVSC (*P*= 0.01).

Table 10.The means of absolute values of discrepancies in three dimensional and the coordinates X.Y.Z inmm. within straight and angulated implants.

			3D	Sd	X	Sd	Y	Sd	Z	Sd
Direct Splinted Technique	PVS	ANGULATED	0.034	0.018	0.023	0.016	0.052	0.032	_**0.106**_*	0.051
		STRAIGTH	0.029	0.022	0.021	0.012	0.033	0.025	_**0.071**_*	0.043
	PE	ANGULATED	0.032	0.023	0.018	0.015	0.062	0.048	0.128	0.053
		STRAIGTH	0.055	0.052	0.024	0.021	0.043	0.048	0.148	0.076
Indirect Snap-On Technique	PV	ANGULATED	0.029	0.023	0.037	0.026	0.049	0.040	_**0.109**_ *	0.071
		STRAIGTH	0.034	0.020	0.032	0.016	0.046	0.026	_**0.053**_ *	0.037
	PE	ANGULATED	0.058	0.061	0.033	0.024	0.080	0.087	0.131	0.084
		STRAIGTH	0.086	0.061	0.035	0.025	0.065	0.071	0.181	0.099

Table 11.paired group comparisons Mann–Whitney U-test

			3D	X	Y	Z
Direct Splinted Technique	**PVS**	Angulated	0.534	1.000	.064	**0.02**
		Straight				
	PE	Angulated	0.12	0.30	0.09	0.70
		Straight				
Indirect Snap-On Technique	**PV**	Angulated	0.26	0.57	0.86	***0.01***
		Straight				
	PE	Angulated	0.06	0.81	0.52	0.06
		Straight				

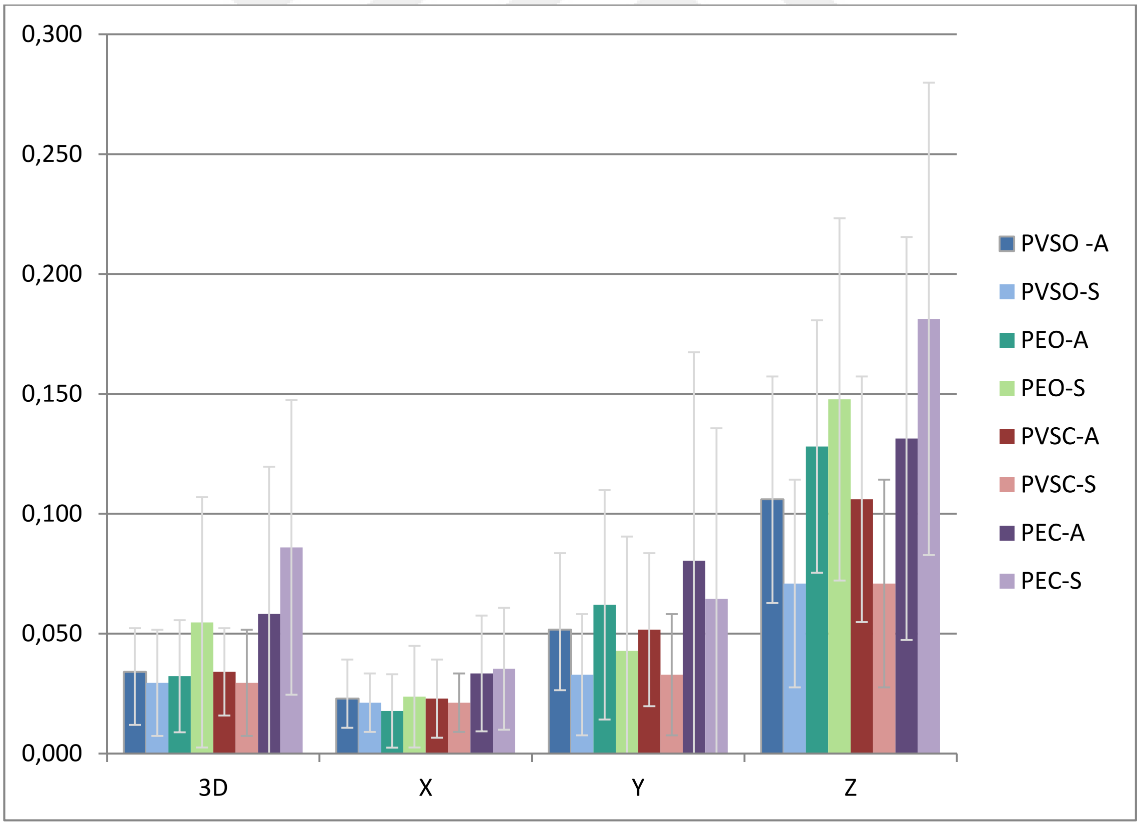

Figure 25.The means of absolute values of discrepancies in three dimensional and the three coordinates X.Y.Z in mm. within straight and angulated implants (A- angulated, S-straight).

