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TRABAJO DE FIN DE GRADO

Grado en Odontología

DIGITAL VS. CONVENTIONAL IMPRESSION ON IMPLANTS

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ABSTRACT

Introduction: In today's survey, a comparison between the two techniques of impression, the digital one and the conventional one, was carried out to evaluate which of the two options is commonly considered more accurate and more reliable in the context of implant-prosthetic studies, analyzing both methods and describing with a quick reference, also to the materials used in both techniques. The goal is to provide the clinician with a framework to understand which impression technique has the best performance for patients and for daily clinical activity. The literature on the accuracy of the impressions generated by scanners applied, above all in full-arch rehabilitation on implants, is very scarce and often contradictory. **Objectives:** The present study focuses on the comparison of the accuracy, in the context of implant-prosthetic field, between the innovative method for making digital impressions and the traditional method of conventional impressions, also considering which one of them is more comfortable for the patient. Moreover, a comparison between conventional techniques is performed to understand which one is more accurate. **Materials and Methods:** The PubMed, MEDLINE and CRAI library medical databases were mainly used for the literature research. **Conclusion:** Digital impression for a single restoration or for a 3-4 elements bridges on implants is as accurate as conventional impression. In the rehabilitation of whole arches, it has been stated that conventional impression is more accurate than digital one, even if some authors claim that the digital one is no less precise than the conventional one. Among the conventional impressions, the indirect technique is the most accurate. The most comfortable technique for patients is the digital one.

Keywords: implants impression, intraoral scanner, extraoral scanner, open-tray impression technique, closed-tray impression technique, CAD-CAM technology, accuracy, precision, digital work-flow.

RESUMEN

Introducción: En la encuesta de hoy, se realizó una comparación entre las dos técnicas de impresión, la digital y la convencional, para evaluar cuál de las dos se considera comúnmente más precisa y confiable en el contexto de los estudios implanto-protésicos, analizando ambos métodos y describiendo con rápida referencia los materiales utilizados en ambas técnicas. El objetivo es proporcionar al médico un marco para comprender qué técnica de impresión tiene el mejor rendimiento para los pacientes y para la actividad clínica. La literatura en este campo, especialmente en la rehabilitación de arcada completa sobre implantes, es muy escasa y contradictoria. **Objetivos:** El presente estudio se centra en la comparación de la precisión, en el contexto de estudios implanto-protésicos, entre el método innovador para realizar impresiones digitales y el método tradicional de impresiones convencionales, teniendo en cuenta también cuál de ellos es más cómodo para el paciente. Además, se realiza una comparación entre las técnicas convencionales para comprender cuál es más precisa. **Materiales y Métodos:** Las bases de datos médicas PubMed, MEDLINE y la biblioteca CRAI se utilizaron principalmente para la investigación de la literatura. **Conclusión:** La impresión digital para una única restauración o para puentes de 3-4 elementos sobre implantes es tan precisa como la impresión convencional. En la rehabilitación de arcadas completas se ha demostrado que la impresión convencional es más precisa que la digital, aunque algunos autores afirman que la digital es igual de precisa que la convencional. Entre las impresiones convencionales, la técnica indirecta es la más precisa. La técnica más cómoda para los pacientes es la digital.

Palabras clave: implants impression, intraoral scanner, extraoral scanner, open-tray impression technique, closed-tray impression technique, CAD-CAM technology, accuracy, precision, digital work-flow.

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1. INTRODUCTION

1.1 Origin of dental implants

The purpose of the dentist is to prevent, treat and rehabilitate the lost oral health condition of the patient. Among these, an especially important role is played by the rehabilitation of oral health, not only for the restoration of health but also for the restoration of aesthetics: today, in fact, society has developed a strong aesthetic sensibility and the cult of exteriority, in a form of perfectionism that sometimes reaches paroxysmal levels, often even not very acceptable, since even the small imperfections characterize the individuality of each of us and the diversities that make us unique.

Rehabilitation involves various treatments, including the repositioning of lost teeth. One of the options to restore an absent tooth is represented by the use of a dental implant: for many years, dental implants have been employed successfully to handle completed or partially edentulous patients, using an implant-supported fixed dental prosthesis (1).

The need to replace missing teeth was already present in antiquity, at the time of the ancient Egyptians, Etruscans and Phoenicians, who used gold ligatures to immobilize teeth that were periodontally sick and also used oxen bones as substitutes for teeth (2).

Therefore, it can be said that, over time, men have striven to create different types of dental implants that replace absent natural teeth's position, both in function, phonation, and aesthetics. The historical scholars bring us the testimonies and evidence, thanks to the archaeological finds, of different materials used to create a dental implant. These materials include shells, ivory, gold wire for ligatures, cobalt, chromium, platinum and iridium (2).

In addition, it was possible to identify different types of dental implant designs, starting from spiral stainless-steel implants up to today's most modern, efficient and cutting-edge designs and structures.

Implant surfaces have been modified, in order to make the external surface as suitable as possible for integration into the mandibular or maxillary bone. Therefore, the implant surfaces were subjected to sandblasting, fluoridation, oxidation, etching and, finally, dressing processes (2).

Over the course of history, scholars and researchers have tried to modify and to perfect the structures, shapes, and materials to make them superior and better suited to the needs of patients.

In the field of implantology, the most relevant and innovative discovery was that of the clinician P. Brånemark. In 1952, Dr. Brånemark, in fact, accidentally discovered the link that was created between bone and titanium, when these two encountered each other. In fact, while he was studying and analyzing the blood flow in rabbit femurs, by putting titanium chambers into their bone, Dr. Brånemark noticed how the bone had joined to the surface of titanium: the metal, indeed, was rigidly connected to the bone and it was not possible to separate them. He also noted that when a fracture occurred, it always took place between bone and bone, never between implant and bone. Therefore, Brånemark exploited this link between bone and titanium implant and adapted this discovery to the field of dentistry. He patented and introduced an implant that had the shape of a dental root, made of two-stage threaded titanium, in addition, he created a set of pure titanium screws, which he called a fixture (2). For the first time, in 1965, this type of implant was placed in his patients. This experiment was the first to be documented in detail and these implants were the best maintained to date.

With its discovery, the concept of osseointegration was introduced, defined by Brånemark as "a direct structural and functional connection between ordered, living bone, and the surface of a load carrying implant"(3).

Over time, after the Brånemark's discovery of the titanium implant, other types of implants have been invented such as, the IMZ implant, the Stryker implant, ITI-sprayed implant and the Core- Vent implant (2).

1.2 Dental implants

Dental implants are metallic structures made of titanium, conic or cylindrical, they act as artificial roots, they are placed inside the maxillary and mandibular bone in the area where the teeth were located, with the aim of supporting a prosthesis that will act as teeth (4). A dental implant is a supporting device over which a prosthesis is located to replace missing teeth. The ability of the implant to create an intimate contact between its metallic surface and the bone in which is located, is called *osseointegration*, defined as a direct, functional and maintained connection, which prevents the implant to move (4). In this way, the dental implant allows the transmission of the occlusal loads to the bone.

It is very common that the implant has the function of supporting a prosthesis: in the case of an implant-based prosthesis, it is extremely important to take into account criteria such as precision and accuracy, even more than in the case of a tooth-supported prosthesis. The reason why precision and accuracy are especially required in aforementioned case is that, thanks to the presence of the periodontal ligament, the tooth can have a minimum mobility (250 microns on each side of the tooth), while for a dental implant is not possible to move because of the direct connection between the bone and the surface of the implant (osseointegration) that, as mentioned before, does not allow the implant to move and, therefore, it is more difficult for a poor fitting implant-based prosthesis to adapt compared to a poor fitting tooth-supported prosthesis (4).

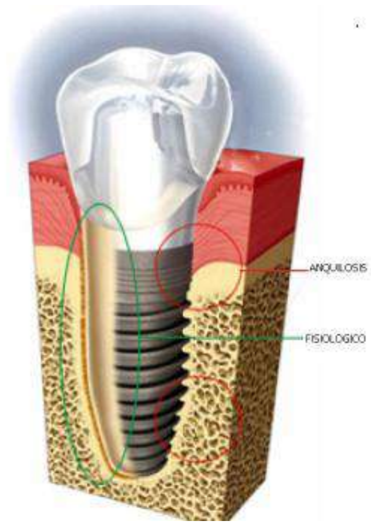


Figure 1 - Union between bone and dental root compared with union between bone and implant surface (4)

The picture shows the two different type of connections: one between the bone and the implant, and the other one between the bone and the surface of a natural tooth. While in the case of natural tooth and bone, the union is physiologically normal, in the case of implant and bone, the union is due to a process called ankylosis. As the matter of fact, in the case of a natural tooth, the periodontal ligament is interposed between the bone and the root of the tooth , while in the case of an implant, there is a direct connection between the bone and the surface of the implant (5). Due to ankylosis, a prosthetic manufacturing process with a very high degree of precision is required, since it does not allow any tolerance, other than that between the implant-abutment elements, given by the manufacture of these pieces (6).

Implants have an active part, the area that will be in contact with the prosthesis, determined by the manufacturer (4). New types of connection have been developed between the implant and the prosthesis or prosthetic elements, thanks to advancement of implantology in the last few years (4).

The implant prosthesis, like the conventional fixed prosthesis, is composed by two structures: an internal part, which gives resistance and support to the prosthesis, and an external structure, which is the responsible for the aesthetic and the original functions (4). The internal part is made of metal, while the external part is made of an aesthetic material, such as ceramic (4). The part of the implant prosthesis that contacts with the implant, is the metallic structure (4). A perfect adjustment is mandatory to avoid any types of tensions (4).

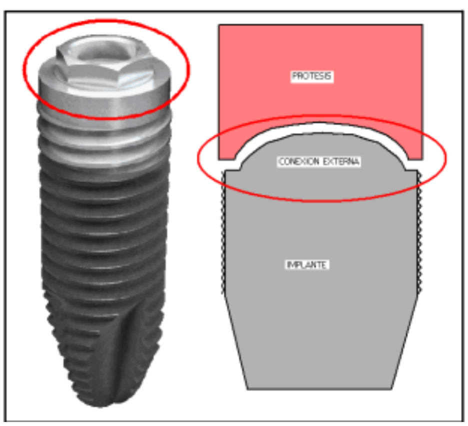


Figure 2 - External connection (4)

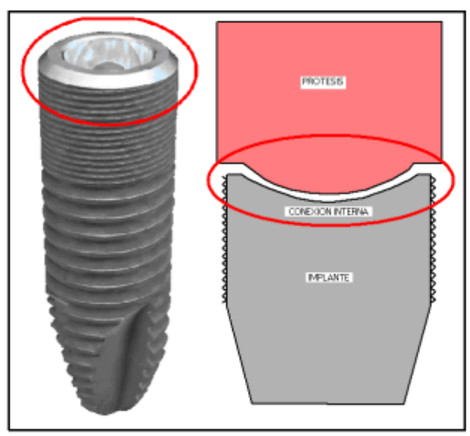


Figure 3 - Internal connection (4)

1.3 Impression techniques

There are two types of impression technique: conventional impression technique and digital impression technique.

A conventional impression is a mold that reproduces the anatomic structures of the mouth of the patient (teeth and gingiva), it is used to create a cast, made of plaster, which replicate the whole dental arch o just a part of the entire arch. Conventional impressions are taken using an impression tray and impression materials.

A digital impression method is a new impression technique which uses an intraoral scanner to detect the structures and the characteristics of dental arches, in order to transfer them into the digital world of the computer (7).

The main therapies that require a dental impression are:

- Study casts
- Wax up
- Fixed and removable orthodontic appliances
- Mouth guard
- Removable prostheses
- Fixed prostheses (including prostheses on implants)
- Indirect tooth reconstructions (inlays or veneers).

Although conventional impression materials and techniques have been improved over the years and give clinically satisfactory results, conventional impressions are affected by numerous factors that influence their quality and reliability (8).

Factors affecting quality and reliability of conventional impressions (8)
• Operator • Type of tray and quality of the adhesion of the impression material to the tray • Intrinsic properties of the impression materials • Manufacturing tolerances • Type and design of the abutment • Impression technique • Implant position (angulation and depth) • Presence of retentive areas and force needed to disinsert the impression • Configuration of the implant-abutment connection, disinfection process • Transport of the impression

All these factors affect the result of the restoration as well as the comfort of the patient, not only due to the necessary repetitions of the impression because of the presence of errors, but also due to nausea reflections, the taste of certain materials, laboriousness, time, effectiveness and cost of the process (8).

To overcome these limitations, a digital dental impression technique has been introduced in recent years.

1.4 Conventional impression procedure

The first phase of the prosthetic rehabilitation is represented by the taking of the impression. This phase is perhaps the most important of the whole procedure, as an error at this moment would affect the outcome of the perfect final fit of the prosthesis on implants. A misfit will lead to biological and mechanical complications. One of the principal aim of the prosthetic rehabilitation process is to obtain a passive fit of the prosthesis on implants and, to reach this objective, the accuracy of the model is essential, therefore also the accuracy of the impression performed and the technique used (9).

The impression allows the identification of the three-dimensional position of the implant, which permits the reproduction of this position on the master model (10).

The dental technician is the person responsible for manufacturing the prosthesis, process that will take place in a dental laboratory and not in the dental clinic. The dentist's task, in this case, is to make a copy of the patient's soft tissue and teeth. This copy must be as faithful to the original as possible, so that the prosthesis fits perfectly to the implant and to adjacent and antagonist teeth, if this were not the case, inaccurate and incorrect work would result. The quality of the impression is especially critical in the case of implant impressions, that is also influenced by the implant-bone junction, characterized by the absence of periodontal ligament, which is the responsible for the physiological mobility of the teeth (8). Indeed, unlike a natural tooth, an osseointegrated implant possesses a high degree of rigidity, due to the absence of the periodontal ligament.

The dentist will perform the impression of the buccal structures of the patient and he will also take some records, which will later be useful for the technician to fabricate the prosthesis. From the impression, taken by the dentist, the dental technician is able to produce a working cast and then, starting from this, he will be able to design and manufacture a prosthesis (8). To make the impression with the conventional technique, the clinician places a special material on an impression tray, which is then compressed against the tissues of the affected area of the oral cavity. The impression should be taken in a bloodless and dry environment. This impression material is initially in a pasty state, and easily adapts to the area to be detected, but then solidifies and becomes elastic in a short time: it can then be removed from the patient's mouth and transferred to the laboratory without changing its shape. At this point, the dental technician will be able to make the model, that is a "positive" copy of the oral area detected by the impression: the impression is a negative and the cast is a positive of the mouth. This procedure allows the dental technician to obtain a series of information on the patient's dental situation without having to examine him directly.

Figure 4 – Pouring of the impression and obtaining of the plaster model (10)

With the casting of the model, the dental technician obtains the reproduction of the shape of the patient's arch. The process is obtained, also in this case, through the use of materials that are poured into the impression in the pasty state, and which then solidify: in general, special gypsum, resins or plastic materials are used, which thanks to their precision allow to obtain reproductions very faithful to the original.

To truly reproduce the patient's dental situation, the dental technician will also use the articulator, which is an instrument that has the function of providing a partial imitation of both the relationship between the mandible (mobile bone of the skull) and maxillary bone (bone of the skull in which the teeth of the upper arch are fixed), and of the dynamic movements of the mandible. Therefore, it is used to put the two arches in the right relationship between them. By fixing the two models (upper and lower) to the articulator, it is possible to simulate the joint relationship that exists in the oral cavity between the patient's upper and lower arch. In this way, the dental technician has, in the laboratory, both the reproduction of the patient's arches, obtained through the models, and, thanks to the articulator, the reproduction of the way in which the arches are positioned relative to each other.

1.5 Materials for conventional impression

As previously mentioned, the dental impression is obtained using a special pasty material, which the clinician places inside the impression tray and with which he records the shape of the patient's arches. The materials used for this purpose are numerous and very different from each other, both in composition, in properties, and in the systems of use and in the methods of storage. An impression material, in order to be defined as a material with a high fidelity of details replication, has to be able to detect any irregularity present in the surface to be detected: it must accurately register a V-shaped crack with the width of 0.02 mm (11).

Although they are materials used mainly by the dentist, it is advisable that the dental technician also knows the characteristics, properties and methods of use of these materials, as some of them could deform or deteriorate if not treated correctly in the laboratory, consequently generating a model not conforming to the original. In turn, this would cause a wrong manufacturing of the prosthesis. It must always be remembered that, before using an impression in the laboratory, the aforementioned dental impression, that comes from the dental office, must be cleaned and disinfected: it is possible to use spray or to submerge the impression in an hypochlorite solution with a concentration that ranges from 0.5-2 %, during a time interval ranging from 5-10 minutes. After that, the disinfectant is removed by rinsing the impression with water for 45-60 seconds.

There are many types of materials for making a dental impression. They can be classified according to different parameters, such as resistance, composition, or type of impression to be taken. However, the main criteria considered to classify an impression material is his physical characteristic. Indeed, it is possible to categorize those materials in rigid and elastic.

Rigid materials are those used first, and, over time, they have been progressively replaced by elastic materials. Currently little employed, they are used only in particular situations.

Instead, elastic materials are widely used nowadays and their use cover almost all prosthetic fields.

1.5.1 Rigid materials for conventional impression

Impression plaster: also called plaster of Paris, it was used in the past to take different types of impressions. Currently, the use of impression plaster is limited to a few specific cases. This is because, due to the rigidity of this type of material, the impression had to be broken before being extracted from the patient's mouth, and subsequently reassembled in the laboratory before pouring the model. This represented a long and difficult process, at the end of which inaccuracies were often found in the finished models. Therefore, today, impression materials chosen are those that are easier to use, while the use of impression plaster is limited only to cases in which a particular rigidity of the material is required and the impression can be withdrawn from the mouth of patient without having to be fractured.

Thermoplastic materials: as the name suggests, they are characterized by their property of becoming plastic, therefore soft, when exposed to a heat source, for example water or hot air, flame. To make them plastic, the clinician is obliged to use these materials at temperatures ranging between 50 and 65 ° C, preheating them and taking the impression when they are still soft, before cooling stiffens them again.

Since the mouth temperature (37 °C) is lower than the softening temperature of these materials, when they are placed in the patient's mouth, they cool down in a short time and stiffen again. At this point the impression can be removed and the model can be cast in the laboratory.

Thermoplastic materials are generally used for the realization of:

- Impressions of small cavities of the teeth in which the inlays will be made
- Peripheral edges of individual trays
- Impressions of single teeth (copper rings are used to take a single tooth impression, they are small cylindrical impression trays that are positioned around individual teeth and with which thermoplastic materials are used) (12).

Pastes based on zinc oxide eugenol: they are very precise materials, generally sold as two viscous masses to be mixed. Their consistency before solidification is like that of toothpaste. These impression materials can be used to take an impression necessary for the relining procedure of a removable prosthesis, with the aim of improving the adhesion of the prosthesis to the underlying tissue.

1.5.2 Elastic materials for conventional impression

Among this class of material, it is possible to find the hydrocolloids and the elastomers.

Hydrocolloids: they are classified into reversible and irreversible hydrocolloids. Agar and alginates are included in this category.

Agar: it is a reversible hydrocolloid with good elastic properties. It can reproduce correctly the majority of the areas that do not present noticeable undercuts. It has good properties of recovery after distortion.

Alginates: they are irreversible hydrocolloids that come in the form of a powder to be mixed with water in appropriate doses.

The main components of alginates are sodium alginate, calcium sulphate, trisodium phosphate, diatomaceous earth, and to a lesser extent zinc oxide, potassium fluoride, aromatic and anti-emetic substances (that inhibit nausea) (12).

Once the powder is mixed, the alginate becomes a soft paste which is subsequently placed in the tray and then inserted into the patient's mouth for impression taking. The time it takes for this material to solidify is about two minutes. To facilitate the dentist, sometimes these materials are marketed with the characteristic of being able to vary their color depending on the phase in which they are used. In fact, during the mixing time, the mass has one color, which changes into another for the time necessary to place the material in the tray, then transforming into another color for the time necessary to take the impression in the oral cavity, up to a last chromatic change which indicates that hardening has occurred.

These materials, thanks to their low cost, are the most used for the taking of impressions, that will later be used to manufacture study models or for models for temporary prostheses, orthodontic appliances, partial prostheses, or even for the first impression of a complete removable prostheses, for antagonist arch to the one on which you are working.

Alginate is very susceptible to the release of water, which causes a dimensional contraction of the material. This can cause important deformations of the model, therefore it is preferable to pour the impression in the shortest possible time, that is to say within 30 minutes of the taking the impression. If this is not possible, or if the impression must be transported to a laboratory far from the dental office, the transport has to be carried out in an airtight humidified container, avoiding that it comes into direct contact with water. Also, in this case it is preferable that the model is cast as soon as possible.

For the correct maintenance of the impression during transport, an airtight container must be used. The dental impression will be placed on a wet and squeezed sponge. On the other hand, the application of wet cotton on the impression is not recommended, because the alginate could absorb water, swelling and deforming, causing an alteration not only of the impression but also of the plaster model and therefore also of the prosthetic product.

