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Evaluating Conventional and Digital Impressions of Single Unit Restorations, and Conventional vs. Digital Impressions from the Laboratory Technicians' Perspective

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EVALUATING CONVENTIONAL AND DIGITAL IMPRESSIONS OF SINGLE UNIT RESTORATIONS, AND CONVENTIONAL VS. DIGITAL IMPRESSIONS FROM THE LABORATORY TECHNICIANS' PERSPECTIVE

Tagreed Alohali

A Thesis Presented to the Faculty of the College of Dental Medicine of Nova Southeastern University in Partial Fulfillment of the Requirements for the Degree of MASTER OF SCIENCE

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Department of Cariology and Restorative Dentistry

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I certify that I am the sole author of this thesis, and that any assistance I received in its preparation has been fully acknowledged and disclosed in the thesis. I have cited any sources from which I used ideas, data, or words, and labeled as quotations any directly quoted phrases or passages, as well as providing proper documentation and citations. This thesis was prepared by me, specifically for the M.S. degree and for this assignment.

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DEDICATION

To my family, especially my husband Khaled, Mom, Dad, sisters, brother, and last but not least my little partner in this journey my dear son Nawaf.

ACKNOWLEDGMENT

This project has been written with assistance from different people who have all been influential in guiding me through the course of the research. I first want to thank God for the strength and dedication he gave me to work on my capstone. I secondly want to extend a hand of gratitude to my supervisor Dr. Rafael Castellon for his valuable advice that helped me develop the quality of this thesis. I would also like to thank him for being patient enough to offer his genuine professional guidance especially during the initial and final stages of my research. I also would like to thank Dr. Cristina Garcia Godoy and Dr. Jeffrey Thompson for their generous help and support throughout the project. I very much appreciate the material assistance I got from the School regarding the provision of sufficient data for the project. Also, I would like to thank DSG, Oral Arts dental laboratories and Mr. Jay Walls for their help in this project. Finally, I want to thank all of my faculties and colleagues from the Community Dentistry department who offered me time and encouragement throughout my studies.

ABSTRACT

EVALUATING CONVENTIONAL AND DIGITAL IMPRESSIONS OF SINGLE UNIT RESTORATIONS, AND CONVENTIONAL VS. DIGITAL IMPRESSIONS FROM THE LABORATORY TECHNICIANS' PERSPECTIVE

Degree date: **June 20th 2016**

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Objectives: To Evaluate the quality of Digital Impressions and Conventional Impressions sent to commercial dental labs and to compare Conventional impressions vs. Digital impressions from the Laboratory Technicians' Perspective. **Background:** The literature lacks studies that evaluate the quality of final impressions of indirect restorations, particularly in the USA, additionally there is a direct relation between impressions accuracy and produced restoration quality, which makes it impossible to produce high quality restoration from poor impression. **Methods:** 259 PVS impressions were evaluated for their quality by a calibrated examiner using a specific evaluation form. Type of tray, arch and required restoration were recorded. Impressions were evaluated for the following: defects related to prepared tooth and finish line (i.e. bubbles, voids, tears, clarity of finish line, and retraction cord left in impression) also, defects in material setting and distortion. Quality

of tooth preparation was not assessed. Impressions were then ranked using 3-point Likert scale: Satisfactory, Questionable, and Unsatisfactory. Similarly, 74 Digital impressions were evaluated using a specific evaluation form by a calibrated examiner. Digital system brand, arch and required restoration were recorded. Impressions were evaluated for the following: inadequate scanned data, unclear margins, improper moisture control, improper powder application, improper occlusal registration, and presence of obstructions. Impressions were ranked using a 2-point Likert scale: Satisfactory or Unsatisfactory. Data was analyzed using Chi Square and Fisher's exact test. Furthermore, a comparison between Conventional impressions and Digital impressions sent to lab was done through a survey answered by dental lab technicians'. **Results:** A total of 57.9% Conventional impressions were satisfactory and a significant difference was noted between tray type groups and impression ranking $c^2(4, n= 257)=17.36$, $p < 0.001$. A total of 78.4% of Digital impressions were satisfactory. Most frequent types of errors in Conventional impressions were the existence of tears, bubbles, and voids at the finish line resulting in unclear preparation margins at 36.3%, where the most frequent error in Digital impressions was inadequate scanned data at 18.9%. Regarding the Survey, 57.69% of technicians determined that number of errors in Digital impressions are less than Conventional impressions, and that the frequency of remakes in Digital impressions are also less than Conventional impressions by 63.46%. The results indicated that a total of 51.92% of the lab technicians advised for a shift to Digital impressions. The study concludes that Digital impression is a better option than Conventional impressions as a measure of its reduced errors and ease of use. **Conclusion:** Within the limitations of this study, when it comes to single unit restorations, dentists have to reconsider their impression taking methods and techniques.