4.5. Comparing Two Technique Regardless Of Material And Angulations

The mean of discrepancies of both splinted open and snap on technique regardless of the material presented in (Table 12) (Figure 26). Paired group comparison showed no significant differences in 3D and Y, Z axes (*P*=0.173, *P*=0.285, *P*=0.687). While the significant difference in x-axis within two technique (*P*=0.000) was found. The mean (SD) of the direct splinted technique in x-axis was 0.021(±0.016)mm, and the mean of snap-on technique was 0.034(±0.023) mm.

Table 12.The mean of discrepancies of direct splinted and indirect snap on technique regardless of the material in mm

	Direct Splinted Technique		**Indirect Snap-On Technique**		***P* value**
	Mean	SD	Mean	SD	
3D	0.038	0.033	0.052	0.051	0.173
X	0.021	0.016	0.034	0.023	***0.000***
Y	0.047	0.040	0.060	0.061	0.285
Z	0.113	0.063	0.119	0.088	0.687

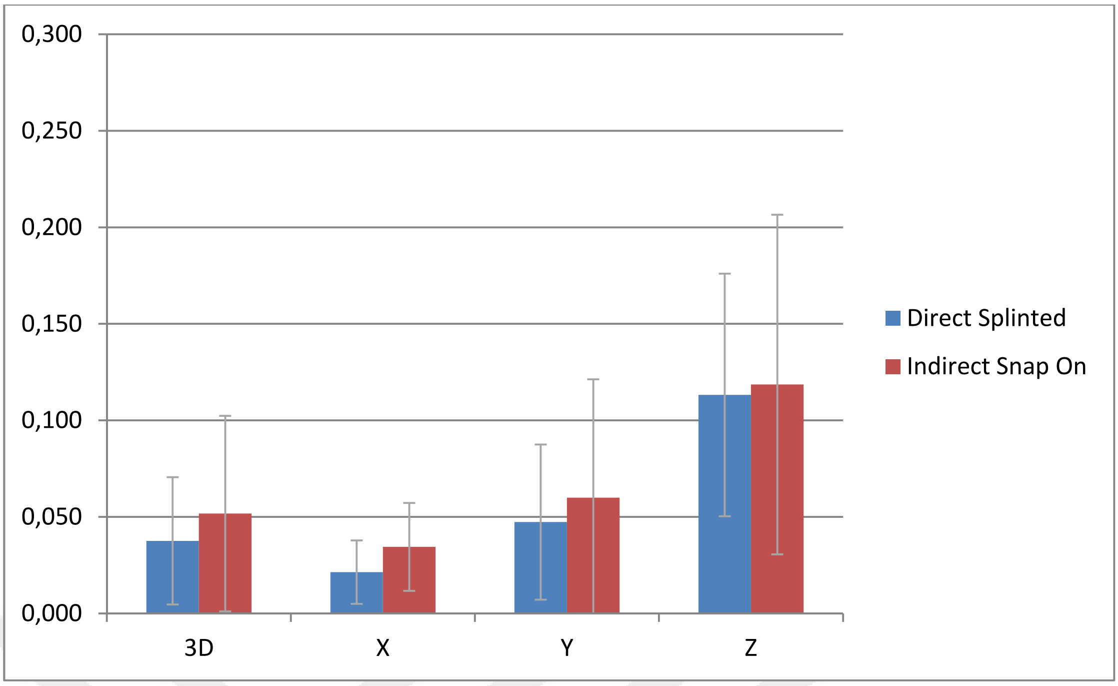

figure 26. The mean of discrepancies of direct splinted and indirect snap on technique in mm regardless of the material and angulations.

4.6. Comparing Two Material Regardless Of Technique And Angulations

The mean of discrepancies of both polyvinyl siloxane and polyether material regardless of the technique presented in (Table 13) (Figure 27). Paired group comparison showed significant differences in 3D and Z axis (*P*= 0.002, *P*=0.000). The mean (SD) of the polyvinyl siloxane in 3D was 0.32 (±0.021) mm, while the mean (SD) of polyether was higher with 0.058 (±0.055) mm. The means (SD) in the z-axis of both polyvinyl siloxane and polyether materials were 0.085(±0.057) and 0.147(±0.081) mm respectively. There were no significant differences in x-axis and y-axis within two material (*P*= 0.507, *P*=0.532) was found.