Figure 5 – Alginate impression and pouring of the impression (12)

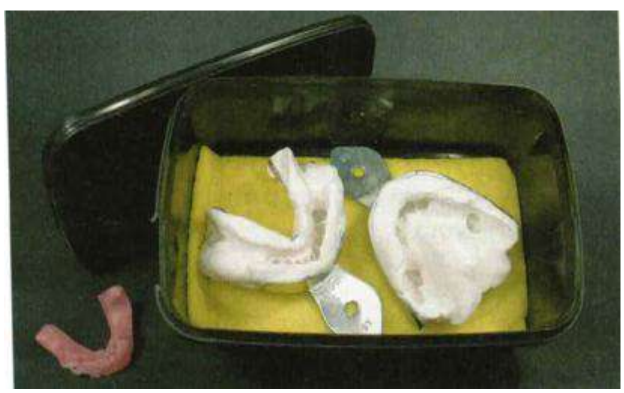


Figure 6 – Correct maintenance of an alginate impression (12)

Elastomers: they are the most used impression materials as they have a high degree of precision, strength and dimensional stability.

The composition of the elastomers is variable, it depends on the choices of the manufacturers and the viscosity of the materials. Polysulfides, polyethers and silicones can be distinguished.

Elastomers are marketed in the form of two masses to be mixed: a base paste and a catalyst, which can be liquid or pasty. A catalyst is a substance capable of activating chemical reactions, generally tending to the hardening of another mass, the base paste, which is in a plastic state until it comes into contact with the catalyst (12).

As the name suggests, one of the most notable characteristics of elastomers is elasticity. Thanks to the elastic memory of these materials, it will be possible to correctly detect the undercut areas in the impression, without permanent deformations occurring. The undercut is the term that indicates the concave and recessed part of a tooth, of a model, etc.

According to the degree of viscosity, that is the property that makes a material more or less fluid, elastomers can be classified into:

- High viscosity elastomers, masses with a pastier consistency
- Low viscosity elastomers, masses with a more fluid consistency.

Generally, with elastomers, the impression is taken in two stages: the first impression that is made is used to detect the structure of the arch and, therefore, a material with high viscosity is used. Once this former material is hardened and the impression is extracted from the patient's mouth, a second elastomer with low viscosity is added and applied to the impression. The characteristic of the latter material is to be very precise and thanks to this second elastomer, a second impression will be taken. At this point the impression will be more detailed than the first one. In fact, the greater fluidity of the second material allows to obtain a greater precision of the impression, as it is able to penetrate even the most hidden areas and the smallest cavities: the lower the viscosity of a material, the greater the details recorded (13).

Regarding the accuracy of these impression materials, according to the ADA specification n° 19, elastomers can detect details up to 0.0025 mm, in particular polyvinylsiloxane is able to reproduce details up to 0.001 mm, reaching a greater degree of precision (14).

Despite the wide range of impression materials offered by the market, those used in the implant-supported impression sector are elastomers, in particular condensation and addition silicones.

Condensation silicones: they were the first elastomeric materials present in the market. Their advantages include:

- High ability to reproduce details
- Good dimensional stability for about 24 hours
- Excellent elasticity
- Insensitive to the humid environment
- Reduced tendency to tear
- Acceptable smell and taste
- Lower cost compared to addition silicones (15).

Addition silicones: they are second generation materials. Unlike condensation silicones, they do not release secondary alcohol products during the bonding reaction, which are the responsible for the volume changes of the material.

The advantages of these materials also include:

- High dimensional stability over time, due to the fact that the shrinkage of the material is 0.05% after 72 hours (16)
- Excellent elastic memory (17)
- Hydro compatible (18).

Polyethers: they are similar to addition silicones. They were born in the 1960s with the aim of obtaining a more dimensionally stable material than condensation silicones. These materials have the following advantages:

- They do not release alcoholic products during the polymerization process, therefore they do not contract (19)
- They have a high degree of precision in reproducing details
- Higher hardness than other elastomers.

These properties make polyethers the materials of choice for full arch cases and for making a precision impression in implant-supported fixed prosthesis.

However, the main disadvantage of these materials is their high cost.

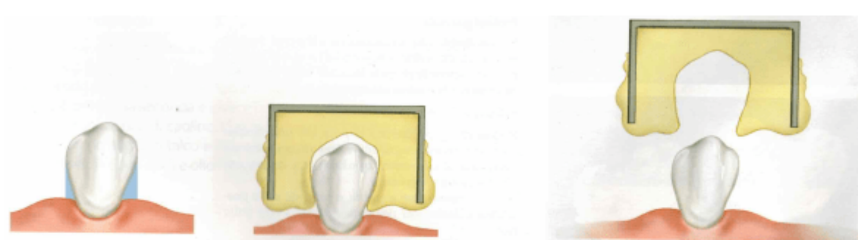


Figure 7 – Property of elastomers to contract and deform when a undercut is present (12)

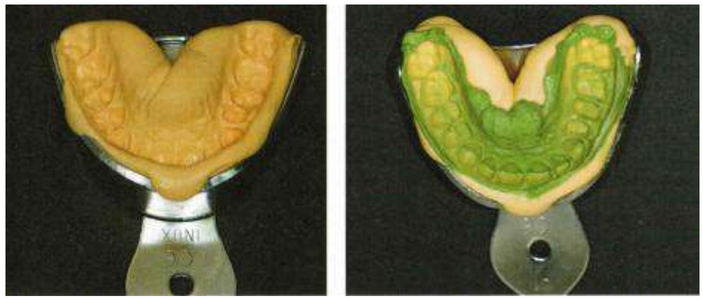


Figure 8 – Elastomer with high viscosity (orange) covered with another elastomer with low viscosity (green) (12)

The impression and the model are the starting point for each type of prosthetic processing. Therefore, the clinician and the dental technician must pay great attention to the detection, treatment and correct development of the impressions and of the models, as the prosthesis will be manufactured from these two. An imprecise model is obtained from an imprecise impression and consequently a non-conforming prosthesis would be obtained.

Classification of impression materials

Class	Impression material	Advantages	Disadvantages	Uses
Rigid	Impression plaster	Accurate No compression It remains rigid	Not elastic It breaks in presence of undercuts It dries the patient's mouth	Position impressions (of elements to be welded, transfers for overdentures, etc.)
	Thermoplastic materias	Precise Stable They can be galvanized better than other materials	Rigid Fragile They can burn the patient	Impression with copper ring Peripheral edges of individual impression trays for removable prostheses
	Pastes based on zinc oxide eugenol	Precise Stable	Fragile	Relining of removable prostheses
Elastic (hydrocolloids)	Reversible hydrocolloids (agar)	Precise They do not compress	They can burn the patient Delicates Noticeably unstable	Fixed denture impressions without noticeable undercuts
	Irreversible hydrocolloids (alginate)	Cheap They do not compress	Significantly unstable Not very precise if they are not cast immediately	Orthodontic: first impression Removable prosthesis: second impression Base paste to support agar

Table 1 – Classification of impression materials (12)

Classification of impression materials

Class	Impression material	Advantages	Disadvantages	Uses
Elastic (elastomers)	Polysulfide rubbers	Precise Stable They do not compress tissues	Slow curing Poor elastic recovery in the polymerization phase	Second impression of removable prostheses
	Condensation silicones	Easy to use Very resistant	Less stable than other elastomers It is difficult to establish the exact proportions between the masses	Fixed denture impressions as a support for other masses Orthodontic impressions Use in the laboratory
	Addition silicones (polyvinylsiloxanes)	Hydrophilic Precise Resistant Stable Extreme versatility of use		Impressions that require precision Double impression technique
	Polyethers	Very hydrophilic Precise Rubber bands Stable	Incompatible with resins	Precision impressions Single-phase techniques

Table 1 – Classification of impression materials (12)

1.6 Technique for conventional impressions on implants

In the field of dental implantology, different techniques have been developed in order to improve the precision and the accuracy of the coping of the oral cavity's structures and the 3D position of the implant located in the mouth of a patient.

The two main techniques are the *indirect technique* and the *direct technique* (4). An agreement on which technique is the best has not yet been reached (4).

1.6.1 Direct technique

In this technique, the abutment is screwed directly to the implant and it does not present an established shape. Therefore, the abutment is individualized directly in the patient's mouth, through a milling process. After that, the impression is made in the same way as with natural teeth. This technique presents several disadvantages related to the milling process, such as the difficulty of milling titanium in the patient's mouth, the generation of heat and stress for the implant and peri-implant tissues and the use of gingival margin retraction systems, used to identify the finishing margins on the model.

Due to the disadvantages listed above, this technique is not used very often in the daily routine.

1.6.2 Indirect technique

Even if this technique is complex, is the most used today. With this technique it is possible to identify the spatial position of the implant. To do that, impression copings (transfer) and analogs, that simulate the implants, are used. The transfer is a metallic cylinder that is screwed to the implant, it is used during the impression procedure in order to identify and to establish the position of the implant with respect to other anatomical and dental structures. In this way, the dental technician can have a reference that he can use during the manufacturing process of the prosthesis.

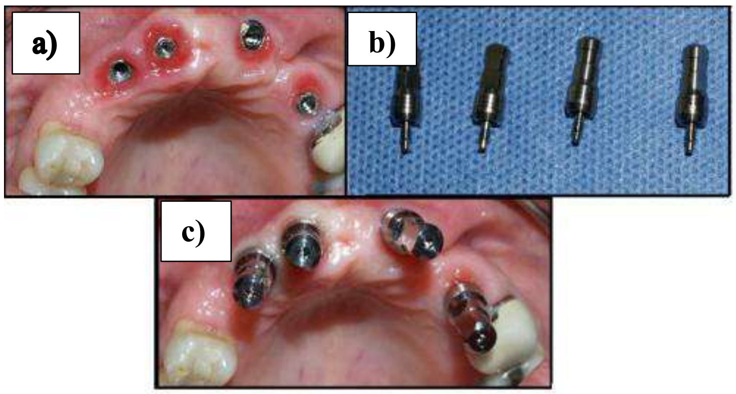


Figure 9 – Impression copings screwed on implants (4)

Unlike the direct technique, in this case the matching of the transfers is more precise and, consequently, the reproduction of the implant's margins will be more accurate.

This technique includes three methods:

A. Pick-up impression technique

B. Tear-off impression technique

C. Pull-up impression technique.

In general, the impression material used is the polyvinylsiloxane because of his excellent ability to detect and record details.

Two different consistency of this same material are used: the putty silicon, which is adapted into the metallic tray, and the light body silicon, which is placed on the transfer surface (4).

Thanks to its fluid composition, the light body silicon is able to copy those elements that require greater detail detection, while the putty silicon records the thickest and general structures and also hosts the light body silicon (4).

A. Pick-up technique

This technique requires the use of splinted transfers to the implants through the means of connecting screws and the use of an individual impression tray fenestrated in correspondence with the aforementioned screws. The custom tray can be made of acrylic. The design of this type of impression tray allows the operator to be able to unscrew the screws connected to the implant when the impression material has hardened. In this way the transfers will remain in the impression tray, "trapped" into the impression material. To do that, screws long enough are necessary (20).

The impression material is placed in the tray and it is brought to the patient's mouth, the position is checked, and enough pressure is exerted, so that the material adapts and the transfer emerges through the hole present in the custom tray. Once the material has set, the screw is unscrewed and removed, then the impression is removed from the mouth. This technique involves the direct inclusion of the transfer within the impression material. Subsequently, the dental technician will couple the analogs to the transfers by tightening the connecting screws before casting the model in the laboratory.

In a situation in which several transfers are present, it is recommended to block them rigidly together, to obtain a better adhesion between the transfer and the impression material, avoiding any movement of the transfers when the analogs are screwed onto them. To block the transfers, several techniques are available, among them it is possible to find:

- Resin application to transfers by the means of a brush
- The use of metal wires to which cyanoacrylate is added
- The use of plaster (21).

Figure 10– Perforated custom tray to take an impression on implants with the open-tray technique (4)

B. Tear-off technique

The tear-off impression technique involves the use of a closed impression tray. The transfer is not incorporated into the impression material, but it remains attached to the implant, inside the patient's mouth. Once the impression tray is removed from the oral cavity of the patient, the transfer is unscrewed, and it is coupled to the analog. An analogue is a replica of the implant, it simulates the implant (4). Transfer-analog complex is then repositioned in the impression material. In this case, the screw used is short. As there is no risk of moving the transfers during screwing, there will be no need to block the transfers between them.

The transfer repositioning procedure is a technique called *repositioning technique* (4).

C. Pull-up technique

This technique has been developed to facilitate the operator during the phase of the taking of the impression, especially in cases in which the patient has a limited oral opening, which makes the screwing and unscrewing procedure of the transfer screws difficult. The transfer used in this technique is made of PEEK, which is a thermoplastic polymer whose properties allow him to be used in a wide range of biomedical situations (22). As this material is radiopaque, it is possible to check if this kind of transfer is correctly insert into the implant platform. In this case, the transfer does not present a screw through which it is screwed to the implant, but he has the connection part that can be attached to the implant platform thanks to his conformation. Once the impression tray is removed from the patient's mouth, the transfer remains stable within the impression material. This kind of transfers can also be used in combination with the transfers used in the pick-up impression, especially in those situation in which the mesial part of the piece to be detected has sufficient space to allow the operator to carry out the screwing and unscrewing procedure, but the distal part of the aforementioned piece does not permit to do that due to anatomical obstacles (23).

1.7 CAD/CAM

With the arrival of information technology, the replacement of manual processes with the digital ones is taking place and the use of digital system are evolving more and more, both for taking the impressions and for creating working models and prosthetic structures.

With the development of CAD/CAM (Computer Aided Design, Computer Aided Manufacture), the dentistry's disciplines, in particular restorative dentistry and prosthodontics, have experiences a relevant change (24).

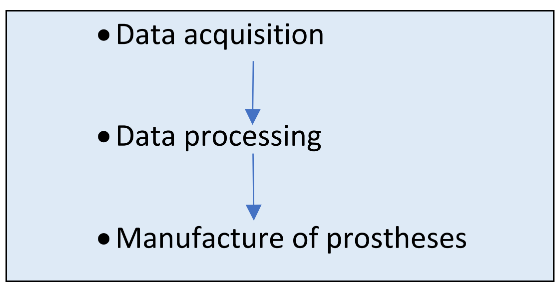
The concepts of CAD/CAM technology were applied to Dentistry thanks to Francois Duret. The idea arose in 1971 and this led to the thesis entitled "Empreinte Optique" which he presented in 1973 at the Claude Bernad University, Lyon, France. He later designed a system that he patented in 1984 and presented at the Chicago Midwinter Meeting in 1989, where he took an impression and fabricated a crown in 4 hours. In parallel, in 1980, Werner Mörmann and Marco Brandestini developed the concept that led to CEREC, the first commercialized system for making digital impressions and fabricating indirect restorations in the dental clinic (8).

The term CAD/CAM encompasses, in a colloquial way, a series of clinical procedures and laboratory treatments and techniques that have as a common denominator the intensive use of software and hardware designed processes, with the aim of making all the prosthetic processes much more precise (7).

The application of the CAD/CAM technology gives its greater contribution in the field of dental prosthetic surgery and in the field of implant surgery, although its constant evolution and sophistication in orthognathic surgery and orthodontics should also be noted (4).

The CAD/CAM systems consists of 3 parts:

- A *data acquisition unit*, which gather all the data that have to be scan, including adjacent and antagonistic structures, and then, transforms this data into virtual impressions, directly by the use of intraoral scanner, or indirectly, starting from a physical model generated through the means of a conventional impression
- A *software*, which is the responsible for the design of the manufactured prosthesis. Starting from a virtual working cast, the software is able to create a virtual restoration;
- A *computerized milling device*, which is able to manufacture the restoration. For this purpose, it can use a solid block of material, processed with the milling technique, or it can use an additive technique (24).



The advantages of CAD/CAM include the digitalization of the impression, of the cast and the use of virtual articulator and facebow (24). The digital impression represents the first step of the CAD/CAM systems (4). A digital impression is the translation of the oral cavity's impression into the digital world of the computer (7).

1.8 Digital impression technique

Two ways to obtain a digital impression exist:

- Starting from a conventional impression, the dental technician will pour the impression, he will create a dental cast, and then, from a physical gypsum model, thanks to a extraoral scanner, he will scan the cast and convert it into a digital model. This technique uses a conventional impression and a conventional model to create a digital file. It is an indirect method to record intraoral data
- Instead of taking a conventional impression, an intraoral scanner is used to record the teeth and the gingiva. In this case, the impression is taken using a device that directly digitalizes the patient's jaws. The process is totally digital (25).

Intraoral digital impression systems project a light onto the object that has to be scan, and then, according to the speed and the projection with which the light rebounds off the sensors, the sensors can register the points on the surface of the scanned object, producing a cloud of points (8). Through a process called *tessellation*, a pattern or model is generated from the points that form the cloud by forming planes starting with geometric figures, in this case with triangles (8).

The technology of intraoral scanners to capture the structures changes from one scanner to the other, as well as the algorithms used to process the image and the way to do that (8).

Intraoral scanners are cameras that make a copy of the areas of the oral cavity, without the need to place trays that keep the alginate, silicone, or polyether in the patient's mouth, avoiding nausea and other unpleasant sensations (4).

Digital production process in the field of implant-prosthesis involves several phases:

- Digitalization of the implant position and of the antagonist arch, starting from a plaster model derived from a traditional impression or starting from a digital impression made by an intra-oral scanner
- Cad design of the prosthesis
- Cam realization of the prosthesis
- Ceramization and/or finishing and/or polishing.

The final aim of these innovative digital technologies is to allow the reduction of the manufacturing times, limiting the intervention by the operator and consequently also limiting the possibility of making mistakes during the making of the prosthesis (26).

1.9 Intraoral digital scanners

Currently, various intraoral scanner devices are available in the market and they are different from each other. As the matter of fact, the manufacturers continually create new products and, therefore, it is difficult for the dentist to be aware of the present-day technologies. Also, the software of the machines are updated very quickly, even considerably changing their performance.

Intraoral scanners work thanks to non-invasive optical technologies without direct contact with the studied object, such as confocal microscopy or triangulation. This type of technology has speeded up the phase of acquiring 3D coordinates that define the geometries of any object. Each type of scanner uses more than one of these technologies in order to reduce and minimize the noise that derives from the intraoral scanning process, to compensate for the fact that the surfaces to be scanned have different optical properties due to the presence of saliva, and to minimize errors resulting from the inevitable relative movements of the detected objects. Moreover, in order to reduce even more the noise and the errors due to the presence of moisture in the area that has to be scan, this surface has to be dried before starting the scanning process (27). To reveal the preparation margins of the prepared teeth, the positioning of the retraction cords inside the sulci is indispensable (27).

Intraoral scanners capture the data in two ways: through fixed images or through video. In the former case single image cameras are used to detect three teeth and collect them in a single image. Fixed images are joined together by the machine software to reconstruct a three-dimensional network of points. As the matter of fact, to record more extensive areas of the arch, several overlapping independent image are collected and then, the software joins them, creating a 3D virtual model (24). To record all the data in a precise way, the camera is located in different angulated positions. Moreover, all those areas that have not been detected by the scanner are deduced by the software and are used to fill the empty spaces of the virtual model (24). The detection of data through the means of fixed image requires more time, while if data are acquired through video, the three-dimensional object is immediately displayed, and the process is faster. Thanks to their ability to scan quickly the surfaces and the objects, intraoral scanners that record data via video are used to scan entire arches, as in the case of more complex prosthetic treatment or orthodontic treatment.

The most famed intraoral scanners used in the dental clinic to perform a digital impression are: CEREC (Sirona Dental System Gmbh, DE); Lava TM Chairside Oral Scanner (3M ESPE, US); iTero (Cadent ltd, US); 3D Progress (MHT S.p.A., IT); Zfx IntraScan (zimmer Dental, DE); Trios (3SHAPED, DK) and CS 3500 (Carestream, US) (28).

	Open/close system	Color matching	Portable	Type of CAD/CAM	Acquisition technology	Powder required	Color image	Imaging type
CEREC Omnicom (Sirona)	Closed	No	No	Digital imaging and in-office manufacturing	White light	No	Yes	Filming (Video)
PlanScan (Planmeca)	Open	No	Yes	Digital imaging and in-office manufacturing	Blue Laser	No	No	Filming (Video)
Trios Color (3 Shape)	Open	Yes	Yes	Image acquisition unit	Blue LED	No	Yes	Photographing (multiple images)
iTero (Align Technology)	Open	No	No	Image acquisition unit	Red Laser	No	Yes	Photographing (multiple images)
True Definition Scanner (3M ESPE)	Open	No	No	Image acquisition unit	Blue LED	Yes	No	Filming (Video)
CS 3500 (Carestream Dental LLC)	Open	No	Yes	Image acquisition unit	White LED	No	Yes	Photographing (multiple images)
Apollo DI (Sirona)	Closed	No	No	Image acquisition unit	NA[a]	Yes	No	Filming (Video)

[a] NA = information not available.