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1.1.1 History of Dental Impressions

Dental impression making and reconstruction dates back to the early 18th century. Despite the fact that there are no historical records of the use of dental impression, a German surgeon, Matthaus Purmann (1648-1711) is noted to have held discussions on how sketches and wax models can be used for making prosthetic appliances (Bremner, 1958). Another German dentist called Philipp Pfaff (1713–1766) was first to describe the impression making procedure through the use of sealing wax softened with hot water to be later on filled with plaster of Paris for the formation of a rigid cast (Guerini, 1909).

In 1787, an advertisement was run by John Greenwood stating that "individuals from any distance could be supplied with artificial teeth by simply sending an impression of their oral cavity taken by wax" (Weinberger, 1942). This advert appeared to be one of the earliest uses of modeling for the construction of dental prostheses. Isaac John Greenwood in a letter written in 1861 to Dr. Jonathan Taft mentioned that neither his father or grandfather John and Isaac Greenwood had used plaster of Paris to make impression models. Isaac stated instead that they had all used beeswax. He went on further to state that together with his brother Clarke, they never used plaster of Paris up until 1820 (Weinberger, 1942).

The use of impression materials cannot be underestimated as they are essential in making copies of the intraoral cavity to enable the production of final restorations. Impression making for the duplication of tooth structures and oral conditions is a central procedure in prosthetic dentistry (Greenwood, 1861).

In 1819, in his book "A Practical Guide to the Management of the Teeth" (Figure 1), Levis, S. Parmly stated that his method of fabricating artificial teeth was a completely new perception and would be perhaps one of the greatest achievements in dentistry. He went on to further explain that, in instances where individuals had lost teeth in either or both their upper and lower jaws, artificial sets could be made by making molds of all the depressions and the risings along the surface of the jaw before corresponding artificial sockets were made (Parmly, 1918).

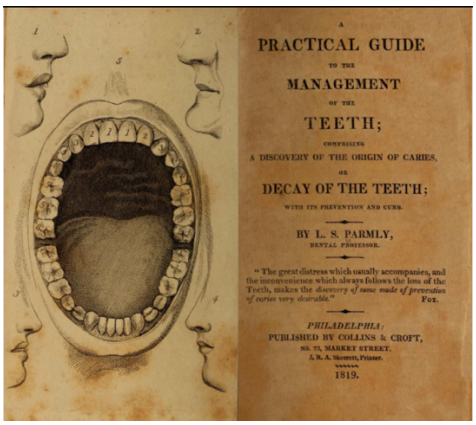
A
PRACTICAL GUIDE
TO THE
MANAGEMENT
OF THE
TEETH;
COMPRISING
A DISCOVERY OF THE ORIGIN OF CARIES,
OR
DECAY OF THE TEETH;
WITH ITS PREVENTION AND CURE.
BY L. S. PARMLY,
DENTAL PROFESSOR.
"The great distress which usually accompanies, and the inconvenience which always follows the loss of the Teeth, makes the discovery of some mode of prevention of caries very desirable."
Fox.
PHILADELPHIA:
PUBLISHED BY COLLINS & CROFT,
No. 73, MARKET STREET.
1819.

Figure 1: Levis, S. Parmly Book titled "A Practical Guide to the Management of the Teeth" (Parmly, 1918).

Delabarre C., a dentist from France in 1820 introduced his very first impression tray (Delabarre, 1820) (Figure 2). Impression trays are significant as they prevent the exertion of pressure from the cheeks to wax. After pushing wax firmly, it would then be gently removed and immersed in cold water to cool (Hoffmann-Axthelm, 1981).

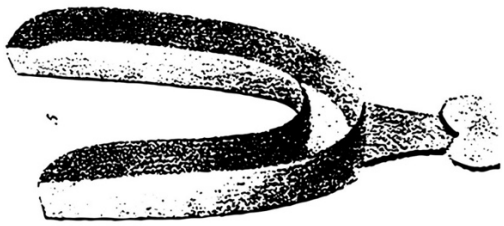

Figure 2: "Impression box or tray from The Anatomy, Physiology and Pathology of The Human Teeth", Paul Goddard, 1844.

An inventor from Australia called Alphons Poller, formulated a material he then called Nogacoll. After his death in 1931, Nogacoll was owned by a company that retailed it using a different name 'Denticole' (Bremner, 1958). Almost 12 years later other brands were produced to the market (Fitch, 1835).

Most of these compounds in the market were made with reversible hydrocolloids with essential materials like agar-agar, which is a vegetable colloid made from seaweed, gelatin like material that would soften on heating and cool when set. This however was a little complicated as the reversible colloid required the need for special injectors, heaters, and trays that water cool. Furthermore, when the Japanese algae was no longer available, native brown algae in America had to be used (Lufkin, 1938). When processed chemically the brown algae produced a new impression material that was more elastic and easier to use as it had an alginate base. When dry alginate powder gets mixed with water they formulated "irreversible hydrocolloid alginate". Which resulted in the discontinue of using reversible hydrocolloids that had agar-agar in its formula. Alginates, on the other hand, proved sustainable, and some are still being used up to date (Heartwell, 1968).

It become evident that the history of impression materials began in the mid-1930s with the advent of reversible hydrocolloids which are some of the first impression materials. Hydrocolloids were used up until 1955 when elastomeric material started to be used (Sharma, Agarwal, Sharma, Kumar & Glodha, 2014). Elastomers promoted improved qualities of reproduced teeth, however, there were problems related to shrinkage that had to be solved (Craddock, 1951).