Table 13. The mean of discrepancies of polyvinyl siloxane and polyether in mm

	polyvinyl siloxane		polyether		*P* value
	Mean	SD	Mean	SD	
3D	0.032	0.021	0.058	0.055	***0.002***
X	0.028	0.019	0.028	0.023	0.507
Y	0.045	0.031	0.062	0.066	0.532
Z	0.085	0.057	0.147	0.081	***0.000***

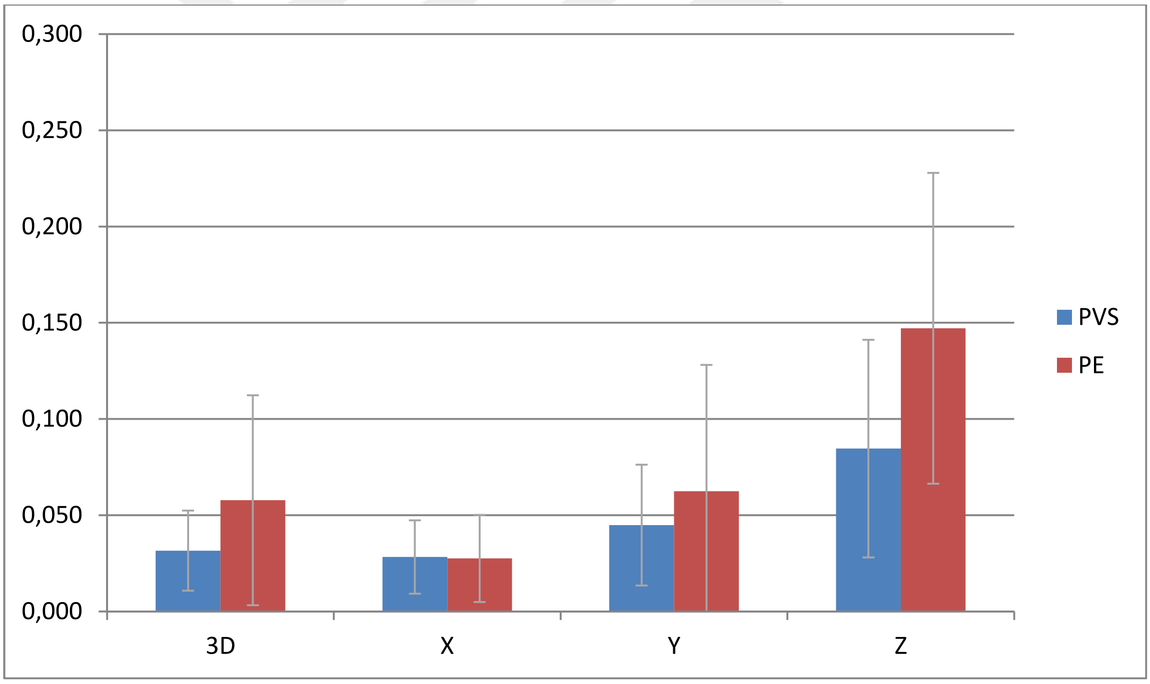

Figure 27. The mean of discrepancies of polyvinyl siloxane and polyether material in mm. regardless of technique and angulations.

4.7. Comparing Angulated And Straight Implants Regardless Of Technique And Material

The mean of discrepancies of both angulated and straight implants regardless of technique and material presented in (Table 14) (Figure 28). Paired group comparison showed no significant differences in all axes.

Table 14. The mean of discrepancies of both aangulated and straight implants regardless of technique and material in mm.

	Angulated		Straight		P Value
	Mean	SD	Mean	SD	
3D	0.038	0.037	0.051	0.048	0.070
X	0.028	0.022	0.028	0.020	0.607
Y	0.061	0.056	0.047	0.047	0.058
Z	0.119	0.066	0.113	0.086	0.168