Table 2 – Comparison of intraoral scanners (24)

The dimensions of the intraoral scanner are important for the handling by the operator and for the comfort of the patient. Nowadays, manufacturers tend to create instruments with dimensions more and more similar to those of the instruments used routinely by dentists.

Figure 11 – Different types of cameras: A) CEREC Omnicam with a design similar to a pen B)TRIOS camera with a design similar to a pistol C) LAVA COS camera with a designs similar to a billiard cue (29).

Intraoral scanners capture what they see, therefore, as in the case of conventional impressions, even for the digital impression it is necessary to manage the soft tissues and eliminate all oral fluids, such as saliva, blood or crevicular fluid.

Moreover, to speed up the process of acquiring the examined dental arch, some scanners require the coating of the arch with a powder before starting the scan. In this way, a thin layer of powder is formed and it creates a pattern, which is recognized by the software, allowing it to overlap subsequent images more easily, thus speeding up the acquisition procedure. This is especially useful in the case of reflective surfaces, such as metal, or in the case of smooth surfaces, that not present reference points, since even the smallest imperfection that is created on the surface by the deposition of the powder permits the overlapping of images, minimizing the errors (8).

While the use of powder represents an advantage as it speeds up the digital arch detection process, on the other hand it can also be considered a disadvantage as the application of the powder can be difficult for the operator and annoying for the patient. Furthermore, another disadvantage is the possible accumulation of powder on the preparations of the teeth which can lead to errors in reading and, therefore, in the manufacture of the prosthesis.

If the scanner contact the dental preparation, the powder will have to be deposited again as it is easily removed with contact. If, on the other hand, the patient accidentally touches the powder with the tongue, the powder will be removed and soaked in saliva. In this case, the protocol provides not only for the deposit of new powder, but first the entire preparation must be cleaned and rinsed carefully, using water, and then dried.

1.10 Scanning technique

Even today there is no intraoral scanning technology or scanner that can currently be considered scientifically accredited to allow a correct operative sequence to perform an optimal digital impression.

This is due to the fact that there is insufficient evidence of standardized procedures and also due to a lack of comparable in vivo studies (29).

The intraoral scanner has to be used in a specific way, performing a movement that allow to reproduce a virtual model with a high level of accuracy, therefore, the scanner has to follow a specific scanning path (30).

Often, some manufacturers of intraoral scanners suggest operative sequences without underlying scientific research.

In general, the occlusal surfaces are the starting point for the scanning procedure because those surfaces are rich in anatomical details, which are used by the camera as reference points, since they are easy to detect. Once the scan of the occlusal surface is finished, the intraoral scanner proceeds around the object and it is moved in all the directions in order to scan the object from various angulations. All the areas that are missing can be detected by scanning again the regions of the object that were not collected with the previous scan. Once the scan of the area is completed, the scanner is moved to the opposite arch in order to scan it, following the same scanning protocol. After that, the patient has to occlude and the scanner, that is placed laterally, will record the inter-cuspal relation. In this way the scanner of inter-occlusal relation is obtained (27).

It was found that the scanning sequence with the highest level of precision and trueness is the one that starts with the scan of the occlusal surface, then moves on to the scan of the palatal surface and ends with the scan of the vestibular surface. If the starting point of the scan is the vestibular surface, followed by the occlusal and the palatal surfaces, the lowest level of precision is obtained (31).

Three parameters are considered to evaluate the three-dimensional measurement: accuracy, resolution and precision (32).

Accuracy is the parameter that represents the error between the obtained measurement and its value which is accepted as true. In the case of repeated measurements of the same value, the accuracy represents the distance between the average of the measured data and the real data. Accuracy is mainly described by two variables: trueness and precision.

Trueness represents that value that is closer to the reference value. Precision is the repeatability of the value when repeated scans are made and subsequently compared with each other by superimposing them. For a dental impression, being as faithful as possible to the original means having a high degree of trueness and precision.

Resolution is defined as the smallest variation of the measurand that can be measured. As far as optical scanners are concerned, it must be said that the density of the point cloud is proportional to the resolution, this means that this density affects the distance between the points of the cloud and, therefore, the ability to describe specific geometric details of small dimensions. A higher resolution is desirable in the dental field but having a greater number of dots does not always imply that the scanned area is better defined: in fact, sometimes, these dots are not always accurate and precise.

Finally, the precision is described by the dispersion of the measures around their mean. It allows to estimate the random component of the error considering several repeated measures.

Presently, there are no objective evaluation criteria to validate the accuracy and precision of the scanner. Even the manufacturers of intraoral scanners do not provide information regarding the acquisition methodology.

Once the data from an intraoral scan has been obtained and, then, the virtual model has been obtained too, the operator can evaluate the quality of the impression through functions that allow him to change, adjust or clean the images (33).

1.11 Scan-body

As mentioned before, a scan-body contains all the details about the position and trajectory of the implant and allows to transfer that information in the virtual working cast.

The dentist directly places the scan-bodies on the implants in the patient's mouth, in order to take the impression through an intraoral digital scanner. On the other hand, the dental technician, mounts the scan-bodies on the analogs contained in the master cast, and then he proceeds to acquire their position thanks to the use of the extraoral scanner.

Currently, the majority of scan-bodies present on the market are made of PEEK (polyether ether ketone), which, as previously mentioned, is a white and opaque material. In addition, these scan bodies made of PEEK are equipped with a screw fixing system on the implant head.

1.12 Advantages and disadvantages of the digital impression

In order to reduce the potential errors of the traditional impression, the digital impression was introduced, its advantages are:

- elimination of bubbles and voids in the critical areas of the impression

- distortion and expansion of the plaster
- removal of impression material from the impression tray
- elimination of the difficulty of preserving and disinfecting the impression with antiseptic solutions
- elimination of the need to transport the impression to the laboratory by subjecting it to sudden changes in temperature and humidity
- reduction of patient discomfort and of the gag reflex thanks to the elimination of the tray, the pain and the unpleasant taste of the impression material
- reduction of the procedure time by eliminating phases such as the selection of the impression tray, the choice and hardening of the impression material, the disinfection procedure and transport to the laboratory
- possibility of archiving the acquired data that can be used in subsequent follow-ups
- ability to view the scanned image directly on the computer, allowing the operator to modify imperfections and adjust preparations
- obtaining a better marginal adaptation compared to what would be obtained with conventional impressions (34).

Among the disadvantages of the optical impression are included:

- intraoral scanners do not have the thrust that is present, instead, in the case of the traditional impression, which is obtained thanks to the pressure exerted by the impression material, therefore, there is no thrust that makes so that the material penetrates all those tiny spaces
- limited precision and trueness when detecting extended arches (27)

- large learning curve for the operator, in fact each intraoral scanner has its own characteristic features
- high costs compared to the costs of the traditional impression, both of intraoral devices and software, which must be periodically updated.

2. OBJECTIVES

The aim of this review is to investigate on the digital and conventional impression techniques.

Main Objective:

- Perform a bibliographic review to determine if digital impressions on implants are more accurate than conventional impressions on implants.

Secondary Objectives:

- To determine which is the most accurate conventional impression technique on implant
- To determine which impression technique is the most comfortable for the patient.

3. MATERIALS AND METHODS

An analysis of the literature was conducted to understand which of the two impression techniques was the most accurate. The PubMed and MEDLINE (US National Library of Medicine, National Institute of Health) medical databases were mainly used for the literature research.

Some publications that are not present in the PubMed archive as they are older, were found through the Google Scholar search engine and through the CRAI library of Universidad Europea de Madrid.

The keywords used in this bibliographic research were entered in the PubMed and MEDLINE database. The research was carried out using the following keywords: implants impression, intraoral scanner, extraoral scanner, open-tray impression technique, closed-tray impression technique, CAD-CAM technology, accuracy, precision, digital workflow.

A total of three bibliographic research were carried out: a small initial search; a second broader one, once the working draft of the bibliographic review was defined and a final third search, more specific, which excludes some inclusion criteria to investigate and try to respond to the objectives of the work.

At the beginning of the research 60 scientific articles were obtained, subsequently, applying the inclusion criteria, only 48 sources were used.

The inclusion criteria to select the articles were:

- Articles published in the last twenty years, but 4 older articles have also been included
- Articles that have the full text available
- Articles and books in Italian, English, Spanish
- Systematic reviews, clinical studies, in vitro studies, articles taken from journals.

The exclusion criteria were:

- Articles that had only the abstract available
- Non-scientific articles or whose origin did not determine
- Articles not published in English, in Spanish or in Italian.

4. DISCUSSION

When we pronounce the word "dentist" the first mental association with this term is fear and pain: patient goes to the dentist when he has pain; moreover, a dental procedure can also cause discomfort/pain, linked to all those inevitably invasive techniques that the patient has to endure, and which are more or less intense in relation to the personal pain threshold of each patient.

Furthermore, dentistry is one of the few branches of medicine in which the patient is always vigilant and from whom collaboration is also expected.

The patient's lack of cooperation, or even the instinctive initiatives or reactions of the patient, that could happen during the dental treatment, can constitute a risk factor and undoubtedly an element that must be considered and always kept under control by the dentist during the performance.

Therefore, over time, researchers have tried not only to refine all invasive techniques and always try to cause the patient as little discomfort as possible, but also to improve the performance of the procedures, speed them up and make them less and less annoying.

Giant steps have been taken in recent decades and with formidable successes in terms of pain, but other fields have also been refined, such as those related to instrumentation and purely technical and mechanical invasive interventions used in a dental context: one of these fields is precisely that one linked to the introduction of digital techniques in the prosthetic field, especially in the sector of dental impressions, in which the introduction of CAD/CAM was a revolutionary discovery.

Until the finding of this innovation, the impression was taken, as mention before, by the dentist or his assistant with the traditional methods described in this study: the chances of success were more or less reliable depending on experience, speed and dexterity of the operator. In fact, in the case of traditional impressions, the professionalism of the healthcare professional and its manual skills are decisive.

The time factor also plays an important role due to the reaction and setting times of the materials, as well as the exposure to external factors (humidity, temperature, etc.) and the state of conservation of these materials. All the previously mentioned factors can determine alterations, which can influence the outcome of the impression procedure.

4.1 Comparison between the accuracy of conventional impression and digital impression on implants

In the literature it is possible to find numerous articles and research that have evaluated the accuracy of traditional impressions. The intraoral scan and the use of CAD/CAM to create the prosthetic product, made it possible to eliminate all the phases of the traditional impression, pouring the plaster model and manufacturing with the traditional method.

This means that there was a reduction in the production time of the prosthesis, but also a decrease in errors. In fact, in the traditional process, the operator can accumulate errors which are then reflected on the final prosthetic product.

The ability of the operator, the techniques for making the plaster model, the contraction of the impression materials and the casting plaster, the temperature and humidity of the environment, are all elements that significantly determine the accuracy of the traditional impression.

Therefore, it can be said that the traditional impression technique and also the entire procedure for making the master cast are operator-dependent, as they are affected by the experience of the operator and are closely linked to the technical knowledge and manual skills of the operator, not only of the dentist but also of the dental technician (35).

Moreover, the accuracy of the master model depends on clinical and laboratory variables, on the type of material chosen to make the impression, the technique used to take the impression (direct or indirect), impression tray types and also on the volumetric changes of the plaster (36) (37) (38).

With new digital technologies, it was possible to take an impression directly in the oral cavity with the digital method, removing part of those errors described above, but not all, since the inconvenience that the technique is influenced by the manual skills and dexterity of the operator is still present also in the digital technique (39) (40).

In fact, for some types of scanners, the dexterity and experience of the operator improve the scanning procedure, while for other types of scanners this "operator influence" variable does not affect the scanning phase or even worsens the results (8).

Today there are few in vivo studies demonstrating the validity of intraoral digital scanning systems.

The results of the study conducted by Joda et al. showed that, in the case of single implant restoration, the fully digital procedure is more efficient, saving time for the clinician at the time of the delivery, and better accepted and tolerated by patients, compared to traditional implant impression (41).

For edentulous patients it is possible to create full arch prostheses supported by implants by scanning the entire arch using a digital scanner. In this case, the study carried out by Papaspyridakos et al. reveals that the digital impression is no less precise than the conventional one (42).

In the study conducted by Mangano et al. it is said that, in the case of a single restoration on implant, or a 3-4 elements bridges on implants, the accuracy of digital impressions is equal to that of conventional impressions; while, in the case of long-span edentulous saddles rehabilitation, with fixed prosthesis supported by natural teeth or by implants, conventional impression still remains the best option, since its accuracy is higher than the accuracy of the digital impression (43).

If the number of implants is limited, the edentulous saddles are extensive and there are soft tissues that are mobile, the intraoral scanning technique will be more difficult than the conventional impression technique: the results of the study conducted by Flugge et al. showed that the precision and the accuracy of intraoral digital scanner diminish when the distance between scan bodies increases (44). Furthermore, Andriessen claimed that the detection of the edentulous mandibular arch by the intraoral scanner still represents a limitation for the digital impression today (45).

It should be noted that the different types of intraoral acquisition techniques can affect the final outcome of the prosthetic product (46).

From the point of view of the duration of the procedure and of the comfort perceived by the patient, Yuzbasioglu et al. proved that the best and most efficient impression technique is the digital one (47).

4.2 Accuracy of conventional impression on implants

As previously described, the two main techniques for taking a conventional impression on implants are the direct one and the indirect one. Each one of them presents advantages and disadvantages.

The direct technique had several disadvantages:

- The difficulty in milling the titanium directly in the patient's mouth

- The creation of heat and stress both for the implant and for the peri-implant tissues generated during the milling procedure
- The use of gingival retraction systems to allow the detection of the finish line
- Without the use of transfers and laboratory analogues, there is no visual or instrumental check on the working model of the final abutment, as this is milled directly in the mouth.

The indirect technique, although more complex, is nowadays the most used. Thanks to the use of impression transfers and analogues that simulate the implants, it is possible to determine the three-dimensional position of the implant and transfer this information to the model. Unlike the direct technique, in this case the matching of the transfers is more precise and therefore the reproduction of the implant margin will also be more precise too. As mentioned previously, the indirect technique consists of three different methods: tear-off impression technique, pick-up impression technique and pull-up impression technique.

With the tear-off impression technique, it is not necessary to block the transfers between them since, using a closed impression tray, the transfer is not removed with the impression, but remains attached to the implants in the patient's mouth. Once the impression has been removed, the transfer is unscrewed, connected to the analog and the transfer-analog complex is repositioned inside the impression.

The disadvantage of this procedure is the repositioning of the transfer-analog complex, since it is not always completely precise.

To limit this problem, the manufacturers have invented various solutions, such as the shape of the transfer or the use of plastic or metal caps inserted on the transfer and removed with the impression itself. In this way the repositioning is easier.

However, this procedure presents two main obstacles:

- during repositioning in the impression, the transfer can be subject to movements
- the presence of a possible dis-parallelism between the implants which involves, especially if pronounced, a high degree of deformation of the impression material during the removal procedure (48).

All these limitations make this technique not very precise compared to the pick-up technique. The pick-up technique is much more precise compared to the tear-off technique, in fact, it allows to reduce the risk of errors during repositioning, which would then affect the prosthetic realization phase in the laboratory (4).

On the other side, the downside is that the patient has to come once more in the dental clinic in order to take the impression for the fabrication of the custom tray (4).

The pull-up technique was created in order to facilitate the taking of an impression, especially in cases where the patient has a limited mouth opening which makes screwing or unscrewing procedures more difficult.

The advantages of this technique include:

- The transfers are made of peek, which being a radiopaque material, it is possible to verify their position in the implant platform
- The transfers are easy and quick to use and therefore very practical for taking a positioning impression
- The transfers remain in the impression in a very stable manner
- These transfers can be used in combination with transfers of the pick-up technique in those cases where the mesial portion of the elements has sufficient space for screwing and

unscrewing procedures, while the distal portion of the elements has anatomical limitations (23).

5. CONCLUSION

1) Digital impression for a single restoration on implant or for bridges with 3-4 elements on implants, is as accurate as conventional impression. In the case of the entire dental arch rehabilitation (full arch prosthesis supported by implants), conventional impression still remains the technique of choice, since its accuracy is superior to that of digital impression. However, some authors argue that in the case of full arch prostheses supported by implants, digital impression is no less precise than conventional one.
2) The indirect method is the most accurate. The indirect pull-up technique is the method of choice par excellence because it facilitates the impression procedure, especially when the patient has a reduced oral opening.
3) The technique that is more tolerated and comfortable for the patient is the digital one.
4) Given the constant evolution of the procedures analysed in this work, as well as the massive introduction of new sophisticated software, further investigations with a standardized protocol will be needed to explore the methodological analysis and to refine the conclusions currently reached.

6. RESPONSIBILITY

Comparison between digital and conventional impression on implants is a broad topic which is constantly updating and, therefore, it needs a constant review by the scientific community to confirm the great results achieved up to now.

The innovations regarding the digital impression procedure aim to reduce the operating time and to enhance the comfort of the patient during the phase of the impression taking, limiting the sensation of nausea and the unpleasant taste of some impression materials.

The reason for conducting this review is to try to establish a more definitive protocol in the prosthetic setting at the time of impression taking.

Because of a small number of in-vivo studies demonstrating the validity of intraoral digital scanning system, additional research would be necessary in this context, to better investigate the subject and to develop a definitive and reliable protocol for taking the impressions on implants. In this way, more information could be found to establish guidelines for the clinicians.

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impression technique and implant angulation on the impression accuracy of external- and internal-connection implants. Int J Oral Maxillofac Implant. 2012;27(6):1422-8.

9. ANNEX

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THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Digital versus conventional implant impressions for partially edentulous arches: An evaluation of accuracy

Amin Marghalani, BDS, MS,[a] Hans-Peter Weber, DMD, DrMedDent,[b] Matthew Finkelman, PhD,[c] Yukio Kudara, CDT, MDT,[d] Khaled El Rafie, DMD,[e] and Panos Papaspyridakos, DDS, MS, PhD[f]

ABSTRACT

Statement of problem. To the authors' knowledge, while accuracy outcomes of the TRIOS scanner have been compared with conventional impressions, no available data are available regarding the accuracy of digital impressions with the Omnicam and True Definition scanners versus conventional impressions for partially edentulous arches.

Purpose. The purpose of this in vitro study was to compare the accuracy of digital implant impressions using 2 different intraoral scanners (IOSs) with that of conventional impressions for partially edentulous arches.

Material and methods. Two partially edentulous mandibular casts with 2 implant analogs with a 30-degree angulation from 2 different implant systems (Replace Select RP; Nobel Biocare and Tissue level RN; Straumann) were used as controls. Sixty digital models were made from these 2 definitive casts in 6 different groups (n=10). Splinted implant-level impression procedures followed by digitization were used to produce the first 2 groups. The next 2 groups were produced by digital impression with Omnicam. The last 2 groups were produced by digital impression with the True Definition scanner. Accuracy was evaluated by superimposing the digital files of each test group onto the digital file of the controls with inspection software.

Results. The difference in 3-dimensional (3D) deviations (median ±interquartile range) among the 3 impression groups for Nobel Biocare was statistically significant among all groups ($P<.001$), except for the Omnicam (20 ±4 µm) and True Definition (15 ±6 µm) groups; the median ±interquartile range for the conventional group was 39 ±18 µm. The difference in 3D deviations among the 3 impression groups for Straumann was statistically significant among all groups ($P=.003$), except for the conventional impression (22 ±5 µm) and True Definition (17 ±5 µm) groups; the median ±interquartile range for the Omnicam group was 26 ±15 µm. The difference in 3D deviations between the 2 implant systems was significant for the Omnicam ($P=.011$) and conventional ($P<.001$) impression techniques but not for the True Definition technique ($P=.247$).

Conclusions. Within the limitations of this study, both the impression technique and the implant system affected accuracy. The True Definition technique had the fewest 3D deviations compared with the other 2 techniques; however, the accuracy of all impression techniques was within clinically acceptable levels, and not all differences were statistically significant. (J Prosthet Dent 2017;■:■-■)

Dental implants have been used for decades to treat partially and completely edentulous patients with implant-supported fixed dental prostheses (IFDPs) with demonstrated success.[1] The advances in computer-assisted design and computer-assisted manufacturing (CAD-CAM) technology have made it a viable alternative to conventional techniques for fabricating IFDPs.[2]

The passive fit of an IFDP may be a significant prerequisite for maintaining a healthy bone-implant interface and is essential for its long-term success.[3,4] Even

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A Brief Historical Perspective on Dental Implants, Their Surface Coatings and Treatments

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Abstract: This review highlights a brief, chronological sequence of the history of dental implants. This historical perspective begins with ancient civilizations and spotlights predominant dentists and their contributions to implant development through time. The physical, chemical and biologic properties of various dental implant surfaces and coatings are discussed, and specific surface treatments include an overview of machined implants, etched implants, and sand-blasted implants. Dental implant coatings such as hydroxyapatite, fluoride, and statin usage are further reviewed.