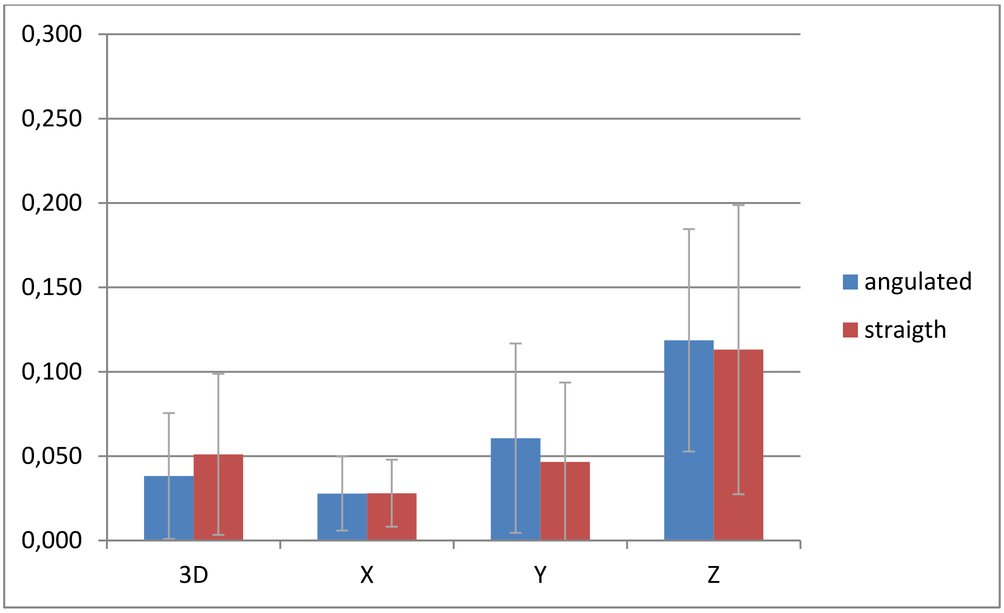

Figure 28. The mean of discrepancies of both angulated and straight implants regardless of technique and material in mm.

4.8 Interaction Between Three Factors

Three-wayANOVA analysis of the three-dimensional discrepancy variable

revealed that (Table 15), the effect of implant angulations was significant (F= 4.162, *P*=0.043). There was a significant effect of both material and technique (F=5.069, *P*=0.026) (F=17.439, *P*=0.000). While the interaction between the angulations and technique was not significant (F=0.381, *P*=0.538). Also the interaction between angulations and material (F=3.843, *P*=0.52). A significant effect was observed in the interaction between technique and material (F=5.323, *P*=0.22). No significant interaction between the three-factor (F=0.038, *P*=0.845).

Source	Type III Sum Of Squares	df	Mean Square	F	Sig.
Angulations	0.007	1	0.007	***4.162***	***0.043***
Technique	0.008	1	0.008	***5.069***	***0.026***
Material	0.027	1	0.027	***17.439***	***0.000***
Angulations * Technique	0.001	1	0.001	.381	.538
Angulations * Material	0.006	1	0.006	3.843	.052
Technique * Material	0.008	1	0.008	***5.323***	***0.022***
Angulations * Technique * Material	0.000	1	0.000	.038	.845

Table 15. ANOVA table for three dimensional discrepancy in total implants

5. DISCUSSION

The clinical fit of an implant prosthesis at the implant-abutment junction is directly dependent on the accuracy of impression technique and cast fabrication. Hence, an accurate implant impression is mandatory to provide an accurate definitive cast, which is the milestone in the fabrication of an accurately fitting prosthesis. The advancement in computer-assisted design/computer-assisted manufacturing technology increased the precision of fit of implant prostheses through improving the framework fabrication procedures accuracy(73).

The accuracy of implant impressions plays a significant role and serve as a starting point in the process of producing good working casts. Several factors influence the accuracy of a final cast for the fabrication of an implant prosthesis, such as the impression technique used, the implant connection type, splinting or surface treatment of impression copings, the type of impression material used, the impression type, implant angulations and number, the depth of implant position, the dimensional stability of the gypsum used to fabricate the cast and the length of the impression copings(11–16). Nowadays we consider that the clinical fit of an implant prosthesis at the implant-abutment junction is directly dependent on the accuracy of impression technique and the fabrication of a precise definitive cast that exactly transfers its intraoral position for the long-term stability of the implant prosthesis(11,17).

The clinical significance of the discrepancies and its thresholds still a controversial. Several authors have published on the acceptable level of implant prostheses misfit, with a range of values reported including 0.010 mm,0.100 mm, and 0.150 mm according to Branemark, Ma, And Jemt respectively(7,21,22). Assuncao et al stated that in a good impression there is a possibility to find a discrepancy of 0.050 mm in any axis(93). An experienced operator cannot detect discrepancies less than 0.030 mm in the fit of an implant-retained framework on multiple abutments, for that reason this figure could be a criterion between acceptable and unacceptable prosthesis (92). Papaspyridakos et al concluded that a maximum range of discrepancy or misfit between 0.059 to 0.072 mm still resulted in a clinical fit with one-piece implant-supported prostheses(74).

5.1 Discussion Of Methodology

The aim of the present study is to evaluate one of the main factor affecting the end fit of the multi-implant supported fixed prosthesis. Evaluation the impression accuracy and three-factor affecting that accuracy: (implant angulation,impression material, impression technique). Through Comparing the impression accuracy in case of a model with four implants, simulating the situation of all on four cases, using two different technique and two different materials. Design of our study included four groups: direct (open) splinted technique with polyvinyl siloxane group (PVSO group), indirect (close) snap-on technique with polyvinyl siloxane group (PVSC group), direct(open) splinted technique with polyether group (PEO group), and indirect(close) snap-on technique with polyether group (PEC group) (table 2).