Keywords: Dental history, implant surface, implants, surface coating.

A BRIEF HISTORY OF DENTAL IMPLANTS

"There's Gold (Ivory and Stone) in them thar (Implants)"!

The history of the evolution of dental implants is a rich and fascinating travelogue through time. Since the beginning of mankind, humans have used dental implants in one form or another to replace missing teeth. In approximately 2500 BC, the ancient Egyptians tried to stabilize teeth that were periodontally involved with the use of ligature wire made of gold. Their manuscripts and texts allude to several interesting references to toothaches. About 500 BC, the Etruscans customized soldered gold bands from animals to restore oral function in humans; they also fashioned replacements for teeth from oxen bones. At about the same period, the Phoenicians used gold wire to stabilize teeth that were periodontally involved; around 300 AD, these innovative peoples used teeth creatively carved out of ivory which were then stabilized by gold wire to create a fixed bridge. The first evidence of dental implants is attributed to the Mayan population roughly around 600 AD where they excelled in utilizing pieces of shells as implants as a replacement for mandibular teeth. Radiographs taken in the 1970's of Mayan mandibles show compact bone formation around the implants-bone that amazingly looks very much like that seen around blade implants! Moreover, around 800 AD, a stone implant was first prepared and placed in the mandible in the early Honduran culture [1].

From Rocks to Roosters- Early Implants Emerge

In the middle of the 1600's periodontally compromised teeth were stabilized in Europe with various substances. From the 1500's to about the 1800's, teeth in Europe were collected from the underprivileged or from cadavers for the use of allotransplantation. During this period, Dr. John Hunter came on to the scene; for many years he worked with "resurrectionists"-people who acquired corpses underhandedly through the robbing of graves. By doing so, he was able to observe and document with great detail the anatomy of the mouth and jaw. In the 1700's, Dr. Hunter suggested transplanting teeth from one human to another; his experiment involved the implantation of an incompletely developed tooth into the comb of a rooster. He observed an extraordinary and astonishing event: the tooth became firmly embedded in the comb of the rooster and the blood vessels of the rooster grew straight into the pulp of the tooth [1, 2]. In 1809, J. Maggiolo inserted a gold implant tube into a fresh extraction site. This site was allowed to heal and then a crown was later added; unfortunately, there was extensive inflammation of the gingiva which followed the procedure [1, 3]. Innumerable substances during this time period were used as implants; these included silver capsules, corrugated porcelain, and iridium tubes [1, 3].

Brothers Strock to Building Spirals

Dr. EJ Greenfield, in 1913, placed a "24-gauge hollow latticed cylinder of iridio-platinum soldered with 24-karat gold" as an artificial root to "fit exactly the circular incision made for it in the jaw-bone of the patient "[4]. In the 1930's, two brothers, Drs. Alvin and Moses Strock, experimented with orthopedic screw fixtures made of Vitallium (chromium-cobalt alloy). They carefully observed how physicians successfully placed implants in the hip bone, so they implanted them in both humans and dogs to restore individual teeth. The Vitallium screw provided anchorage and support for replacement of the missing tooth. These brothers were acknowledged for their work in selecting a biocompatible metal to be used in the human dentition [5]. The Strock brothers were also thought to be the first to place the first

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History

The discovery, development and clinical application in medicine and dentistry has been described and illustrated extensively in two books by Elaine Williams-McClarence: A Matter of Balance (1992) and Close to the Edge – Brånemark and the development of Osseointegration (2003) and the book The Book On Osseointegration by Brånemark et al.(2005), published by Quintessence books-Berlin, Germany.

During vital microscopic studies in animal and man of blood as a mobile tissue, even in bone and marrow in animals, an optical titanium chamber was used, being implanted. It turned out to be extremely difficult to remove for further use. After several years, when I moved from Lund to Gothenburg 1959 working with orthopaedics and plastic surgery, came the possibility to use the experimental findings in some clinical situations e.g. secondary clefts, joint prostheses and limb prostheses. Later on tumour defects were also considered in our international collaboration.

Because I was a counsellor for PhD students in different dental and medical professions I could assemble a wide range of doctoral theses on tissue reaction and healing, even in irradiated tissue. This also enabled me to see a large number of patients with defects in various parts of their body.

I obtained in the late -50ies a major research grant from NIH to study the formation and release of new formed erythrocytes into the bone marrow sinusoids, which were my special interest. This made me relatively independent and also allowed requiring special equipment.

P-IB Anatomen0001

At the department of plastic surgery in Gothenburg, Sweden there was a patient with a secondary cleft, who lost his lower teeth. Since we had repaired mandible and tibia

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AJUSTE DE LAS ESTRUCTURAS METÁLICAS
COLADAS O FRESADAS
SOBRE IMPLANTES DE CONEXIÓN
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Doctorando.: J. Raúl Fernández Encinas
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Salamanca, noviembre de 2015.

Implant Restorations:
A Step-by-Step Guide

2nd Edition

Chapter 1: Introduction to Implant Dentistry

INTRODUCTION

The successful, long-term clinical use of dental endosseous implants requires some type of biologic attachment of implants to bone. In 1969 Brånemark and others defined this process as osseointegration (Brånemark and others 1977). This process has been subsequently studied by numerous authors and has come to identify the functional stability of the endosseous implant/bone connection (Davies 1998). The histology and biomechanics of osseointegration is beyond the scope of this text; the reader is referred to other sources for further information and increased understanding relative to osseointegration.

Treatment of edentulous or partially edentulous patients with endosseous implants requires a multidisciplinary team approach. This team generally consists of an implant surgeon, restorative dentist and dental laboratory technician. Each team member needs to be aware that implant dentistry is a restorative-driven service and the ultimate success of implant treatment will be measured, at least in part, by the aesthetic and functional results as perceived by patients. The design of the prosthesis, whether it be a single implant retained crown or a full-arch prosthesis, will have a major impact on the number, size, and position of the implant(s) that will be used in a particular treatment plan. Treatment planning for implant dentistry must therefore begin with the restorative phase prior to considering the surgical phases of treatment.

Brånemark and co-workers introduced a two-stage surgical protocol into North America in 1982 (Zarb 1993). Numerous, long-term clinical studies have proven the efficacy of titanium, endosseous implants (Adell 1981; Sullivan and Sherwood 2002; Friberg and Jemt 1991; Testori and Del Fabbro 2002). Many clinicians now consider osseointegration of dental implants to be predictable and highly effective in solving clinical problems associated with missing teeth (Davarpanah and Martinez 2002).

PURPOSE OF TEXTBOOK

The purpose of this textbook is to provide clinicians and dental laboratory technicians with a step-by-step approach to the treatment of certain types of edentulous and partially edentulous patients with dental implants. Six types of patient treatments are featured. The treatments are illustrated with emphasis on diagnosis and treatment planning, restorative dentist/implant surgeon communication and restorative treatments, on an appointment-by-appointment basis. Implant components are identified for each specific appointment. Laboratory procedures and work orders are also included. Implant loading protocols are discussed for each particular case presentation.

The biologic and theoretical aspects of osseointegration are not reviewed. Osseointegration is defined as clinically immobile implants; absence of peri-implant radiolucencies as assessed by an undistorted radiograph; mean vertical bone loss less than 0.2 mm annually after the first year of occlusal function; absence of pain, discomfort and infection (Smith and Zarb 1989). Clinical verification of osseointegration can be difficult at best. Some implants that have been considered successful at the second surgical or impression appointments have subsequently failed prior to or after completion of the prosthetic portion of treatment. Zarb and Schmitt (1990) have found that "late failures" occurred 3.3% of the time in patients with mostly edentulous mandibles. Naert and Quirynen (1992) published a report that contained data from partially edentulous patients, maxillae and mandibles. They reported late failures of 2.5%. Late failures are important to clinicians and patients because of the additional expense and treatment that patients may elect to undergo in replacing prostheses on failed implants.

This text concentrates on how clinicians may successfully incorporate implant restorative dentistry into their practices. A team approach is emphasized among members of the implant team: restorative dentists, implant surgeons, dental laboratory technicians, dental assistants and office staff. Appointment sequencing, laboratory work orders and fee determination for restorative dentists are also discussed, including identification of fixed overhead, implant components, laboratory costs and profit margins.

Clinicians have multiple implant systems to choose from. There are similarities and differences among systems, including but not limited to macroscopic surface morphology, implant/abutment connections, diameters, thread pitch, and screw hex/morphology. This textbook illustrates the surgical and restorative components manufactured by 3i®, Implant Innovations, Inc., Palm Beach Gardens, FL. The author is not a representative of Implant Innovations, Inc., and purchased all the components that were used. The principles described in this textbook should be applicable to other implant manufacturers.

ECONOMICS OF IMPLANT DENTISTRY

One of the major reasons cited by general dentists relative to including or excluding implant dentistry in their practices is the cost involved in dental implant treatment. Levin has reported that more than 35% of patients referred

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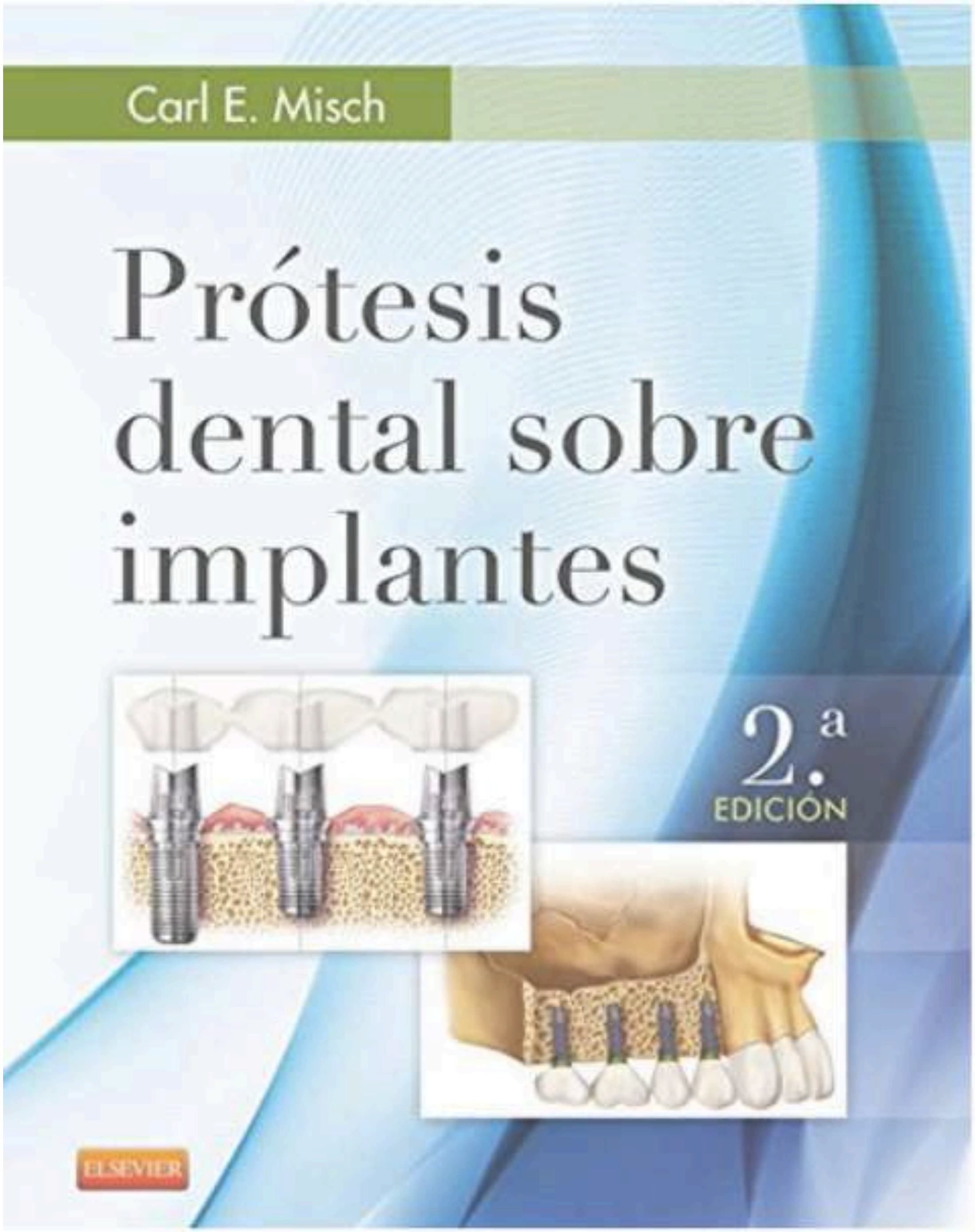
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Odontólogo.

Centro Iª implantología Madrid.

Consenso de una nueva nomenclatura protética y nuevos casos cien por cien digital superiores a cinco implantes

Figuras 18 y 19.

Mención Europea

Influencia de diversos Factores Clínicos en el Comportamiento de diferentes Escáneres Intra-Orales.

Estudio in vitro de diversos factores que influyen en la precisión y comportamiento de uso de seis escáneres intra-orales con distinta tecnología en impresiones sobre múltiples implantes.

TUTORES DE TESIS:

Promotor: Guillermo Pradíes Ramiro

Co-promotor: Mutlu Özcan

Influence of Prosthesis Fit and the Effect of a Luting System on the Prosthetic Connection Preload: An In Vitro Study

Joke Duyck, DDS, PhD[a]
Ignace Naert, DDS, PhD[b]

Purpose: It was the aim of this study to evaluate the efficiency of a luting technique that is said to compensate for misfits of implant-supported prostheses by means of a combined screw retained–luted fixation of the prostheses to the supporting abutments. **Materials and Methods:** One three-unit prosthesis was made on cylindric abutments, and one was made on conical abutments. Two more prostheses were made, one on the cylindric and one on the conical abutments, with the luting system. The preload was measured in different fit and misfit situations, with and without the use of the luting system. The preload is a combination of internal preload (positive axial forces), which is a clamping load that keeps the implant-prosthesis components together, and external preload (axial forces and bending moments), which is the result of a deformation of the implant-prosthesis complex during fixation caused by prosthesis misfit. The external preload on the supporting abutments after screw tightening the prostheses was used as an indicator for the quality of fit of the prostheses. **Results:** The axial forces were lower and the bending moments were higher in cases of misfit in comparison with the optimal fit situation. The luting system generally did not decrease the registered external preload. Except for one test condition, even higher bending moments were registered on the supporting abutments when the luting system was used. **Conclusion:** For the prostheses evaluated in this study, the luting system was not effective in reducing the external preload on the supporting implants caused by prosthesis misfit. Although the luting system could compensate for visual misfit, it failed to really improve the load conditions of the supporting implants. *Int J Prosthodont 2002;15:389–396.*

As soon as oral implants were introduced in prosthodontics, methods were developed to achieve an optimal prosthesis fit. The degree of misfit between a prosthesis and its supporting implants is a source of clinical concern because the inherent mobility of the periodontal ligament is lacking around implants. Implants consequently cannot accommodate a possible distortion of the implant-prosthesis complex caused by misfit. This misfit has been suggested as a reason for biologic[1–4] or mechanical[5] implant complications. Nevertheless, several animal[6,7] and clinical[8,9] studies could not prove a correlation between prosthesis misfit and biologic implant failure, thereby suggesting good biologic tolerance against prosthesis misfit. One animal study even suggested that misfit might stimulate bone growth.[10]

On the other hand, there are indications that misfit can lead to loosening or mechanical failure of implant components.[5] This possible negative effect of prosthesis misfit is due to the mechanical stress in the implant-prosthesis complex, which builds up during

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Accuracy of two impression techniques with angulated implants

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Statement of problem. Accurate recording of implant locations is required so that definitive restorations are properly supported and do not place additional stress on the implants. Angulated implants may result in inaccurate impressions, and the impression technique may affect the accuracy of the definitive cast.

Purpose. The purpose of this study was to determine the effect the combined interaction of impression technique, implant angulation, and implant number has on the accuracy of implant definitive casts.

Material and methods. One definitive stone cast was fabricated for each of 6 experimental groups and 1 control group. All 7 definitive casts had 3 implants arranged in a triangular pattern creating a plane. In the 6 experimental groups, the center implant was perpendicular to the plane of the cast while the outer implants had 5, 10, or 15 degrees convergence towards or divergence away from the center implant. The control definitive cast had all 3 implants parallel to each another and perpendicular to the plane of the cast. Five open tray and 5 closed tray addition silicone impressions were made of each definitive cast. Impressions were poured with type IV dental stone, and a fine tip measuring stylus was used to record multiple axis (X-Y-Z) coordinates on the top surface of the implant hex and on the cast base. Computer software was used to align the data sets and vector calculations determined the difference in degrees between the implant angles in the definitive cast and the duplicate casts. Statistical analysis used repeated-measures ANOVA (α=.05) with post-hoc tests of significant interactions.

Results. The angle errors for the closed and open tray impression techniques did not differ significantly (P=.22). Implant angulations and implant numbers differed in average angle errors but not in any easily interpreted pattern (P<.001). The combined interaction of impression technique, implant angulation, and implant number had no effect on the accuracy of the duplicate casts compared to the definitive casts (P=.19).

Conclusions. The average angle errors for the closed and open tray impression techniques did not differ significantly. There was no interpretable pattern of average angle errors in terms of implant angulation and implant number. The magnitude of distortion was similar for all combinations of impression technique, implant angulation, and implant number. (J Prosthet Dent 2007; 97: 349-356)

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Shark fin test and impression quality: A correlation analysis

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Impression taking

ABSTRACT

Objectives: To evaluate the correlation between the shark fin test and the dimensional accuracy of impressions, surface detail reproduction of impressions and rheological properties of impression materials within the manufacturer's recommended working time.
Methods: Four chemically different types of impression material (Flexitime: VPS; Fusion: Polyether/VPS blend; Impregum: classical Polyether; P2: new Polyether) were subjected to the shark fin test as well as three other test regimes. Dimensional accuracy was determined as being the discrepancy in diameter between a steel master cone and stone dies poured from impressions taken from the steel master cone at defined 30 s intervals after mixing within the manufacturer's recommended working time. Surface detail reproduction was calculated as being the difference in average arithmetic roughness (R_a) between a ground dentin surface and the corresponding area of the impressions, taken at the same 30 s intervals. Phase angle and storage modulus were measured using a rotational rheometer. Spearman's Rho was used for correlation analysis.
Results: With respect to the majority of impression materials used, significant correlations mainly exist between shark fin test data, phase angle and storage modulus. No correlation was found between the results of the shark fin test versus dimensional accuracy, respectively, surface detail reproduction.
Conclusions: Results obtained from the shark fin test within the manufacturer's recommended working time do not allow predictions regarding the dimensional accuracy or surface detail reproduction of impressions as clinically relevant material characteristics.

1. Introduction

The shark fin test (SFT) was developed by 3M ESPE[b] several years ago as "a simulated application of impression material" for illustrating the flow properties of its Polyether product Impregum during impression taking.[c] In a couple of international conference contributions (IADR: 1997, 2004–2006; AADR: 2001 and 2006; CED-IADR: 2004; PEF-IADR: 2006) and two journal articles,[1,2] the SFT was used to compare the flow properties of different impression materials. However, a medline database search using the terms "shark fin" and "shark fin test", respectively, revealed no hit in peer-reviewed literature. Summarizing the information from the available data sources as well as the marketing brochures[d] of 3M ESPE, the SFT is

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[b] Impression Materials Update: Studies show clinical advantages in using innovative "soft" polyether versus vinyl polysiloxane. Leaflet 3M ESPE 2004.
[c] http://www.hellmann.com/spotlight.cfm [homepage on the internet]. Solution Spotlight! [updated 15 August 2006].
[d] Impregum. Technical Product Profile 3M ESPE No. 70200947334/01 (01.05).

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Impression Materials in Fixed Prosthodontics: Influence of Choice on Clinical Procedure

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Keywords
Impression; models; fixed prosthodontics; physical properties.

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Abstract

The purpose of this article is to review impression materials used for fabricating fixed restorations in dentistry. Their compositions, properties, advantages, and disadvantages are presented and compared. How these properties influence clinical decisions is also described. This review helps the clinician choose which material is more suitable for a specific case. A broad search of the published literature was performed using Medline to identify pertinent current articles. Textbooks, the Internet, and manufacturers' literature were also used to supplement this information. It is limited to impression materials used in fixed prosthodontics. The review gives basic knowledge of ideal impression material properties and discusses traditional and, primarily, more recently developed products, such as polyethers, poly(vinyl siloxane), polysulfides, and condensation silicone materials. Clear advantages and disadvantages for these impression materials are provided along with the role that compositional variations have on the outcome of the impression. This should enable clinicians and technicians to easily identify the important physical properties of each type of impression material and their primary clinical indications.