The implant-level impression was used although, abutment level impression technique consider to be more favorable in case of internal connection implant systems. It could be difficult to select and choose the appropriate abutment especially in case of extensive rehabilitation cases, where vertical spaces and implant angulations could be assessed more easily and precisely in the laboratory. From that point of view, implant level impression technique will show a great advantage(40,98).

Directed splinted techniquehas been chosen for two groups (PVSO and PEO groups) in this study. The reason that many authors had advised splinting the impression coping together before making the impression in order to increase the accuracy and avoid the distortion particularly while fastening the implant analogs to its related coping, which have been reported to might lead to rotational distortion(31,32). Many materialshave been used as splinting material like light-curing composite resin, impression plaster, orthodontic wire, acrylic resin and auto polymerizing acrylic resin(20,33). The most commonly used material as splint is auto polymerizing acrylic resin, the dimensional shrinkage of resin is one of the main drawback points, which need to be considered.Mojon et al. investigated the shrinkage behavior of acrylic resin and reported that total shrinkage of 6.5% - 7.9% and around 80% of the total shrinkage occurs within the first 17 min(34). Some authors had stated that such shrinkage might lead to distortion of the impression coping position within the impression material (35).

In order to avoid this disadvantage in the present study,prefabricated transparent bars were used and connected to the impression copings using self-cure acrylic resin. Which provide an easy and fast method to make the splint and more applicable to the clinic(99).

Moreover, theindirectsnap-on technique was used for two groups (PVSC and PEC groups) in our study. The main advantage of this technique that it provides the simplicity of the indirect technique, and at the same time provide comparable accuracy to the direct technique. Lorenzoni et al. stated that the use of transfer plastic cap with the indirect technique provides a higher accuracy for the impression. Reported that discrepancies in x-axis without the application of transfer cap was 3·4 (±0·7)mm as compared with the application of transfer cap 0·2 (±0·04)mm. Discrepancies in Z-axis without transfer cap were 0·28 (±0·03)mm, while with transfer cap 0·17 (±0·02)mm were found(41). Shim et al investigated indirect snap-on technique, concluded that indirect snap-on impression technique have the convenience of using closed trayand their reproducibility is similar to that of direct impression technique (13).

The methodology of our study was standardized in order to avoid the effect of the other variable. That includes the use of a new coping for each impression in order to avoid the error which mightproduce from the reuse of the coping(97). All the impression were done using a custom tray with 3mm space in order to provide enough and uniform thickness of the impression material, some author reported an effect of the impression material thickness on the end outcome(24,60).Using an auto-mixing machine for both polyether and polyvinyl siloxane material to avoid error and inhomogeneity of hand mixing. To decrease the effect of the dimensional changes of impression material the manufacture instruction was followed and all the impressions were poured within 24 hours and not before 1 hour in order to get the best results(100). In order to decrease the error out of pouring procedure,two-step pour technique wasused, that the impression is poured with auto-mixing machine up to the half of the implant analogs, and after the set of the first pour around 1-hoursecond pour was performed. It has been reported that this technique decreases the stone expansion(82). In addition, type four stone were used which consideredbeing the best stone material in term of less dimensional changes(63). A Single operator did the whole laboratory steps to decrease the intraoperator errors.

While making the scan for the prepared models, an O-ring abutment where attached over each implant analog. In order to avoid the use of contrast spray which reported to form around 12 µm layer thickness(74).Sandblasting where performed to each abutment to make it readable for the scanning machine. In addition the same abutment (o-ring) where used for the same implant number in order to avoid the difference within those abutments and avoid the inherited machine tolerance which has been reported to be around 50 µm(7). Other author reported that implant component ranging from 22 to 100 µm(21). For the measuring procedure, the operator was blinded regarding the group's models through using the coding to decrease the interoperator error.

Regarding methodology of discrepancies measurements, different methods have been used to measure and quantify the 3-D displacement on the x-, y- and z-axis between the implant models made with different impression techniques including computerized coordinate measuring machine, 3-D photogrammetric, travelling microscope, computerized tomography (CT) scan and more recently optical scanning and digitization(11).Several studies indirectly assessed the implant impression accuracy by assessing the fit and/or distortion of fabricated frameworks on the resultant models with strain gauges and compared the fit and/or distortion of the frameworks on the reference master models(90).