The success rate of prosthetic tasks relies on several factors including dimensional accuracy, detail reproduction of impressions, and the corresponding models from which a restoration can be manufactured in the laboratory.[1] This success rate is imperiled when one looks at clinical studies. Impression making is an important step to get a perfect cast, as the aim of an impression is to produce a dimensionally stable "negative" to serve as the cast mold. To attain this goal, many impression materials are suitable for use. The materials should reproduce the static and oral structures accurately for an optimum cast.[2] The exactitude of the final restorations depends greatly on the impression materials and techniques used. In fact, the accurate reproduction of preparation margins in an impression is a necessary requirement for achieving good marginal quality. In vitro, the marginal precision of a dental restoration is 50 μm on average.[3-5] This margin is the sum of all relative and absolute errors accumulated throughout the process, starting from the impression until the restoration is finally produced. It is therefore important to have a minimal error rate in each stage to reduce the cumulative effect of all the steps (e.g., using a CAD/CAM system). Despite rapid technical progress in the CAD/CAM field, conventional impressions are still required for transporting information from the dentist to the dental laboratory. CAD/CAM systems (such as Procera, Everest Kavo, Lava 3M) scan the finish line from the master cast made of gypsum. In the future, intraoral chairside scanners (e.g., the CEREC-Sirona dental systems) might replace the need for making impressions. Digital impressions will be sent to the laboratory where the technician will digitally cut and mark the margins, thus eliminating the impression step.

Until this technical skill becomes a common procedure, the use of conventional impressions is still the gold standard for dentists. To be accurate, these impressions need good impression materials.

The aim of this review is to give a detailed overview of all appropriate dental impression materials for fixed prosthodontics. An emphasis on clinical implications in relation to their properties will also be given.

Brief history of dental impression materials

In the 1950s and 1960s, hydrocolloids were the preferred impression materials. Since the introduction of hydrocolloids in the mid-1930s, the impression of undercuts became possible. In the 1950s, polysulfides and condensation reaction silicones (C-type silicones) were used reliably in fixed prosthodontics.

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Long-term dimensional stability and reproduction of surface detail of four polyvinyl siloxane duplicating materials

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ABSTRACT

Objectives: Duplicating materials must routinely accurately reproduce the details of dental casts and thus contribute significantly to the close adaptation and success of a removable prosthesis or fixed indirect restoration. It is important to establish the long-term dimensional stability of polyvinyl siloxane materials (PVS) as they are widely used in dental technology and over the duration of a course of treatment, are stored under dental laboratory conditions. The dimensional stability of four PVS duplicating materials was investigated over a 13-week period.

Materials and methods: Forty PVS duplicate moulds of a partially dentate maxillary arch were produced from four materials (Elite double 8, Gemini transparent, C & J pourable silicone and Z Dupe). Three dimensions were measured in triplicate at baseline 1, 5, 9 and 13 weeks using computerised image analysis. Half of the specimens were measured following storage at room temperature (21 ± 2 °C) and half at 37 °C to represent storage in hot climates. Specimens for scanning electron microscopy were prepared by duplicating a rugosity standard.

Results: At room temperature two materials Elite Double 8 and Z Dupe showed no statistically significant dimensional change, the other two materials showed a slight increase of dimensions. Specimens stored at 37 °C showed greater differences in dimensions with Z Dupe showing statistically significant shrinkage. SEM investigation showed no surface deterioration of two materials.

Conclusions: None of the materials showed a change in dimension greater than 2% and the four PVS materials showed good dimensional stability over the time period of the study.

1. Introduction

Accurate duplicates of dental models are required for diagnosis, planning and successful completion of restorative treatment. Duplicating materials are used to form laboratory impressions of a master cast to fabricate duplicate models to be used during the course of prosthodontic treatment. In removable prosthodontics duplicate models serve multiple purposes. One of these is as a refractory cast onto which the wax pattern of a metal framework can be laid down. A second use is for final processing of acrylic elements onto a framework. During the construction of indirect restorations in fixed prosthodontics, duplicate casts are used for the production of laboratory constructed provisional restorations and diagnostic wax ups. Duplicating materials must routinely accurately reproduce the details of the master cast and thus contribute significantly to the ultimate close adaptation and success of a removable prosthesis or any fixed indirect restoration.

Traditional agar duplicating materials require purpose developed equipment, are time consuming to use and can only

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Trends in Elastomeric Impression Materials

R G CRAIG • Z SUN

SUMMARY

In the past three years more addition silicones have been supplied as hydrophilic materials and heavier viscosities have been provided in automatic mixing cartridges. Also, a polyether is now supplied in an automatic mixing system. There has been an increase in the number of products available as monophase or single viscosity systems. Both addition silicones and polyethers are available as bite registration materials.

INTRODUCTION

Reviews of the four general types of elastomeric impression materials and commercial products were reported by Craig (1986), and Craig, Urquiola, and Liu (1990). More recently Farah and Powers (1989, 1992) reviewed and qualitatively ranked crown and bridge impression materials and bite registration materials; the present review mainly was based on data presented in the 1992 paper. Also recently, Kim, Craig, and Koran (1992) reported on the viscosity of five monophase addition silicones as a function of shear rate.

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Since the earlier reviews by Craig (1986) and Craig and others (1990), the following trends in elastomeric impression materials have occurred: (1) more addition silicone products are now supplied as hydrophilic materials, (2) automatic mixing has been extended from low and medium to high and even putty consistencies, (3) more monophase, or single consistency, addition silicone impression materials are available, (4) putty impression materials are being supplied as soft as well as regular products, (5) automatic mixing has been extended to polyether materials, and (6) addition silicones and polyethers have found increased application as bite registration materials and are available as hand and automatic mixing types.

It is the purpose of this paper to present quantitatively the properties of the newer products not reviewed earlier by Craig (1986) and Craig and others (1990) but reported qualitatively by Farah and Powers (1992).

METHODS AND MATERIALS

The products included in this review are listed in Table 1 along with the manufacturer, consistency type, type of mixing, batch number, and type of impression material. The bite registration materials evaluated are listed in Table 2, which also lists their manufacturer, type of material, type of mixing, and their batch number.

Table 1 lists a number of manufacturers that produce hydrophilic addition silicones since the introduction of the first hydrophilic material, Express by 3M. There initially was some concern that adding a surfactant to the silicone would decrease its shelf

Jemt T. Implant treatment in elderly patients. *Int J Prosthodont* 1993;6:456–461.

The experiences in treating 48 patients, 80 to 90 years old, with 254 implants in both arches were evaluated in this retrospective study. The majority of the patients were restored with implant-supported fixed restorations. A failure rate of 2.5 percent was reported at abutment connection, and three 7-mm implants were lost following placement of the prosthesis in one patient. Eighty-two percent of the patients were treated without additional appointments beyond the protocol. Some patients experienced postinsertion problems affected by muscle control, such as cheek biting. All patients adapted to the implant-supported prostheses within 1 year. No major maintenance problems were encountered during an average follow-up period of 3 years. The authors conclude that healthy, vital elderly patients can undergo osseointegrated implant treatment with an implant prognosis similar to that of younger patients.

Reprint Requests: Dr. Torsten Jemt, The Brånemark Clinic, Public Dental Health Service, Faculty of Odontology, Medicinaregatan 12, 413 90 Göteborg, Sweden.

Liou A, Nicholls JI, Yuodelis RA, Brudvik JS. Accuracy of replacing three tapered transfer impression copings in two elastomeric impression materials. *Int J Prosthodont* 1993;6:377–383.

This laboratory investigation tested the accuracy of reseating tapered transfer impression copings for implant-supported prostheses into the polymerized impression. Five clinicians repositioned combinations of three impression copings (Dental Imaging Associates, Implant Innovations, and Steri-Oss) into two impression materials (Impregum F and Extrude). Modifications to the impression copings enabled analysis of any rotational errors during reseating. Coordinate measurements were made. Statistical analysis revealed that the general process of reseating impression copings was inconsistent and relatively inaccurate. No significant differences were noted with either of the impression materials tested, and multiple reseating into the same impression did not significantly alter accuracy. The Steri-Oss and Dental Imaging Associates copings could be replaced more accurately than the Implant Innovations copings. The one guiding surface, or facet, of the Steri-Oss copings appeared to minimize orientation errors during reseating. A "popping" sound during reseating was generally associated with minimal error. Since reseating impression copings is relatively imprecise, the authors suggest repeating the seating of the impression coping if this characteristic sound is not heard.

Reprint Requests: Dr. Jack Nicholls, Department of Restorative Dentistry, University of Washington, D767 Health Sciences Building, Room 56, Seattle, WA 98195.

Oesterle LJ, Cronin RJ, Ranly DM. Maxillary implants and the growing patient. *Int J Oral Maxillofac Implants* 1993;8:377–387.

The clinical implications of placing osseointegrated implants in the maxillae of prepubertal patients were postulated. The authors compared the potential behavior of osseointegrated implants during craniofacial growth in the maxillae with results from investigations using implants as growth markers (Bjork), osseointegrated implants in pigs, and ankylosed teeth. Beyond age 7, two-thirds of maxillary growth occurs from changes within the maxillae. Transverse maxillary growth accelerates during puberty and is principally the result of the midpalatal suture. Interruption of this growth site with fixed implant-supported prostheses involving either side of the suture could interrupt normal maxillary transverse growth. Vertical skeletal growth of the maxillae includes sutural displacement and the complex combination of apposition and resorption of the maxillary alveolus. It is postulated that during growth and development an osseointegrated implant, by remaining stationary in the alveolus, would become buried occlusally by apposition, and exposed apically in the nasal sinus by resorption. The eruption of the permanent dentition results in the following dental arch changes: (1) significant increases in transverse arch width; (2) slight decreases in anteroposterior length; (3) anterior movement of the dental arch; and (4) increased height of the alveolar process. Osseointegrated implants placed in this dynamic growth field most probably will not migrate during development as seen in the unankylosed natural dentition. Since craniofacial development in the maxilla is relatively unpredictable, caution is advised when considering the placement of implants prior to the eruption of the permanent dentition.

Reprint Requests: Dr. Larry J. Oesterle, 11693 East Lake Place, Englewood, CO 80111.

Hydrophilic Poly(Vinyl Siloxane) Impression Materials: Dimensional Accuracy, Wettability, and Effect on Gypsum Hardness

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Indiana University School of Dentistry

Three hydrophilic poly(vinyl siloxane) impression materials, containing an intrinsic surfactant, were compared with a hydrophobic poly(vinyl siloxane) and a polyether impression material. The hydrophobic poly(vinyl siloxane) material was dimensionally more accurate than the hydrophilic poly(vinyl siloxanes) in two of three measured dimensions, but the difference was small. The polyether material was the most wettable, and the hydrophilic poly(vinyl siloxanes) were more wettable than the hydrophobic poly(vinyl siloxane). However, when a topical surfactant was used, no difference in wettability was noted between the hydrophilic and hydrophobic poly(vinyl siloxanes), and their wettability was comparable to the polyether material, indicating that the topical surfactant was more effective than the intrinsic surfactants. Stone dies made from the hydrophobic poly(vinyl siloxane) material were harder than those obtained from the other materials. *Int J Prosthodont 1991;4:240–248.*

When poly(vinyl siloxane) impression materials were introduced, many desirable properties were noted; however, it was apparent that their hydrophobic nature could result in gypsum dies and casts with surface voids. To improve wettability, topical surfactants have been applied to impression surfaces prior to introducing gypsum materials. An extensive study by McCormick et al[1] compared the wettability of 65 impression material brands when water or two commercially available surfactants were topically applied to the impression surface. The two commercial surfactants improved the wettability of most of the poly(vinyl siloxane) materials. Polyether impression materials were found to be the most wettable when water was used as the surfactant, but there was no predictable improvement in wettability when the commercial surfactants were used. These data support the work by Lorren et al,[2] who showed polyether impression materials to be the most wettable when compared to silicone or polysulfide. The polyether materials produced specimens with the lowest contact angles and fewest bubbles. Lacy et al[3] tested several topical surfactants and found two that improved the wettability of polyether but none that improved the wettability of the polysulfide or condensation-reaction silicones. In that study, the topical surfactants were applied and the impressions were then rinsed with water and air dried. Norling and Reisbick[4] found a significant reduction in the number of air voids in dental stone when surfactants were incorporated into the base material of polysulfide and condensation-reaction silicone impression materials prior to mixing.

Hydrophilic poly(vinyl siloxane) impression mate-

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Reprint requests: Dr Rose Marie Jones, Department of Prosthodontics, Indiana University School of Dentistry, 1121 W Michigan Street, Indianapolis, Indiana 46202.

Dimensional accuracy and surface detail reproduction of two hydrophilic vinyl polysiloxane impression materials tested under dry, moist, and wet conditions

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Statement of problem. A major limitation of vinyl polysiloxane (VPS) impression materials is their hydrophobicity. There are 2 aspects to this problem, the wettability of the polymerized impression by dental gypsum materials and the ability of the unpolymerized material to wet intraoral tissues. To address this problem, manufacturers have added surfactants and labeled the new products as *hydrophilic vinyl polysiloxane*.

Purpose. The purpose of this investigation was to compare dimensional accuracy and surface detail reproduction of 2 hydrophilic VPS impression materials, when used under dry, moist, and wet conditions.

Material and methods. A total of 102 impressions were made of stainless steel metal dies similar to those described in American Dental Association (ADA) specification 19. The dies had 2 vertical and 3 horizontal lines inscribed on their superior surfaces. Impressions were made under dry, moist, and wet conditions. Dimensional accuracy was measured by comparing the average length of the middle horizontal line in each impression to the same line on the metal die, by use of a measuring microscope with an accuracy of 0.001 mm. A 2-way analysis of variance and least significant difference post hoc test were used to compare mean dimensional changes (α=.05). Surface detail reproduction was evaluated in 2 ways: (1) by use of criteria similar to ADA specification 19 for detail reproduction, continuous replication of at least 2 of the 3 horizontal lines, and (2) by use of a method developed for this study that categorized the impressions as satisfactory or unsatisfactory based on their surface characteristics: presence of pits, voids, or roughness. Pearson χ^2 (α=.05) was used to compare detail reproduction results.

Results. Conditions (dry, moist, and wet) did not cause significant adverse effects on the dimensional accuracy of either material. The mean dimensional change and SD were 0.005% ± 0.002% or less. With both surface detail analyses, dry, moist, and wet conditions had a significant effect on the detail reproduction of both materials (P<.05). Only under dry conditions did both impression materials continuously replicate at least 2 of the 3 horizontal lines 100% of the time. Under moist conditions, 82% of the Aquasil impressions and 100% of the Reprosil impressions were judged satisfactory, while under wet conditions, only 47% Aquasil and 11% Reprosil impressions were satisfactory. With the additional surface detail characterization, only under dry conditions were impressions produced with clinically acceptable surface quality (Aquasil 77% and Reprosil 100% satisfactory).

Conclusions. Dimensional accuracy of both materials tested was well within ADA standards. Best surface detail results were obtained only under dry conditions for both materials. (J Prosthet Dent 2003;90:365-72.)

CLINICAL IMPLICATIONS

Although the 2 impression materials tested in this in vitro investigation are advertised as hydrophilic, evaluation of the impressions' surface characteristics revealed that both materials performed reliably only under dry conditions. Under moist and wet conditions, both materials performed inconsistently. These results suggest that when these materials are used, moisture control remains a vital factor for predictable success.

Funded in part by the Rinehart Foundation, University of Missouri-Kansas City School of Dentistry.

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Master Cast Accuracy in Single-Tooth Implant Replacement Cases: An In Vitro Comparison. A Technical Note

Paolo Vigolo, Dr Odont, MScD[1]/Fulvio Fonzi, CDT[2]/Zeina Majzoub, DCD, DMD, MScD[3]/
Giampiero Cordioli, MD, DDS[4]

Purpose: *This in vitro study evaluated the accuracy of master casts obtained by using (1) copings modified by sandblasting and coating their roughened surfaces with impression adhesive before final impression procedures and (2) gold machined UCLA abutments as impression copings in final impression procedures for single-tooth implant replacement cases.* **Materials and Methods:** *A polymeric resin model with a standard single implant was used to simulate a clinical situation. A group of 20 impressions were made using square impression copings sandblasted to roughen their external surfaces at a supragingival level and then coated with Impregum polyether adhesive; a second group of 20 impressions were made using gold machined UCLA abutments as impression copings. The castable part of the UCLA abutments was secured with resin to the gold machined section of the UCLA abutment to prevent movement of the castable part itself on the gold machined portion during the impression procedures; the castable portion of the UCLA was also coated with the Impregum polyether adhesive to improve the stability of the gold machined UCLA abutment inside the impression material. Master casts fabricated for both groups were analyzed to detect rotational position change of the hexagon on the implant replicas in the master casts with reference to the resin model.* **Results:** *The rotational position changes of the hexagon on implant replicas were significantly less variable in the master casts obtained using gold machined UCLA abutments as impression copings than in the master casts achieved with the roughened square impression copings.* **Discussion:** *Improved precision of the impression was achieved when the gold machined UCLA abutments were used as impression copings.* **Conclusion:** *This report suggests that using gold machined UCLA abutments as impression copings in the final impression procedures can enable the clinician to achieve a more accurate orientation of the implant replicas in the laboratory master casts for single-tooth implant replacement cases.* INT J ORAL MAXILLOFAC IMPLANTS 2005;20:455–460

Key words: *dental implants, implant abutments, master casts, single tooth replacement*

Transfer of the exact position and orientation of implants to the working cast is particularly important in implant restorative procedures.[1–3] When a multiple-abutment restoration is fabricated, the pickup impression copings can be joined together with acrylic resin or composite to stabilize them within the impression material. Similar procedures are not applicable for single-tooth replacement, which may imply that minor movements of the impression coping retained inside the impression material can occur during all the procedural transfers which lead to the master cast. As a result, transfer of the exact position of the implant with its hexagonal head to the working cast may be tri-dimensionally inaccurate. This inaccuracy can lead to the fabrication of a definitive single-tooth crown that, clinically, may present occlusal and/or interproximal contacts dissimilar from those achieved by the technician on the working casts.

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In Vitro Implant Impression Accuracy Using a New Photopolymerizing SDR Splinting Material

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ABSTRACT

Purpose: The study aims to evaluate three-dimensionally (3D) the accuracy of implant impressions using a new resin splinting material, "Smart Dentin Replacement" (SDR).

Materials and Methods: A titanium model of an edentulous mandible with six implant analogues was used as a master model and its dimensions measured with a coordinate measuring machine. Before the total 60 impressions were taken (open tray, screw-retained abutments, vinyl polysiloxane), they were divided in four groups: A (test): copings pick-up splinted with dental floss and fotopolymerizing SDR; B (test): see A, additionally sectioned and splinted again with SDR; C (control): copings pick-up splinted with dental floss and autopolymerizing Duralay® (Reliance Dental Mfg. Co., Alsip, IL, USA) acrylic resin; and D (control): see C, additionally sectioned and splinted again with Duralay. The impressions were measured directly with an optomechanical coordinate measuring machine and analyzed with a computer-aided design (CAD) geometric modeling software. The Wilcoxon matched-pair signed-rank test was used to compare groups.

Results: While there was no difference ($p = .430$) between the mean 3D deviations of the test groups A (17.5 µm) and B (17.4 µm), they both showed statistically significant differences ($p < .003$) compared with both control groups (C 25.0 µm, D 19.1 µm).

Conclusions: Conventional impression techniques for edentulous jaws with multiple implants are highly accurate using the new fotopolymerizing splinting material SDR. Sectioning and rejoining of the SDR splinting had no impact on the impression accuracy.

KEY WORDS: accuracy, edentulous jaw, implant impression technique, impression copings, passive fit, splinting material

INTRODUCTION

The accuracy is an important factor for the success and survival of an implant-retained prosthesis. The precise transfer of the three-dimensional (3D) intraoral implant relationship to the master cast is a critical step to achieve a passive fit.[1–4] The insufficient accuracy during the impression-making technique and/or manual steps during prosthesis fabrication may lead to misfit of the prosthesis and subsequent to technical, mechanical, and biological complication such as occlusal discrepancies screw or abutment loosening, fracture of the prosthetic components, implant fractures, and loss of osseointegration.[5–8] Differently from natural teeth, osseointegrated implants have no periodontal ligament to compensate any inaccuracy of implant-retained prosthesis.[9] Inaccurate frameworks of implant-retained prosthesis can cause stress at the implant/bone interface, plaque accumulation, affecting soft and/or hard tissues

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CLINICAL APPLICATIONS OF BIOMATERIALS

Review Article

Polyetheretherketone (PEEK) for medical applications

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Abstract Polyetheretherketone (PEEK) is a polyaromatic semi-crystalline thermoplastic polymer with mechanical properties favorable for bio-medical applications. Polyetheretherketone forms: PEEK-LT1, PEEK-LT2, and PEEK-LT3 have already been applied in different surgical fields: spine surgery, orthopedic surgery, maxillo-facial surgery etc. Synthesis of PEEK composites broadens the physicochemical and mechanical properties of PEEK materials. To improve their osteoinductive and antimicrobial capabilities, different types of functionalization of PEEK surfaces and changes in PEEK structure were proposed. PEEK based materials are becoming an important group of biomaterials used for bone and cartilage replacement as well as in a large number of diverse medical fields. The current paper describes the structural changes and the surface functionalization of PEEK materials and their most common biomedical applications. The possibility to use these materials in 3D printing process could increase the scientific interest and their future development as well.