Other studies indirectly assessed the implant impression accuracy by evaluating the fit of frameworks with microscopes (29,82,91). Lastly, other studies evaluated the accuracy of the implant impressions by measuring inter-implant distances of the working casts in relation to a reference control cast (18,24,30,33,35,92,93).However, with the advent of 3-D measurement devices, a 2-D assessment of the accuracy cannot be accepted today for scientific purposes. Optical scanning and dedicated software for superimposition of the scanning datasets is currently an efficient and precise technique to measure and compare the 3-D discrepancies at the microscopic level between different groups and thus seems to be the recommended technique for future investigations(11,94).

Discrepancies can be measured as "absolute" or "relative" values, depending on the reference point from which the measurement is done. Barret et al used the absolute discrepancies where the reference point was positioned outside of the distortion medium(49). In contrast using the relative discrepancies with a reference point within the distortion medium, even in some studies using one of the implants as a reference. This technique could be clinically more relevant(24,27,69).

For our study design, optical scanning was used as it consider one of the most accurate methods(11). Even optical scanning became one of the main steps in manufacturing the prosthesis framework with CAD CAM milling machines. For that reason, even the scanning systemic error which is around 10-8 µm. Could be included in the overall value of the produced models discrepancies in order to make the prosthesis. In addition, Our study evaluated the relative discrepancies related to reference point positioned on the posterior part of the palate. which consider within the distortion medium, this method has been used by many previous studies(62,76,95,96,101,102). We prefer this method over the inter-implant discrepancies measurementbecause that method could be misleading if all implants show discrepancies in vertical (z-axis). Discrepancies were evaluated in three-dimensional position and transitionaldiscrepancies in the three axes (x, y, z) which is the best and most reliable method rather than just using three-dimensional discrepancies which again could not show the real and exact discrepancies for each implant.

One of the advantages of our study, an anatomical model with edentulous upper jaw was used. Simulating the clinical situation in term of undercut and spaces between implants. It simulates the strain generated during impression removal from patient mouth instead of using smooth and flat blocks. Another advantage of our study that a precise measuring method was used for assessing the dimensional changes. Where the Scanning machine which was used has a systemic error of 7-10 µm. While the measuring procedure on the three-dimensional designing program had an error of 3 µm, which consider accurate enough for our measurement. It should be noted that stander deviationsof our data regardless of PEC group which show high variation, were falling within 0.016 and 0.065 mm. Which considered acceptable compared to the previous studies. Although this deviation could be explained through machining tolerance of implant component, impression material contraction, stone expansion and operator error.

5.2. Discussion Of Results

Regarding the findings of our study, the first hypothesis that no significant differences between the four groups regarding impression accuracy were rejected, analysis of variance revealed that there was a significant difference between the groups related to three-dimensional discrepancies (P=0.003), Furthermore there was a significant difference between the groups related to the x-axis discrepancies (P=0.001). Even that there was no significant difference between the groups related to the y-axis discrepancies (P=0.673), A significant difference between the groups related to the z-axis discrepancies (P=0.000).

The second hypothesis that no significant difference between direct splinted technique and indirect snap-on technique regardless of the impression material type was rejected. Where a significant difference in x-axis within two technique (P= 0.000) was found. The mean of the open splinted technique in x-axis was 0.021(±0.016)mm, and the mean of snap-on technique was 0.034(±0.023) mm.

Martinez- Rus et al. in a previousin vitro study evaluated the impression accuracy of a model with eight implants with different angulations (0°, 15°, 30°) using four different techniques, indirect technique, un-splinted direct technique, acrylic resin-splinted direct technique, and metal splinted direct technique, Twenty impressions were done with polyether impression material. In comparison with the master cast, the casts made by the acrylic resin-splinted direct technique showed a mean of 0.084 mm, and metal-splinted open techniques had a mean of 0.038 mm, which was the most accurate method. Unsplinted direct technique recorded the highest distortion with a mean of 0.172mm followed by those obtained from the indirect technique with a mean of 0.158mm. This result in agreement with our result that splinted technique produced the best accuracy. But a best result found in our study related to indirect technique, which could be explained by that we used polyvinyl siloxane impression material in PVSC group, which show an accuracy comparable to the PVSO group(32).

Shim et al. investigated the impression accuracy of three models with two implants each positioned in different angulations (parallel, 15°mesiodistal, and

15°buccolingual) using three techniques indirect technique, indirect snap-on technique, and direct technique. Impressions were done with polyvinyl siloxane impression material. The result of this investigation revealed that no significant difference between the error rates of indirect snap-on technique, direct technique. While the indirect technique was significantly different from other two technique. These finding in agreement with our results, that indirect snap-on technique with a polyvinyl siloxane (PVSC group) provide comparable results to the direct technique with a polyvinyl siloxane (PVSO group).

Tsagkalidis et al. investigate the accuracy of three different impression techniques (open non-splinted, open acrylic-resin splinted, and close snap-on) for 6 internal-connected implants with angulations of (0°, 15°, 25°) using polyether. Splinted impression technique providedthe highest accuracy. Results showed that at 25° of implant angulations, the highest accuracy was obtained with the splinted technique (0.039 ±0.05 mm) while the worst results were recorded with the snap-on technique (0.085 ±0.09 mm); at 15° angulations, no significant differences were found between splinted (0.22 ±0.04 mm) and non-splinted technique (0.15 ±0.02 mm) and the lowest accuracy obtained with the snap-on technique (0.95 ±0.15 mm)(79). These finding in agreement with our results, where in case of polyether impression material, PEO group was significantly more accurate than the PEC group in 3D and x-axis ($P=0.034$, $P=0.007$). Although direct splinted, and indirect snap-on techniques showed a comparable result with polyvinyl siloxane impression material. Where no significant difference was found between PVSO and PVSC groups in 3D, y-axis, z-axis. But a significant difference was found in the x-axis, The PVSO group showed a mean of 0.022(±0.014)mm. While ThePVSC group showed a mean of 0.035(±0.018) mm.

Saidat et al. compare the accuracy of two different impression techniques for the All-on-Four implant therapy protocol. 40 models were prepared using the direct and indirect technique with both implant and abutment level technique, polyvinyl siloxane where used. Coordinate measuring machine was used for measuring 3D positional discrepancies. The result of this investigation showed less linear and rotational displacement with implant level impression for the direct technique when compared with the indirect technique. Mean discrepancies of 0.121(±0.144) mm and 0.182(±0.201)mm related to straight and angulated implants respectively were recorded for implant level direct technique. while the mean discrepancies of implant level indirect technique group were 1.21 (±0.67) mm for straight implants and 0.523(±0.72) mm for angulated(96). These findings disagree with our finding, no differences was found between PVSO and PVSC group in the 3D position. That could be explained by that in our study indirect snap-on technique were used, which have been reported to be more accurate than indirect technique without plastic cap(41). Even the mean values of 3D discrepancies and the standard deviation value were too high compared to our study which might raise a question about the reliability of those findings.

Alexander Hazboun et al compared both direct and indirect impression technique accuracy for a model with six internal connection implant with angulations 0°, 15°, 30°. Polyether impression material was used. The finding showed that no significant difference between both techniques. The mean difference in linear discrepancies in models made with direct impression technique was 0.024 (±0.019) mm. The mean difference in linear discrepancies in models made with a indirect impression technique was 0.023 (±0.021) mm(38). These findings disagree with our finding that a significant difference in 3D discrepancies wasfound between PEO and PEC groups. where PEO group showed a better result with a mean of 0.043(±0.042) mm, while the PEC group had a mean of 0.072(±0.062) mm. There was no clear explanation for this disagreement, unless that the methodology of this study is questionable; that three view of digital photograph where used to assess the discrepancies. which is not enough to give a clear and a real result .

Conrad et al. investigated the effect of implant angulations on the impression accuracy, using the direct and indirect technique. Polyvinyl siloxane material was used. One control group with three parallel implants, six experimental group with difference angulations (5°,10°,15°). The result of this study revealed that the angle errors for the indirect and direct impression techniques did not differ significantly(62). This in agreement with our result that PVSO and PVSC group did not show a significant difference in 3D, y-axis, z-axis. But a significant difference was found in the x-axis, The

PVSO group showed a mean of 0.022(±0.014) mm. While The PVSC group showed a mean of 0.022(±0.014) mm.

Lee HJ et al. compared direct splinted and indirect impression technique accuracy using the fit of prefabricated frameworks and measuring the vertical gap with a light microscope. Three definitive casts, each with three implant analogs at different angulations of 0°, 30°, 40°.polyvinylsiloxane impression material was used. The indirect and direct splinted technique showed significantly different vertical gap according to angulations of implant. With 0°angulationsmodel, a mean of 0.087(±0.040)mm was recorded for indirect technique, while a better result with direct splinted technique with a mean 0.045(±0.021) mm. The mean vertical gap with 30° model was0.090(±0.044)mm and 0.052(±0.014) mm related to indirect and direct splinted technique respectively. The means at 40° model were 0.112(±0.050)mm and 0.049(±0.012)mm related to indirect and direct splinted technique respectively(103). This study could not be compared exactly to our study because of the different techniques in assessing the discrepancies. Although it clear that it does not agree with our study, where the difference between our PVSO and PVSC was not significant, unless in the x-axis. The PVSO group showed a mean of 0.022(±0.014)mm. While The PVSC group showed a mean of 0.035(±0.018)mm. Which not clear if such difference will lead to the same value of framework misfit. Moreover, this study used the indirect technique, while we used the indirect snap-on technique which has been reported to be more accurate(41).