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1 Introduction

Polyetheretherketone (PEEK) is a polyaromatic semi crystalline thermoplastic polymer with chemical formula $(–C_6H_4–O–C_6H_4–O–C_6H_4–CO–)_n$ [1]. PEEK was commercialized for the industry in the 1980s [2]. It was proposed as a material for biomedical application in 1998 by Invibio Ltd. (Thornton-Cleveleys, UK). In the same year Victrex PEEK business (Imperial Chemical Industry, London UK) launched PEEK-OPTIMA for long-term implantable applications [2, 3]. Describing the properties of PEEK-optima LT1 materials we should differentiate the unfilled PEEK biomaterial from PEEK-composites. Implants based on the PEEK composites have been developed as an alternative to conventional metallic or ceramic devices [4]. PEEK-LT1 can contain varying amounts of bioactive materials like hydroxyapatite (HA) and β-tricalcium phosphate. PEEK polymer devices were first reported for fracture fixation, using carbon reinforcement in a PEEK matrix [5]. All structural changes in PEEK materials are developed to increase their biomechanical and biological properties. Today the medical application of PEEK materials is common in several surgical fields. One possible classification based on clinical application of PEEK materials i.e. PEEK based implants is presented below.

1.1 Clinical classification of PEEK implants

(1) PEEK for bone replacement-maxillo-facial and cranial implants.
(2) PEEK for spine surgery-spinal cages.
(3) PEEK for orthopedic surgery.
    (a) for bone and hip-replacement-articulation implants.

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One clinical visit for a multiple implant restoration master cast fabrication

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The making of a one-piece, long-span, implant-supported prosthesis with conventional procedures frequently has difficulties associated with the accuracy of fit. This article presents a clinical and laboratory procedure for making an accurate implant working cast that facilitates fabrication of the casting on the master cast. The procedure demonstrates the process of sectioning and rejoining of the resin between the transfer copings and then pouring the impression by first joining the analogs alone with impression plaster, sectioning it, and rejoining it again to stabilize the analogs, and finally, using dental stone to pour the impression. Clinical, radiographic, and laboratory (optical microscope) measurements for one clinical implant restoration confirm the accuracy of fit of this one prosthesis made with this procedure. Its advantage is that it can allow fabrication of the final casting on the cast, thereby eliminating the clinical time necessary to obtain repetitive solder indexes, and thus minimizing inconvenience to the patient. (J Prosthet Dent 1997;78:550-3.)

As implant dentistry continues to evolve, it is more widely recognized that implant restorations require different procedures compared with traditional crown and bridge prosthodontics.[1-4] In particular, when restoring multiple unit implant-supported restorations, presoldering (metal framework only) or postsoldering (after porcelain application) procedures are required because of errors in the transfer of the relationship of the implants to the working cast. Errors that result from the transfer of implant position during the impression procedures often make it necessary to section and solder metal frameworks repeatedly.[1,5,6] This problem is particularly important with implant-supported prosthesis because, in contrast to natural teeth where the periodontal ligament allows tooth movement of 28 µm[6] in a vertical direction, and in a horizontal direction 56 to 73 µm in posterior teeth and 69 to 108 µm in anterior incisor teeth,[7] an implant can only move 2 to 3 µm[6] vertically and 12 to 66 µm in a labiolingual direction, because of lack of a periodontal ligament.[8,9] Thus the relational accuracy of the implant-supported restoration to adjacent implant abutments must be greater. Because of this, the inaccuracy of the casting in an implant-supported prosthesis with the conventional lost wax casting procedures to cast one-piece, full-arch implant frameworks is both imprecise and inaccurate as judged against the passive fit requirement.[4] The consequences of a lack of fit include micromovement that may break the cement-implant attachment and, with a screw-in prosthesis, loosening of the coping screw.[10] When the prosthesis is loosened from the implant interface, physiologic masticatory stresses are magnified at that interface and can result in displacement or screw fracture. Therefore, to achieve a close fit of the prosthesis to the implant, implant-supported crowns are made individually and soldered together from intraoral transfers to minimize framework distortion.[10-13] There are two significant sources of error in framework distortion: One is the shrinkage of the resin material (curing contraction is 0.6% linear)[14] used to join the implants impression coping at the time the master impression is obtained, and the second is expansion that takes place during setting of the dental stone (type III, setting expansion is 0.3%)[14] used for the master cast.

Phillips et al.[15] studied the accuracy of implant impressions obtained with three types of transfer copings, tapered copings, square copings, and square copings splinted with acrylic resin. He found that square and square/resin coping techniques showed no significant difference. However, Assif et al.[16] compared three impression procedures relative to the accuracy in a laboratory cast. The first procedure used autopolymerizing acrylic resin to splint the transfer copings. The second involved splinting the transfer copings directly to an acrylic resin custom tray. In the third, only impression material was used to orient the transfer copings. The procedure that uses acrylic resin to splint transfer copings in the impression material was significantly more accurate than the two other procedures.

This report describes a clinical and laboratory procedure for fabricating an accurate implant working cast. It uses the process of sectioning and rejoining of the resin between the transfer copings and then the master cast is made: pouring the impression by first, joining the analogs alone with impression plaster (setting expansion is 0.06%),[17] sectioning the plaster connection, and rejoining it again to stabilize the analogs, then using stone for

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Review

Advancements in CAD/CAM technology: Options for practical implementation

CrossMark

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ABSTRACT

Purpose: The purpose of this review is to present a comprehensive review of the current published literature investigating the various methods and techniques for scanning, designing, and fabrication of CAD/CAM generated restorations along with detailing the new classifications of CAD/CAM technology.

Study selection: I performed a review of a PubMed using the following search terms "CAD/CAM, 3D printing, scanner, digital impression, and zirconia". The articles were screened for further relevant investigations. The search was limited to articles written in English, published from 2001 to 2015. In addition, a manual search was also conducted through articles and reference lists retrieved from the electronic search and peer-reviewed journals.

Results: CAD/CAM technology has advantages including digital impressions and models, and use of virtual articulators. However, the implementation of this technology is still considered expensive and requires highly trained personnel. Currently, the design software has more applications including complete dentures and removable partial denture frameworks. The accuracy of restoration fabrication can be best attained with 5 axes milling units. The 3D printing technology has been incorporated into dentistry, but does not include ceramics and is limited to polymers. In the future, optical impressions will be replaced with ultrasound impressions using ultrasonic waves, which have the capability to penetrate the gingiva non-invasively without retraction cords and not be affected by fluids.

Conclusion: The coming trend for most practitioners will be the use of an acquisition camera attached to a computer with the appropriate software and the capability of forwarding the image to the laboratory.

Contents

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ORIGINAL ARTICLE

Digital evaluation of the reproducibility of implant scanbody fit—an in vitro study

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Abstract Dental restorations are increasingly manufactured by CAD/CAM systems. Currently, there are two alternatives for digitizing dental implants: direct intra-oral data capturing or indirect from a master cast, both with transfer caps (scanbodies). The aim of this study was the evaluation of the fit of the scanbodies and their ability of reposition. At the site of the first molars and canines, implants were placed bilaterally in a polymer lower arch model (original model), and an impression was taken for fabricating a stone cast (stone model). Ten white-light scans were obtained from the original and the stone model with the scanbodies in place. The scanbodies were retrieved after each scan and re-attached to the same implant or lab analogue. The first scan of the series served as control in both groups. The subsequent nine scans and control were superimposed using inspection software to identify the discrepancies of the four scanbodies in both experimental groups. The systematic error of digitizing the models was 13 μm for the polymer and 5 μm for the stone model. The mean discrepancy of the scanbodies was 39 μm (±58 μm) on the original implants versus 11 μm (±17 μm) on the lab analogues. The difference in scanbody discrepancy between original implants and lab analogues was statistically significant ($p<0.05$, Mann–Whitney *U* test). Scanbody discrepancy was higher on original implants than on lab analogues. Fit and reproducibility of the scanbodies on original implants should be improved to achieve higher accuracy of implant-supported CAD/CAM fabricated restorations.

Keywords Implants · Scanbodies · CAD/CAM · Impression · Model scanning

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Introduction

High-precision transfer of the clinical situation into dental laboratory is one of the crucial factors for highly accurate prosthetics on natural teeth as well as dental implants. This transfer includes the implant position as well as the inclination [1, 2]. The absolute passive fit of the prosthodontics—the declared goal of any rehabilitation—is, however, ruled out by various sources of error [3]. For implant-supported restorations, discrepancies are particularly detrimental because of the rigid osseointegration of the implants. Those discrepancies may lead to both mechanical and biological complications. Stress-induced porcelain chippings, screw loosenings and fractures of the screw, abutment, or even the implant, were reported [4–9]. Biological complications as mucositis, periimplantitis [10–12], and implant loss caused by inappropriate loading were discussed, too [13].

The precision of intra-oral impressions is one of the most important factors to achieve a perfect fit [14]. Impression techniques and impression materials affect the precision of intra-oral data transfer [15, 16]. Conventional impressions are associated with transfer problems caused by shrinkage, variable layer thickness or separation of the impression material from the tray, and warping of the impression [17]. Additional problems are caused by the

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Direct mechanical data acquisition of dental impressions for the manufacturing of CAD/CAM restorations

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ABSTRACT

Objectives: The basic prerequisite for the production of dental restorations by means of CAD/CAM technologies is the data acquisition (digitization). Currently, two methods are available, i.e. the extraoral digitization of master casts and the direct intraoral data acquisition. However, it seems to be beneficial to immediately digitize impressions directly at the dental office in order to combine the high precision of mechanical digitizing methods and to shorten the production process.

The aim of this study was to investigate the measurement uncertainty ($\pm 2\sigma$) and the three-dimensional accuracy of the immediate tactile in-office digitization of dental impressions and of the mechanical digitizing of ceramic master dies using a high-precision touch-probe digitizer.

Methods: The experimental set-up consisted of ceramic master dies representing tooth 13 and 36 as well as their identical virtual models (CAD models). Fifteen one-step putty-wash impressions were taken from each tooth. The impressions as well as the ceramic master dies were digitized applying a standardized procedure. The datasets were aligned to the corresponding CAD models; then, a computer-aided three-dimensional analysis was performed.

Results: The digitizing of the dental impressions showed a measurement uncertainty of 5.8, mean positive deviations between 27 and 28 μm, and mean negative deviations between −21 and −31 μm. The digitizing of the ceramic master dies showed a measurement uncertainty of 2.8, mean positive deviations between 7.7 and 9.1 μm, and mean negative deviations between −8.5 and −8.8 μm.

Conclusion: Mechanical digitizers show a very low measurement uncertainty and a high precision. The immediate tactile in-office digitization of impressions cannot be recommended as adequate data acquisition method for CAD/CAM restorations. It is recommendable to digitize clinical sites extraorally, i.e. after taking an impression and fabricating a model cast thereof.

1. Introduction

When using computer-aided technologies for the production of dental restorations, the minimum requirements are to digitize the abutment teeth. The digitizing accuracy is a major factor, which has an influence on the fit of fixed restorations.[1,2] Currently, the data acquisition is either performed directly in the patient's mouth (intraoral) or indirectly after taking an impression and fabricating a master cast (extraoral). Regardless of the digitizing mode applied, clinical parameters, e.g.

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ABSTRACT

Accuracy of merging scans of definitive fixed prosthodontic impressions to obtain single, accurate digitized master casts

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Introduction: Many impressions sent to commercial laboratory dental technicians may include marginal defects. In order to fabricate accurate restorations, digital technology may be used to merge digital files of defective impressions into a single Standard Tesselation Language (STL) file, free of errors.

Material and Methods: Ivorine teeth on a dentoform were prepared to receive a posterior fixed dental prosthesis (FDP). A flawless impression was made in a sectional tray using polyvinyl siloxane (PVS) impression material. An extraoral scanner was used to digitize the impression; this was the reference cast. Wax was used to create defects on the buccal and lingual margins of the preparations. Fifteen conventional sectional PVS impressions were made of the FDP preparations. After impressions were made, the wax was removed, and new defects were made on the mesial and distal margins of the preparations and an additional 15 conventional sectional PVS impressions were made in the same fashion. All impressions were digitized using the same extraoral scanner. For each pair of impressions, 2 STL files were created with the defects that had been incorporated on alternating preparation margin surfaces. The 2 STL files were then merged and a master cast was created by eliminating the defects using the scanned data. This master cast was compared to the reference cast using a reverse engineering software. Positive errors were counted as areas were the margins of the preparations on the master cast were raised in comparison to the reference cast, while negative errors were counted as areas were the margins of the preparations on the master cast were depressed in comparison to the reference cast. Statistical analysis was done using Microsoft Excel 2016 (Microsoft, WA, USA).

Results: The mean average error in the sample was -0.4 µm. The average upper limit of 95% confidence interval was 36.5 µm, while the average lower limit of 95% confidence interval was -37.3 µm. The mean RMS of the errors found was 18.9 µm.

Conclusions: Merging digitized definitive impressions to correct marginal defects resulted in master casts with high level of accuracy relative to the standard reference.

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Recent advances in dental optics – Part I: 3D intraoral scanners for restorative dentistry

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ABSTRACT

Intra-oral scanning technology is a very fast-growing field in dentistry since it responds to the need of an accurate three-dimensional mapping of the mouth, as required in a large number of procedures such as restorative dentistry and orthodontics. Nowadays, more than 10 intra-oral scanning devices for restorative dentistry have been developed all over the world even if only some of those devices are currently available on the market. All the existing intraoral scanners try to face with problems and disadvantages of traditional impression fabrication process and are based on different non-contact optical technologies and principles. The aim of this publication is to provide an extensive review of existing intraoral scanners for restorative dentistry evaluating their working principles, features and performances.

1. Background

Three-dimensional scanning of the mouth is required in a large number of procedures in dentistry such as restorative dentistry and orthodontics. The aim of the 3D mapping of the oral cavity is to create *digital impressions*.

Restorative dentistry is of course the main field that require the application of very accurate 3D intraoral scanners. For the realization of any dental prosthesis it is necessary to realize three-dimensional mathematical models of the dentition, performing a reverse engineering procedure. Then the prosthesis can be realized by means of CAD/CAM systems.

At present, according to the traditional work flow, this procedure starts at the dentist's office, and the steps leading to prosthesis's creation are as follows:

- the dentist captures the traditional impression by means of impression trays and impression materials;
- the dentist sends the impression tray to the dental laboratory;
- the laboratory's technician pours plaster inside the tray;
- after the hardening he scans the plaster model to have the 3D virtual digital model of the full arch;
- the technician can design the prosthesis by means of CAD/CAM systems and send the file to a milling machine;
- the milling machine produces the prosthesis;
- the prosthesis is applied by the dentist and refined inside the patient's mouth to verify and adjust the occlusion.

Basically, the 3D digital model is used to design the prosthesis and as an input to the program of the milling machine referring to CAD/CAM systems. It can also be used to perform surgery simulations or to build plastic models of the teeth by means of rapid prototyping techniques.

The whole traditional process is often slow and affected by errors. Furthermore, although the traditional impression taking process is very cheap, it is certainly bothering for the patient and, at the present state of the art, definitively obsolete.

By means of devices here described, the dentist can scan the teeth in vivo and he can directly create the virtual 3D model of the dentition. This allows bypassing the dental laboratory for a lot of steps.

According to the state of the art, there are three kinds of workflows in restorative dentistry. The traditional workflow has been described above; it is the oldest and is illustrated in Fig. 1.

Abbreviations: AFI, accordion fringe interferometry; AWS, active wave-front sampling; CAD/CAM, computer aided design/computer aided manufacturing; CLSM or LSCM, confocal laser scanning microscopy; HIPAA, health insurance portability and accountability act; LASER, light amplification by stimulated emission of radiation; LED, light emitting diode; MEMS, micro electro-mechanical system; NA, numerical aperture; OCT, optical coherence tomography; OBJ, alias wavefront technologies file format; PLY, polygon file format or Stanford triangle format; PMT, photo-multiplier tube; SLA, stereo-lithography; S/N or SNR, signal-to-noise ratio; USB, universal serial bus

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Review Article

Intraoral Scanner Technologies: A Review to Make a Successful Impression

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To overcome difficulties associated with conventional techniques, impressions with IOS (intraoral scanner) and CAD/CAM (computer-aided design and manufacturing) technologies were developed for dental practice. The last decade has seen an increasing number of optical IOS devices, and these are based on different technologies; the choice of which may impact on clinical use. To allow informed choice before purchasing or renewing an IOS, this article summarizes first the technologies currently used (light projection, distance object determination, and reconstruction). In the second section, the clinical considerations of each strategy such as handling, learning curve, powdering, scanning paths, tracking, and mesh quality are discussed. The last section is dedicated to the accuracy of files and of the intermaxillary relationship registered with IOS as the rendering of files in the graphical user interface is often misleading. This overview leads to the conclusion that the current IOS is adapted for a common practice, although differences exist between the technologies employed. An important aspect highlighted in this review is the reduction in the volume of hardware which has led to an increase in the importance of software-based technologies.

1. Introduction

Since the eighteenth century, conventional impression techniques have been used to register the three-dimensional geometry of dental tissues. Nevertheless, volumetric changes of impression materials and expansion of dental stone seem error-prone, and thus the process requires the services of an excellent dental laboratory [1–3]. To overcome these difficulties, impression with IOS (intraoral scanner) was developed for dental practice [4]. The implementation of the IOS device in dental practices coincided with the development of CAD/CAM (computer-aided design and manufacturing) technology in dentistry, with numerous advantages for practitioners. Nowadays, IOS and CAD/CAM provide easier planning of treatment, case acceptance, communication with laboratories, reduced operative time, storage requirements, and reduced treatment times [5–7]. The last decade has seen an increasing number of optical IOS, and these are based on different technologies; the choice of which may impact on clinical use [6].

To allow the practitioner to make an informed choice before purchasing or renewing an IOS, this article is divided in three distinct parts. The first presents the different technologies employed by the current IOS for the capture of image and the generation of a digital file by the software, the second

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Intraoral scanning systems – a current overview

Intraoralscanner: eine aktuelle Übersicht

Zusammenfassung

Innerhalb weniger Jahre hat sich das Angebot an intraoralen optischen Abformsystemen deutlich vergrößert. Die Möglichkeiten und das Potenzial der digitalen Abformung mit intraoralen optischen Abformsystemen sind heutzutage unumstritten. Zahlreiche Innovationen sowie Indikationserweiterungen in den Bereichen Kieferorthopädie und Implantologie lassen die intraoralen Scansysteme als äußerst vielversprechend und zukunftsträchtig erscheinen. Die digitale Abformung mittels Intraoralscannern ist der konventionellen Abformtechnik in manchen Punkten bereits deutlich überlegen. Die vielseitige Integration der digitalen Abformung in Diagnostik- und Therapiekonzepte im Rahmen eines „Healthcare-Pakets" für den Patienten erscheint besonders erwähnenswert. So bleibt mit Spannung zu sehen, wann die digitale Abformung – ähnlich wie bereits etablierte digitale Applikationen im alltäglichen Leben – ein selbstverständlicher Bestandteil der zahnärztlichen und zahntechnischen Tätigkeit sein wird. Innerhalb des vorliegenden Artikels wird eine Übersicht über die Vorteile und Einschränkungen der digitalen Abformung mit Intraoralscannern gegeben. Zudem liefert er eine Zusammenfassung sämtlicher heutzutage relevanter Intraoralscanner.

Schlüsselwörter: *digitale Abformung, Intraoralscanner, Übersicht*

Abstract

There is no doubt today about the possibilities and potential of digital impression-taking with the aid of intraoral optical impression systems, and the past few years have seen a considerable increase in the range of optical intraoral scanners available on the market. On the strength of numerous innovations and a wider range of indications in orthodontics and implantology, intraoral scanning systems appear to be a highly promising development for the future. Digital impression-taking with intraoral scanners has already shown itself in some respects to be clearly superior to conventional impression-taking. Particularly worthy of mention is the versatile integration of digital impressions into diagnostic and treatment concepts to provide a customizable healthcare solution for the patient. It remains exciting to look forward to future developments that will allow us to observe digital impression-taking – as with other digital applications already established in everyday life – becoming firmly established in the routine of dentistry and dental technology. This article presents an overview of the benefits and limitations of digital impression-taking using intraoral scanning systems, and includes a summary of all the relevant intraoral scanners available on the market at present.

Keywords: *digital impression, intraoral scanning, review*

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Impact of digital intraoral scan strategies on the impression accuracy using the TRIOS Pod scanner

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Objectives: Little information is available on the impact of different scan strategies on the accuracy of full-arch scans with intraoral scanners. The aim of this in-vitro study was to investigate the trueness and precision of full-arch maxillary digital impressions comparing three scan strategies. **Method and Materials:** Three scan strategies (A, B, and C) were applied each five times on one single model (A, first buccal surfaces, return from occlusal-palatal; B, first occlusal-palatal, return buccal; C, S-type one-way). The TRIOS Pod scanner (3shape, Copenhagen, Denmark) with a color detector was used for these digital impressions. A cast of a maxillary dentate jaw was fabricated and scanned with an industrial reference scanner. This full-arch data record was digitally superimposed with the test scans (trueness) and within-group comparison was performed for each group (precision). The values within the 90/10 percentiles from the digital superimposition were used for calculation and group comparisons with nonparametric tests (ANOVA, post-hoc Bonferroni). **Results:** The trueness (mean ± standard deviation) was 17.9 ± 16.4 µm for scan strategy A, 17.1 ± 13.7 µm for B, and 26.8 ± 14.7 µm for C without statistically significant difference. The precision was lowest for scan strategy A (35.0 ± 51.1 µm) and significantly different to B (7.9 ± 5.6 µm) and C (8.5 ± 6.3 µm). **Conclusions:** Scan strategy B may be recommended as it provides the highest trueness and precision in full-arch scans and therefore minimizes inaccuracies in the final reconstruction. *(Quintessence Int 2016;47:343–349; doi: 10.3290/j.qi.a35524)*

Key words: accuracy, digital impression, intraoral scan, precision, strategy, trueness

An increasing number of dentists are using intraoral scanners in their daily practice as an alternative to conventional physical impression taking.[1] The introduction of intraoral impression taking allows for digitizing data as early as possible in the digital workflow, leading to greater productivity for the dentist and the technician. For short-span tooth or implant-based reconstructions within the same quadrant the risk of producing errors in the digitizing process is considered low, as the scan sensor captures a relatively large surface in relation to the total area required.[2,3] Several in-vitro studies have shown high levels of accuracy using different intraoral scanners.[2,4-6] However, systematic deviations may occur for full-arch scans, and the transfer to the clinical situation has not yet been investigated.[7] While the manufacturers provide information on the suggested method of performing the scans, the clinicians undergo a learning curve with a specific

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ORIGINAL ARTICLE

Utilization of Digital Technologies for Fabrication of Definitive Implant-Supported Restorations

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ABSTRACT

The introduction 7 years ago of specially coded healing abutments dramatically simplified the task of obtaining implant impressions. Such coded abutments eliminated the need for impression copings, instead enabling supragingival impressions to be made and sent to the laboratory for fabrication of patient-specific abutments and restorations. Combining this technology with digital oral scanning has the potential to further simplify the time between impression-making and delivery of a definitive restoration, and it offers additional benefits to both patients and clinicians. This article explains how oral scanners can be used to obtain digital impressions of encoded healing abutments. A case report illustrating this approach is also presented.

CLINICAL SIGNIFICANCE

This article describes a new technological approach to implant dentistry utilizing intraoral scanning modalities. The clinical workflow will highlight the digital transfer of necessary information to fabricate a patient-specific implant abutment and final prosthesis.

(J Esthet Restor Dent ••:••–••, 2011)

INTRODUCTION

Over the last 100 years, techniques and materials for restoring compromised teeth have evolved dramatically. Nowhere has this been more pronounced than in the field of implant dentistry. From its inception as a protracted and unesthetic treatment of last resort for individuals who had lost all their mandibular dentition, implant dentistry has been transformed into the standard of care for many individuals with hopeless or missing teeth. Clinicians now can provide patients with highly esthetic restorations, often in a significantly compressed time frame. As a result, the implant-dental sector today is one of the fastest growing areas within dentistry.

Computer-aided design and computer-aided manufacturing (CAD/CAM) techniques have been transforming the dental field in parallel with these developments. Introduced to dentists in 1971, CAD/CAM techniques were used to create the first dental prototype in 1983, and the first crown was milled and installed in a mouth without any laboratory involvement in 1985.[1] By 1998, customized implant abutments were being created with CAD/CAM technology.[2] Because these are patient-specific, such abutments, like cast custom abutments, have the potential to provide improved peri-implant soft-tissue support, essential to achieving an optimal esthetic result.[3] The CAD/CAM process moreover eliminates the inherent dimensional inaccuracies of waxing,

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Review

Advancements in CAD/CAM technology: Options for practical implementation

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ABSTRACT

Purpose: The purpose of this review is to present a comprehensive review of the current published literature investigating the various methods and techniques for scanning, designing, and fabrication of CAD/CAM generated restorations along with detailing the new classifications of CAD/CAM technology.

Study selection: I performed a review of a PubMed using the following search terms "CAD/CAM, 3D printing, scanner, digital impression, and zirconia". The articles were screened for further relevant investigations. The search was limited to articles written in English, published from 2001 to 2015. In addition, a manual search was also conducted through articles and reference lists retrieved from the electronic search and peer-reviewed journals.

Results: CAD/CAM technology has advantages including digital impressions and models, and use of virtual articulators. However, the implementation of this technology is still considered expensive and requires highly trained personnel. Currently, the design software has more applications including complete dentures and removable partial denture frameworks. The accuracy of restoration fabrication can be best attained with 5 axes milling units. The 3D printing technology has been incorporated into dentistry, but does not include ceramics and is limited to polymers. In the future, optical impressions will be replaced with ultrasound impressions using ultrasonic waves, which have the capability to penetrate the gingiva non-invasively without retraction cords and not be affected by fluids.

Conclusion: The coming trend for most practitioners will be the use of an acquisition camera attached to a computer with the appropriate software and the capability of forwarding the image to the laboratory.

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A review of 243 errors possible during the fabrication of a removable partial denture: Part I

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Everyone who participates in any step of the fabrication of a removable partial denture must share in the success or failure of the restoration. Some seemingly innocuous deviations can be accumulative and cause serious problems, so everyone should review the procedures that they use on a regular basis. Parts I through III of this article present a personal and generic (but by no means comprehensive) list of errors that can occur when a removable partial denture is fabricated. Results that can be attributed to these errors are identified, and a possible solution for each error is described. This information is useful to the entire dental team: the dentist, dental assistant, office manager, and dental technician. The articles also include 18 notes that may be beneficial to personnel in the office and/or in the laboratory. (J Prosthet Dent 2001;86:251-61.)

Good technique pays off. These words are not merely a motto to hang on the wall in the laboratory but words of wisdom.[1] Good technique demands that everyone involved give adequate attention to all details required for safe and efficient operations. This means that good dentistry depends on the integrity, knowledge, and skills possessed by the entire dental team, which includes the dentist, dental nurse, dental assistant, office manager, and dental technician. A great force working against good technique is the habit of taking shortcuts. Shortcuts are risky attempts to save time by modifying a proven procedure. A proven procedure is one that accomplishes an operation efficiently while reducing the possibility for errors to a minimum. A procedure that may be "accepted" or "approved" is not always a proven procedure.

Increased chairtime required for adjusting misfit dentures, dissatisfaction and pain experienced by patients, and remakes resulting from shortcut practices indicate that they rarely save time. One of Murphy's Laws[2] says that there is never enough time to do it correctly in the first place, but always plenty of time to do it over. It is a good idea for everyone involved in a dental practice to frequently review the procedures used. Many seemingly innocuous deviations can creep into one's technique without notice. These deviations can add up to serious problems.

The results of many errors made during the fabrication of removable partial dentures (RPDs) may not be recognizable when they occur. This article, therefore, has 3 aims: (1) to advise personnel involved in the fabrication of RPDs of potential errors, (2) to call attention to results that can be attributed to these errors, and (3) to identify steps that can be taken to avoid these errors. The errors are listed in the order that they would occur during the fabrication of an RPD.

IMPRESSIONS: ERRORS, PROBLEMS, AND SOLUTIONS

Currently, irreversible hydrocolloid impression material (irreversible hydrocolloid) seems to be the material of choice for making RPD definitive impressions. It therefore is the impression material referenced in this article. Errors for handling it are described. The advantages of irreversible hydrocolloid seem to outweigh the advantages of other impression materials; it has only a few disadvantages.

The advantages of irreversible hydrocolloid compared with other impression materials include the following: First, the use of irreversible hydrocolloid does not require specialized equipment or customized trays; this is not the case with agar and other elastomeric materials. Satisfactory results can be obtained with the use of non–water-cooled stock metal trays modified by application of impression compound and cotton fibers.[1] Second, the setting time of irreversible hydrocolloid is easy to control by adjusting the water temperature.[1] Third, most impression cleanup is much easier with irreversible hydrocolloid than with polysulfide elastomeric materials. Fourth, irreversible hydrocolloid does not stain clothing like elastomerics. Fifth, irreversible hydrocolloid can be mixed more easily than some of the elastomeric materials. Sixth, because irreversible hydrocolloid materials are more elastic than the elastomeric materials, full-arch impressions are easier to remove from the mouth. As a result, loose and mobile teeth are less apt to be extracted when the impression is removed, and isolated teeth are less apt to break when the cast is separated from the impression. Seventh, irreversible hydrocolloid is not as easily displaced by saliva as some of the elastomeric materials

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In vitro comparison of master cast accuracy for single-tooth implant replacement

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Statement of problem. The inaccuracy in transferring the position of the hexagonal head of a single implant to the working cast can result in a final single tooth crown, which clinically may present occlusal and/ or interproximal contacts that are different from those contacts on the master cast obtained by the technician.
Purpose. This in vitro study evaluated the accuracy of the master casts obtained using square pick-up impression copings for single-tooth replacement. Copings used were (1) copings as sold by the manufacturer, and (2) copings modified by sandblasting and coating with impression adhesive their roughened surfaces before final impression procedures.
Material and methods. A polymeric resin model with a standard single implant was used to simulate a clinical situation. A group of 20 impressions were made using nonmodified impression copings; a second group of 20 impressions were fabricated with modified copings. Master casts fabricated for both groups were analyzed to detect rotational position change of the hexagon on the implant replicas in the master casts in reference to the resin model.
Results. The rotational position changes of the hexagon on implant replicas were significantly less variable in the master casts obtained with the modified impression copings than in the master casts achieved with the nonprepared copings.
Conclusion. Improved precision of the impression was achieved when the adhesive-coated copings were used. (J Prosthet Dent 2000;83:562-6.)

CLINICAL IMPLICATIONS

This report suggests that sandblasting and coating the roughened surface of the impression copings before final impression procedures will enable the clinician to achieve a more accurate orientation of the implant replicas in the laboratory master casts in single-tooth implant restorations.

The transfer of the exact position and orientation of the implants to the working cast is particularly important in implant restorative procedures.[1-3] When a multiple abutment restoration is fabricated, the pick-up impression copings can be joined together with acrylic resin or composite to stabilize them within the impression material. Similar procedures are not applicable for single-tooth replacement, which may imply that minor movements of the impression coping retained inside the impression material can occur during all the procedural passages, leading to the master cast. As a result, the transfer of the exact position of the implant with its hexagonal head to the working cast may be tri-dimensionally inaccurate. This inaccuracy can lead to the fabrication of a final single tooth crown that, clinically, may present occlusal and/ or interproximal contacts different from those achieved by the technician on the working casts.

Numerous reports have evaluated the importance of various clinical and laboratory steps in the elaboration of accurate master casts in regular crown and fixed partial denture procedures such as impression materials,[4-6] use of custom trays,[7,8] and use of adhesives in the impression tray.[9] In multiple abutment implant prosthodontics, many technical variations have been suggested to improve the accuracy of the final master casts. Carr[10] compared a direct and an indirect impression technique for a 5-implant model and concluded that the direct transfer method produced a more accu-

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Evaluation of impression accuracy for osseointegrated implant supported superstructures

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Statement of problem. An often-debated issue still exists concerning implant impression techniques, whether to splint impression copings. Different configurations are available for these copings for a variety of manufacturers' implant systems.
Purpose. This study evaluated and compared 4 impression techniques in terms of their dimensional accuracy to reproduce implant positions on working casts.
Material and methods. A master model was designed to simulate a clinical situation. Impressions were made using 4 techniques: (1) tapered impression copings not splinted; (2) squared impression copings not splinted; (3) squared impression copings splinted with autopolymerizing acrylic resin; and (4) squared impression copings with a lateral extension on one side not splinted. Reference points machined onto the master model and onto special healing abutments were compared after abutments were transferred to casts using the 4 techniques. Measurements were made using a Reflex microscope, capable of recording in the x-, y-, and z-dimensions.
Results. The dimensional accuracy was high and, although statistically significant (P=.022; power > 80%), a maximum distortion difference of only 0.31% was registered.
Conclusion. The dimensional accuracy of all the techniques was exceptional and the observed differences can be regarded as clinically negligible. (J Prosthet Dent 2000;83:555-61.)

CLINICAL IMPLICATIONS

The results of this study suggest that there seems to be no clinical advantage in splinting impression transfer copings with an autopolymerizing acrylic resin.

A major objective in making an implant-supported prosthesis is the production of superstructures that exhibit a passive fit when connected to multiple abutments.[1-8] One requirement to ensure passive fit is to make an accurate impression.[9] This concept of passive adaptation has been defined as a strictly tolerated metal-to-metal interface between an implant superstructure and the implant abutments.[10] Failure to produce a passive fit can result in the generation of considerable stresses in a screw-retained prosthesis when the superstructure is connected to the abutments, which may lead to complications and mechanical failure.[11-16]

Stress measurements, using a strain-gauge technique, have shown compression and tension on the transmucosal abutments during fixation of the framework.[17] Forced tightening of the superstructure can result in microfractures of bone, a zone of marginal ischemia and healing with a nonmineralized attachment to the implant.[16,18] Adequate stress distribution may also encourage maintenance of marginal bone close to the implant.[1]

The first stage in achieving an accurate, passively fitting prosthesis is reproducing the intraoral relationship of the implants with an impression.[19,20] Conventional impression materials and techniques have been the subjects for clinical research at many materials science laboratories. Rigid and elastic materials have been used in dentistry for duplicating soft and hard tissue dimensions and relationships.[21-25] Spector et al[26] evaluated 3 impression techniques and concluded that the magnitude of distortion was similar in each and that none of the techniques produced an accurate cast. Humphries et al[27] studied 3 techniques that used polyvinyl siloxane impression material and reported that all 3 techniques did produce an accurate cast but the tapered copings were the most accurate. Brånemark et al[2] reported another procedure of linking copings together intra-

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Comparison of impression materials for direct multi-implant impressions

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Statement of problem. Given that meticulous implant prosthodontic procedures are recommended to obtain the best possible intraoral fit, impression materials that are suitable for use with a direct impression technique warrant further investigation.

Purpose. This in vitro study compared the amount of torque required to rotate a square impression coping in an impression and evaluated the accuracy of solid implant casts fabricated from different impression materials.

Material and methods. Two direct transfer implant impressions were made using 8 impression materials; the torque required to rotate an impression coping in the impressions was calculated. Ten direct transfer implant impressions were made from the master model and poured in a die stone (Resin Rock) for 3 of the 8 initial impression material groups. Linear distances between steel balls placed on each abutment replica were measured with a traveling microscope to determine distortion in the impression procedure for each group. Data were analyzed ($P=.05$) with ANOVA and Ryan-Einot-Gabriel-Welsch multiple range test for post hoc.

Results. With a 1-way ANOVA, average torque values among the material groups differed significantly ($P=.001$). Polyether (medium consistency) was found to produce the highest overall torque values, followed by addition silicone (high consistency), and then polysulfide (medium consistency). Statistically significant difference was also found among the 3 material groups' mean absolute cast error using a 1-way ANOVA ($P=.0086$). Implant casts made from polyether (medium) or addition silicone (high) impressions were significantly more accurate than casts made from polysulfide medium impressions.

Conclusion. On the basis of the results of this study, the use of either polyether (medium) or addition silicone (high) impression is recommended for direct implant impressions. (J Prosthet Dent 2000;83:323-31.)

CLINICAL IMPLICATIONS

Use of medium consistency polyether and high consistency addition silicones is recommended to make a direct implant impression, depending on the amount of hard tissue undercuts present in the arch. In this study, polyether minimized the chance of accidental displacement of the direct impression coping when the abutment replicas were tightened. Addition silicone in a partial edentulous arch facilitates the removal of the impression tray when hard tissue undercuts are present, although care must be taken to avoid accidental rotation of the impression coping. A double impression technique using a lower consistency addition silicone wash did not appear to present any advantage for use in direct implant impressions.

Although true "passive fit" of multi-implant–supported prostheses to their intraoral implant abutments does not seem attainable,[1-6] it remains unclear what degree of implant prosthesis misfit will lead to complications. For this reason, meticulous and accurate implant prosthodontic procedures are recommended as a means to attain the best possible fit.[5] The implant cast is the foundation on which the prosthesis is indirectly fabricated. The use of the implant cast as a reference for extraoral implant framework fit facilitates the clinician's evaluation of fit.

Strategies to achieve fit may be completed on the master cast before the patient's clinical appointment. Several strategies have been suggested to reduce the distortion of the implant framework, namely, laser welding of titanium implant framework,[7,8] or use of electric discharge machining of the gold cylinders of the implant framework to the abutment replicas.[9-11] Many intraoral techniques used to improve framework fit may also be used on the implant cast, given adequate accuracy.[5] Although absolute accuracy of the implant cast does not appear to be attainable at this time,[3,12-14] it has been suggested that the distortion of the implant

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Will digital impressions eliminate the current problems with conventional impressions?

Making impressions with polyether and vinyl polysiloxane impression materials is an everyday procedure in almost every general dental practice. Manufacturers have developed and refined these materials to the level at which it is nearly impossible to blame the impression material for restoration misfits. These materials are accurate and stable.[1-3]

Digital impression devices are on the dental market, and it is expected that others will be available soon. The current digital impression devices are the recently introduced Cadent iTero (Carlstadt, N.J.) and the 3M ESPE Lava Chairside Oral Scanner C.O.S. (St. Paul, Minn.).[4] Additionally, the manufacturers of computer-directed in-office milling systems CEREC (Sirona Dental Systems, Charlotte, N.C.) and the new E4D system (D4D Technologies, Richardson, Texas) are working to provide digital impressions that can be sent to dental laboratories.

The digital impression concept is emerging rapidly on the high-tech horizon. Some optimistic proponents infer that digital impressions will solve the challenges now observed with conventional elastomer impressions. However, there are several reasons, other than the properties of conventional impression material, for the inaccuracies that arise in conventional impressions for crowns and fixed prostheses.

I will address the several known problems observed with conventional impressions; discuss whether or not digital impressions will eliminate those problems, thus potentially improving the quality of indirectly made dental restorations; and appraise the apparent cost of making digital impressions versus that of making conventional elastomer impressions.

Gordon J. Christensen, DDS, MSD, PhD

SOFT-TISSUE MANAGEMENT

Perhaps the most significant reason for the inadequacy of some impressions made with elastomer impression materials, as observed by dental laboratory technicians, is the lack of visibility of the subgingival margins of tooth preparations (J. Shuck, vice president, sales and marketing, Glidewell Laboratories, oral communication, Jan. 9, 2008). This problem is related directly to inadequate soft-tissue management at the time the impression is made. In a previous JADA column,[5] I have outlined the most easily used soft-tissue management techniques.

Impressions are changing

Deciding on conventional, digital or digital plus in-office milling

Digital dental impression devices have been introduced to the profession, potentially eliminating the need for taking conventional impressions for crowns and fixed prostheses. I have discussed this concept in previous columns in this journal.[1,2] However, additional changes to the concept are emerging, creating confusion among dentists and causing them to wonder whether there is a need to change their impression techniques. The many questions I hear about this topic from dentists attending continuing education courses can be distilled into the following four.

- "Should I continue to make impressions in the conventional manner using conventional materials?" Both scientific evidence and clinical observation have shown that currently available impression materials—vinyl polysiloxane, polyether, the newer material vinylsiloxanether and the older reversible hydrocolloid—provide excellent reproduction of tooth preparations.[3-9]
- "Should I purchase a device that makes digital impressions?" With a digital impression device, the clinician creates the impression digitally and sends the data to a laboratory capable of working with this technology; the laboratory then creates the restorations and sends them to the dentist for placement. Two popular digital impression devices now competing on the market are the iTero (Cadent, Carlstadt, N.J.) and the Lava Chairside Oral Scanner C.O.S. (3M ESPE, St. Paul, Minn.). Both of these devices limit the dentist to the use of laboratories that have, and are trained to use, the laboratory devices associated with the respective impression devices. These devices and this technical concept are proving themselves to be viable alternatives to conventional impression making.[10-14]
- "Should I purchase a device that makes digital impressions and also provides the ability to mill some types of restorations in the clinical office?" The two competing devices are CEREC (Sirona Dental Systems GmbH, Bensheim, Germany) and the E4D Dentist System (D4D Technologies, Richardson, Texas). The ability of computer-aided design/computer-aided manufacturing (CAD/CAM) devices to produce clinically acceptable restorations has been reported many times in the dental literature.[15-27] Other companies soon

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CLINICAL ORAL IMPLANTS RESEARCH

Tim Joda
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Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial

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Key words: crossover, dental implant, digital, impression, patient satisfaction, randomized-controlled trial

Abstract

Objectives: The aim of this randomized controlled trial was to compare patient-centered outcomes during digital and conventional implant impressions.