The third hypothesis, that no significant difference between both impression material polyvinyl siloxane and polyether regardless of the technique was rejected. Where significant differences in 3D and Z axis ($p= 0.002$, $p=0.000$) were found. The mean of the polyvinyl siloxane in 3D was 0.032 (±0.021) mm, while the mean of polyether was higher with 0.058 (±0.055)mm. The means in the z-axis of both polyvinyl siloxane and polyether materials were 0.085(±0.057) mm and 0.147(±0.081)mm respectively.

This in agreement with a previous study which concluded that polyvinyl siloxane did demonstrate a statistically significant, though numerically slight, superiority for angular distortion with a difference of 0.643° (66). Which could be explained by the more favorable modulus of elasticity (rigidity) which allows easy removal of the impression in case of angulated implants as the case in our study(12,35,49).Wee reported a similar recommendation, that because of the high rigidity of polyether, which might be a good advantage in term of preventing rotational movement of the impression coping within the impression. it became difficult to handle the polyether in case of partially edentulous cases because of the present undercuts, the same principle can be applied for the extreme angulated implants(24). Lorenzoni et al reported same results that there was a significant difference between polyether and polyvinyl siloxane groups and the best result was achieved through indirect snap-on technique with a polyvinylsiloxane(41). On the other hand our results disagree with many previous authors who reported that both polyether and polyvinyl siloxane material could provide accurate comparable results(1,12,25,35,48–50,66,69–72,100).

The fourth hypothesis that no significant difference between straight and angulated implants impression accuracy was accepted. That according to our findings paired group comparison showed no significant differences in all axis. This result might be miss leading because of the polyether impression material groups which affect the whole behavior of the sample. Implant angulations effect on the accuracy of implants impression has been investigated in many studies, Kim had reported that presence of angulated implant will lead to more distortion in the implant impression(27). Papaspyridakos et al. reported in a systemic review that angulated implants greater than 20 degrees will lead to less accurate impressions(74).Assuncao et al. compared accuracy of impression technique and material related to 4 different angulations 90°,80°,75°,65°. metal matrix with four implants was prepared as control model and different techniques and material was used, as a result they concluded that the less angulated the implant was the more accurate was the impression provided, the greatest dispersion occurred in implants at 65°(104).

On the other hand, some authors found that there was no significant difference between angulated and straight implant effect on impression accuracy(62,90). Gillian et alinvestigated the implant angulations effect by comparing the accuracy of close and open tray technique in case of angulated implants, a model with six implants with different angulations 0°,15°,30 °was prepared and 12 experimental casts were prepared with each technique. The result showed that there was no difference in the accuracy between the different angulated implants in both groups(38).

The fifth hypothesis was rejected where a significant difference was found between straight and angulated implants within PVSO and PVSC groups. that even that the 3D and x-axis, y-axis showed no significant difference.there was a significant difference in the z-axis within PVSO group with a mean of 0.071(±0.043)mm for straight implants and 0.106(±0.051)mm for angulated implants. Also a significant difference in z-axis within PVSC with a mean of 0.053(±0.037) mm for straight implants and 0.109(±0.071)mm for angulated implants. Some author reported that the effect of implant angulations can be increased in case of internal connection implant system (78), as it is the situation in our study. Furthermore, the results of polyether groups were not significant because both the angulated and straight implants had a closer result which was far worse than that of the polyvinyl siloxane groups.

6. CONCLUSION

The following conclusion were drawn out of this study:

- The direct splinted technique with polyvinyl siloxane showed the lowest discrepancies with mean discrepancies of 0.032 (±0.020)mm in 3D, 0.022(±0.014)mm in x-axis, 0.042(±0.030)mm in y-axis, and 0.088(±0.050) mm in z-axis.
- The indirect snap-on techniquewith polyvinyl siloxane showed the closest accuracy to the direct splinted technique with polyvinyl siloxane. with mean discrepancies of 0.031 (±0.022)mm in 3D, 0.035(±0.021)mm in x-axis, 0.047(±0.033)mm in y-axis, and 0.081(±0.063)mm in z-axis.
- Polyether impression material groups showed higher discrepancies, particularly in the z-axis. with a mean of 0.138(±0.065)mm for PEO group, and a mean of 0.156(±0.094)mm for PEC group.
- Implant angulation showed a clear effect on impression accuracy (P=0.043).And a better result could be reached with polyvinyl siloxane material (P= 0.002).

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