Material and methods: In a crossover study design, intraoral scanning (IOS) [test] as well as classical polyether impressions [control] were both performed on 20 patients for single-tooth replacement with implant-supported crowns. The sequential distribution of either starting with the test or the control procedure was randomly selected. Patients' perception and satisfaction on the level of convenience-related factors were assessed with visual analogue scale (VAS) questionnaires. In addition, clinical work time was separately recorded for test and control procedures. Statistical analyses were performed with *Wilcoxon signed-rank tests* and corrected for multiple testing by the method of *Holm*.

Results: On VAS ranging from 0 to 100, patients scored a mean convenience level of 78.6 (SD ± 14.0) in favor of IOS compared to conventional impressions with 53.6 (SD ± 15.4) ($P = 0.0001$). All included patients would prefer the digital workflow if in the future they could choose between the two techniques. Secondary, IOS was significantly faster with 14.8 min (SD ± 2.2) compared to the conventional approach with 17.9 min (SD ± 1.1) ($P = 0.0001$).

Conclusion: Based on the findings of this investigation, both impression protocols worked successfully for all study participants capturing the 3D implant positions. However, the digital technique emerges as the most preferred one according to patient-centered outcomes and was more time-effective compared to conventional impressions.

Healthcare-related validation should be associated with objective criteria to assess treatment efficiency. The various stakeholders representing patients, the healthcare providers, the industry or third-party players concentrate on different endpoints (Anderson 1998).

Treatment outcomes in implant therapy can be distinguished into four subgroups: (i) longevity and survival, (ii) physiological impact, (iii) psychological effect, (iv) economic factors (Guckes et al. 1996). This classification includes categories of primary relevance to patients but also outcomes of their indirect concern, though maybe of greater interest to the clinician. Therefore, the clinicians' as well as the patients' appraisals should be taken into account for efficiency assessment of implant treatment (Grogono et al. 1989).

However, studies are limited to dental implant survival and clinical/radiographically surrogate parameters (den Hartog et al. 2008). In contrast, patient-centered outcomes of implant treatment protocols have been unattended for years and are only gradually integrated into clinical trials (Pommer et al. 2011). Scientific information on patient satisfaction levels as well as the investigation of psychological and social effects following implant therapy is still rare in the current literature (Abduo & Lyons 2013). Most studies reported on edentulous patients with implant-supported removable prostheses

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CLINICAL ORAL IMPLANTS RESEARCH

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Digital versus conventional implant impressions for edentulous patients: accuracy outcomes

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Key words: accuracy, dental implants, digital impressions, edentulous, implant impressions, impression techniques

Abstract

Purpose: To compare the accuracy of digital and conventional impression techniques for completely edentulous patients and to determine the effect of different variables on the accuracy outcomes.

Materials and methods: A stone cast of an edentulous mandible with five implants was fabricated to serve as master cast (control) for both implant- and abutment-level impressions. Digital impressions ($n = 10$) were taken with an intraoral optical scanner (TRIOS, 3shape, Denmark) after connecting polymer scan bodies. For the conventional polyether impressions of the master cast, a splinted and a non-splinted technique were used for implant-level and abutment-level impressions (4 cast groups, $n = 10$ each). Master casts and conventional impression casts were digitized with an extraoral high-resolution scanner (IScan D103i, Imetric, Courgenay, Switzerland) to obtain digital volumes. Standard tessellation language (STL) datasets from the five groups of digital and conventional impressions were superimposed with the STL dataset from the master cast to assess the 3D (global) deviations. To compare the master cast with digital and conventional impressions at the implant level, analysis of variance (ANOVA) and Scheffe's *post hoc* test was used, while Wilcoxon's rank-sum test was used for testing the difference between abutment-level conventional impressions.

Results: Significant 3D deviations ($P < 0.001$) were found between Group II (non-splinted, implant level) and control. No significant differences were found between Groups I (splinted, implant level), III (digital, implant level), IV (splinted, abutment level), and V (non-splinted, abutment level) compared with the control. Implant angulation up to 15° did not affect the 3D accuracy of implant impressions ($P > 0.001$).

Conclusion: Digital implant impressions are as accurate as conventional implant impressions. The splinted, implant-level impression technique is more accurate than the non-splinted one for completely edentulous patients, whereas there was no difference in the accuracy at the abutment level. The implant angulation up to 15° did not affect the accuracy of implant impressions.

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Passive fit of implant-fixed complete dental prosthesis (IFCDP) depends on the accuracy of the implant cast, which is directly dependent on the accuracy of the impression technique (Jemt & Hjalmarsson 2012; Papaspyridakos & Lal 2013). There are several clinical and laboratory variables that affect the accuracy of an implant cast, namely impression and pouring techniques, impression material and die stone properties, machining tolerance of prosthetic components, and implant angulation and depth (Ma et al. 1997; Papaspyridakos et al. 2014a).

The first and most significant step is the impression procedure. Different implant impression techniques have been used to generate a definitive cast that will ensure the accurate clinical fit of IFCDPs. A recent systematic review on the accuracy of implant impressions showed that the splinted technique is superior to the non-splinted option for both partially and completely edentulous patients (Papaspyridakos et al. 2014a). The necessity for splinting the impression copings has been advocated in several studies, while others have shown no

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BMC Oral Health

RESEARCH ARTICLE

Open Access

Intraoral scanners in dentistry: a review of the current literature

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Abstract

Background: Intraoral scanners (IOS) are devices for capturing direct optical impressions in dentistry. The purpose of this narrative review on the use of IOS was to: (1) identify the advantages/disadvantages of using optical impressions compared to conventional impressions; (2) investigate if optical impressions are as accurate as conventional impressions; (3) evaluate the differences between the IOS currently available commercially; (4) determine the current clinical applications/limitations in the use of IOS.

Methods: Electronic database searches were performed using specific keywords and MeSH terms. The searches were confined to full-text articles written in English and published in peer-reviewed journals between January 2007 and June 2017.

Results: One hundred thirty-two studies were included in the present review; among them, 20 were previous literature reviews, 78 were in vivo clinical studies (6 randomized controlled/crossover trials, 31 controlled/comparative studies; 24 cohort studies/case series; 17 case reports) and 34 were in vitro comparative studies.

Conclusions: Optical impressions reduce patient discomfort; IOS are time-efficient and simplify clinical procedures for the dentist, eliminating plaster models and allowing better communication with the dental technician and with patients; however, with IOS, it can be difficult to detect deep margin lines in prepared teeth and/or in case of bleeding, there is a learning curve, and there are purchasing and managing costs. The current IOS are sufficiently accurate for capturing impressions for fabricating a whole series of prosthetic restorations (inlays/onlays, copings and frameworks, single crowns and fixed partial dentures) on both natural teeth and implants; in addition, they can be used for smile design, and to fabricate posts and cores, removable partial prostheses and obturators. The literature to date does not support the use of IOS in long-span restorations with natural teeth or implants. Finally, IOS can be integrated in implant dentistry for guided surgery and in orthodontics for fabricating aligners and custom-made devices.

Keywords: Intraoral scanners, Optical impressions, Accuracy, Time efficiency, Clinical use

Background

Intraoral scanners (IOS) are devices for capturing direct optical impressions in dentistry [1–3]. Similar to other three-dimensional (3D) scanners, they project a light source (laser, or more recently, structured light) onto the object to be scanned, in this case the dental arches, including prepared teeth and implant scanbodies (i.e. cylinders screwed on the implants, used for transferring the 3D implant position) [2, 3]. The images of the dento-gingival tissues (as well as the implant scanbodies) captured by imaging sensors are processed by the scanning software, which generates point clouds [3, 4]. These point clouds are then triangulated by the same software, creating a 3D surface model (mesh) [3, 4]. The 3D surface models of the dentogingival tissues are the result of the optical impression and are the 'virtual' alternative to traditional plaster models [4, 5].

Although IOS are becoming widespread in clinical dental practice, only a few reviews on the use of these devices are available in the literature [5–8].

The purpose of the present narrative review was therefore to:

- identify the advantages and/or disadvantages of using optical impressions compared to conventional impressions;

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RESEARCH AND EDUCATION

Evaluation of the accuracy of 7 digital scanners: An in vitro analysis based on 3-dimensional comparisons

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ABSTRACT

Statement of problem. As digital impressions become more common and more digital impression systems are released onto the market, it is essential to systematically and objectively evaluate their accuracy.

Purpose. The purpose of this in vitro study was to evaluate and compare the trueness and precision of 6 intraoral scanners and 1 laboratory scanner in both sextant and complete-arch scenarios. Furthermore, time of scanning was evaluated and correlated with trueness and precision.

Material and methods. A custom complete-arch model was fabricated with a refractive index similar to that of tooth structure. Seven digital impression systems were used to scan the custom model for both posterior sextant and complete arch scenarios. Analysis was performed using 3-dimensional metrology software to measure discrepancies between the master model and experimental casts.

Results. Of the intraoral scanners, the Planscan was found to have the best trueness and precision while the 3Shape Trios was found to have the poorest for sextant scanning ($P<.001$). The order of trueness for complete arch scanning was as follows: 3Shape D800 >iTero >3Shape TRIOS 3 >Carestream 3500 >Planscan >CEREC Omnicam >CEREC Bluecam. The order of precision for complete-arch scanning was as follows: CS3500 >iTero >3Shape D800 >3Shape TRIOS 3 >CEREC Omnicam >Planscan >CEREC Bluecam. For the secondary outcome evaluating the effect time has on trueness and precision, the complete- arch scan time was highly correlated with both trueness ($r=0.771$) and precision ($r=0.771$).

Conclusions. For sextant scanning, the Planscan was found to be the most precise and true scanner. For complete-arch scanning, the 3Shape Trios was found to have the best balance of speed and accuracy. (J Prosthet Dent 2016;■:■-■)

Intraoral digital impression making has evolved beyond single tooth preparations and sextant scanning to include the ability to record complete arches. Intraoral digital scanners allow the dentist to capture the surface of the teeth, implant scanbodies, and soft tissues in 3 dimensions, enabling instant evaluation of the digital cast and near instant communication to the laboratory, 3-dimensional (3D) printer, or chairside milling unit. Similarly, computer-aided design and computer-aided manufacturing (CAD-CAM) has revolutionized the way dentistry is practiced and has become integrated into patient care.[1,2] Recent advances in chairside and laboratory digital technology have cultivated an enhanced environment for the widespread use of digital dentistry.[1,2]

Two events that have increased the acceptance of digital technology are the emergence of newer and more user friendly intraoral digital scanners and the adoption of digital technology into dental school curricula.[3] Deficiencies with elastomeric impression materials and techniques have been documented to support the need for new and better impression techniques.[4-8] Commonly reported weaknesses of elastomeric impression materials

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Applicability and accuracy of an intraoral scanner for scanning multiple implants in edentulous mandibles: A pilot study

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Statement of problem. In the past 5 years, the use of intraoral digitizers has increased. However, data are lacking on the accuracy of scanning implant restorative platforms for prosthodontics with intraoral digitizers.

Purpose. The purpose of this clinical pilot study was to assess the applicability and accuracy of intraoral scans by using abutments designed for scanning (scan abutments) in edentulous mandibles.

Material and methods. Twenty-five participants with complete mandibular overdentures retained by 2 implants and frameworks were included in this study. Scan abutments were placed on the implants intraorally and scanned with the iTero intraoral scanner. Also, scan abutments were placed on the implant analogs of the definitive casts and scanned with an extraoral laboratory scanner (Lava Scan ST scanner). Two 3-dimensional computer-aided design models of the scan abutments with predetermined center lines were subsequently imported and registered, together with each of the scanned equivalents. The distance between the centers of the top of the scan abutments and the angulations between the scan abutments was assessed. These values were compared with the measurements made on the 3-dimensional scans of the definitive casts, which were the participants' original definitive casts used for fabrication of soldered bars. The threshold for distance error was established to be 100 µm.

Results. Four of the 25 intraoral scans were not suitable for research because the intraoral scanner was not able to stitch the separate scans together. Five of the 21 suitable scans demonstrated an interimplant distance error >100 µm. Three of the 25 intraoral scans showed interimplant angulation errors >0.4 degrees. Only 1 scan showed both an acceptable interimplant distance (<100 µm) and an acceptable angulation error (<0.4 degrees).

Conclusions. Based on the intraoral scans obtained in this study, distance and angulation errors were too large to fabricate well-fitting frameworks on implants in edentulous mandibles. The main reason for the unreliable scans seemed to be the lack of anatomic landmarks for scanning. (J Prosthet Dent 2014;111:186-194)

Clinical Implications

The scans of 2 implants in edentulous mandibles made with scan abutments by using the iTero IOS system lacked sufficient overlapping and stable reference points to make them usable for implant frameworks.

With the development of intraoral scanning, a shift has occurred in impression making. Although the first intraoral digitizers were commercially available 2 decades ago, it is only recently that the popularity of these systems has grown.[1-5] In the past 5 years, 5 new intraoral digitizers have been developed and successfully introduced.[1] Increased accuracy and efficiency seems to be one explanation for the growing success. Recently

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Influence of Scanning Strategies on the Accuracy of Digital Intraoral Scanning Systems

Einfluss von Scanstrategien auf die Genauigkeit von digitalen intraoralen Scansystemen

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Zusammenfassung

Die digitale intraorale Abformung spielt eine zentrale Rolle in der modernen CAD/CAM-gestützten Zahnmedizin. Sie ermöglicht neue Behandlungsoptionen für den Patienten und beschleunigt den Workflow bei der Restaurationsherstellung. Die wichtigste Aufgabenstellung bei einem intraoralen Scansystem besteht heutzutage darin, insbesondere in größeren Scanbereichen genauer zu arbeiten und die klinische Handhabung für den Zahnarzt zu vereinfachen. Ziel dieser Studie ist es, unterschiedliche Scanstrategien in vitro auf ihre Genauigkeit bei Scans des gesamten Zahnbogens zu untersuchen. Für die digitale Abformung mit den Systemen Lava COS, Cerec Bluecam und Cadent iTero wurde ein Referenzmeistermodell verwendet. Bei jedem Scanprotokoll wurden Richtigkeit und Präzision bestimmt. Lava COS lieferte dabei mit dem vom Hersteller empfohlenen Scanprotokoll eine Richtigkeit von 45,8 µm. Mit einem anderen Scanprotokoll ergab sich eine signifikant niedrigere Genauigkeit (Richtigkeit ± 90,2 µm). Auch bei Cerec Bluecam erweist sich ein optimales Scanprotokoll mit einer Richtigkeit von ± 23,3 µm im Vergleich zu ± 52,5 µm mit einem Standardprotokoll als vorteilhaft. Das puderfreie Cadent iTero Scansystem konnte den kompletten Zahnbogen mit einer Richtigkeit von ± 35,0 µm und einer Präzision

Abstract

The digital intraoral impression is a central part in today's CAD/CAM dentistry. With its possibilities, new treatment options for the patient is provided and the prosthetic workflow is accelerated. Nowadays, the major issue with intraoral scanning systems is to gain more accuracy especially for larger scan areas and to simplify clinical handling for the dentist. The aim of this study was to investigate different scanning strategies regarding their accuracy with full arch scans in an in-vitro study design. A reference master model was used for the digital impressions with the Lava COS, the Cerec Bluecam and a powderfree intraoral scanning system, Cadent iTero. The trueness and precision of each scanning protocol was measured. Lava COS provides the a trueness of 45.8 µm with the scanning protocol recommended from the manufacturer. A different scanning protocol shows significantly lower accuracy (trueness ± 90.2 µm). Cerec Bluecam also benefits from an optimal scanning protocol with a trueness of ± 23.3 µm compared to ± 52.5 µm with a standard protocol. The powderfree impression system Cadent iTero shows also a high accurate full-arch scan with a trueness of ± 35.0 µm and a precision of ± 30.9 µm. With the current intraoral scanning systems, full arch dental impressions are possible

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RESEARCH ARTICLE **Open Access**

Comparison of digital and conventional impression techniques: evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes

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Abstract

Background: The purpose of this study was to compare two impression techniques from the perspective of patient preferences and treatment comfort.

Methods: Twenty-four (12 male, 12 female) subjects who had no previous experience with either conventional or digital impression participated in this study. Conventional impressions of maxillary and mandibular dental arches were taken with a polyether impression material (Impregum, 3 M ESPE), and bite registrations were made with polysiloxane bite registration material (Futar D, Kettenbach). Two weeks later, digital impressions and bite scans were performed using an intra-oral scanner (CEREC Omnicam, Sirona). Immediately after the impressions were made, the subjects' attitudes, preferences and perceptions towards impression techniques were evaluated using a standardized questionnaire. The perceived source of stress was evaluated using the State-Trait Anxiety Scale. Processing steps of the impression techniques (tray selection, working time etc.) were recorded in seconds. Statistical analyses were performed with the Wilcoxon Rank test, and $p < 0.05$ was considered significant.

Results: There were significant differences among the groups ($p < 0.05$) in terms of total working time and processing steps. Patients stated that digital impressions were more comfortable than conventional techniques.

Conclusions: Digital impressions resulted in a more time-efficient technique than conventional impressions. Patients preferred the digital impression technique rather than conventional techniques.

Keywords: Digital impression, Clinical efficiency, Patient comfort, Patient preference

Background

The introduction of computer-aided design/computer aided manufacturing (CAD/CAM) technology in dentistry has resulted in more accurate manufacturing of prosthetic frameworks, and greater accuracy of dental restorations, and the technology has improved since the 1980s [1,2]. The development strategy of CAD/CAM techniques included automating the production process and optimizing the quality of restorations by using new biocompatible materials, especially high performance ceramics, such as zirconia and lithium disilicate [3]. Several reports have demonstrated the potential for accurate and precise restorations using CAD/CAM technology [4-7].

According to the 8th edition of The Glossary of Prosthodontics Terms, "impression" is defined as "a negative likeness or copy in reverse of the surface of an object; an imprint of the teeth and adjacent structures for use in dentistry" [8]. The accuracy of the impression depends on the materials themselves [9-13], impression tray types [14-16], and impression techniques [17-19]. Each step in the process introduces potential human and/or material error [20,21].

There is some variability in impressions and the resulting master casts, depending on the technique and material used by the operator [22]. The accuracy of master casts has been the subject of numerous research projects,

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The Effect of Impression Technique and Implant Angulation on the Impression Accuracy of External- and Internal-Connection Implants

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Purpose: *The purpose of this in vitro study was to investigate the effect of impression technique and implant angulation on the impression accuracy of external- and internal-connection implants using a novel experimental device.* **Materials and Methods:** *An experimental device was designed and fabricated to make in vitro impressions by means of open- and closed-tray techniques. Impressions of eight implants with two different connections (four external-hex and four internal-hex) at three angulations (0, 15, and 25 degrees) were made using a medium-consistency polyether material. Evaluation of implant impression accuracy was carried out by directly measuring the difference in coordinate values between the implant body/impression coping positioned on the base and the impression coping/laboratory analog positioned in the impression using a touch-probe coordinate measuring machine. Experimental data were analyzed by two-way analysis of variance. The significance level of all hypothesis testing procedures was set at $P < .05$.* **Results:** *The results showed that: (1) for implants with external connections, impression accuracy is not significantly affected by the impression technique, implant angulation, or their interaction; and (2) for implants with internal connections, impression accuracy is significantly affected only by implant angulation: impression inaccuracy was greater at the 25-degree implant angulation.* **Conclusions:** *Within the limitations of this in vitro study, the open- and closed-tray techniques had no effect on the accuracy of multiple implant impressions. The interaction between impression technique and implant angulation was also not significant. However, implant angulation significantly affected the impression accuracy when implants with internal connections were used.* Int J Oral Maxillofac Implants 2012;27:1422–1428

Key words: *external-connection implants, implant angulation, impression accuracy, impressions, internal-connection implants*

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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 implant-supported prosthesis.[1–3]

Several studies have examined the clinical variables affecting the accuracy of the implant impression, such as differing impression techniques,[4,5] the use of different impression materials and trays,[6,7] splinting or not splinting the implants,[8] the relative implant angulations,[9–11] and the lengths of impression coping connections.[11] The relevant scientific literature reveals many controversial issues regarding the accuracy of impressions using open-tray (pickup) and closed-tray (transfer) techniques in situations where three or more implants were placed.[4,12–20] Most researchers have reported that the open-tray technique is more accurate and predictable than the closed-tray technique using