In 1955, Pearson S.L introduced the use of elastic materials from synthetic rubber (Hoffmann-Axthelm, 1981). The first elastomeric material produced were Polysulfides. And they continued to be used for a while until polyethers were introduced. After rubber-based polysulfide and polyether materials, silicone-based materials followed, these are still being used (Pearson, 1955).

Elastic polyether was developed after polysulphides before the introduction of polyvinylsiloxane (PVS) materials. Aside from the revolution in types of impression materials, also a variety impression techniques and trays have gradually evolved over time. It then becomes probable that in the future, there will be a further development of new techniques that will help to make work easier (Heartwell, 1968).

CLASSIFICATION OF IMPRESSION MATERIAL		
Non Elastic	Elastic	
1922 Waxes, Gums, Resins	SYNTHETIC ELASTOMERS	HYDROCOLLOIDS
1927 Plaster of Paris	1955 Polysulfides	1925 Agar-Agar
1934 Zinc Oxide Eugenoul	1958 Condensation Silicone Type I Silicone	1943 Alginate
1935 Impression Compound	1966 Polyethers	
1974 Eugenoul-Free Paste	1976 Addition Silicone Type II Sillicone	

Figure 3: Classification of Impression Materials (Sharma et al., 2014).

As illustrated in (Figure 3), impression materials are characterized by two distinct subgroups; non-elastic and elastic materials. Non-elastic materials include; eugenol-free paste, zinc-oxide eugenol, impression compounds, waxes, resins and gums together with plaster of Paris. These were used between the periods of 1922-1974 (Sharma et al., 2014). Hydrocolloids agar-agar and alginates fall under the elastic group but were used from around 1925 and 1943 respectively. Most of the materials currently used are referred to as synthetic elastomers, and they also fall under elastic materials. These are the materials often used in the conventional impression making (Craddock, 1951).

1.1.2 Revolution in Dental Impressions

Aside from Conventional impressions, digital impression started in the 1950s with the use of the CAD/CAM technology and since then it has been developed and used. It began with numerical machines, then in the 1960s, it evolved with the revolution of computer software (Birnbaum & Aaronson, 2008). The CAD/CAM technology was formally introduced by

Dr. Francois Duret in his 1973 thesis paper, "Empreinte Optique" (Optical Impression). After obtaining a patent in 1984, he took it to the Chicago Midwinter Meeting in 1989 where he demonstrated how a dental crown can be fabricated. Dr. Werner Mörmann and Marco Brandestini both electrical engineers at the time were also developing the concept, their first CAD/CAM system is what is now referred to as CEREC and was introduced officially into the market in 1987. Other digital impression technologies like E4D Dentist, Itero and Lava have since then based their constructions from the CEREC system (Duret & Termoz, 1987).

1.2 Conventional Impressions Overview

Restorative dentists have an array of impression materials and techniques from which they can choose when making impressions in fixed prosthodontics, operative, and implant dentistry. With handling and choice of impression materials, accurate reconstructions can be made (Donovan & Chee, 2004). This section will cover a review of the trays, materials, and techniques used in conventional impressions.

1.2.1 Materials

Despite the partial usage of some reversible hydrocolloids, synthetic elastomers are the materials commonly used in conventional impressions. They include poly-sulphides which were introduced in 1955, condensation silicones (Type I Silicones) introduced in 1958, polyethers in 1966 and addition silicones (Type II Silicones) in 1976 (Donovan & Chee, 2004).

Impression materials have some properties that vary considerably providing a basis for their unique applications in different clinical situations. Some of these properties include hydrophilicity, workability, elastic recovery, dimensional stability, accuracy and flexibility just to mention a few (Donovan & Chee, 2004). All these are explored in this review.

Synthetic Elastomers

The most common synthetic elastomers used in Conventional impressions include; condensation silicones, polyvinylsiloxane (PVS), polysulfide rubber and polyether impression materials. Special attention is given to PVS materials as they are the most widely used in restorative dentistry today (Donovan & Chee, 2004).

PVS materials meet the accuracy requirements of the American Dental Association (ADA) Specification #19 of having the best capability of fabricating precision castings to a fine detail of 25 micrometers and less. They additionally have the best elastic recovery at 99% (ability to readily flow to undercut areas, set and rebound to original shapes when removed from the mouth) (Klooster, Logan, & Tjan, 1991). This together with its exceptional dimensional stability (can be poured at the convenience of the dentist) makes it good for accurate second pours, it makes PVS materials efficient as they can be poured at any time (Donovan & Chee, 2004).

PVS materials have one disadvantage, on interaction with latex material, unpolymerized PVS is prevented from polymerizing (Neissen, 1986). This prevention for un-polymerization occurs during the mixing of putty materials when latex gloves are worn (Reitz & Clark, 1988). To prevent its occurrence, the use of vinyl and synthetic latex

gloves, as well as the powder often found on gloves, is advised as they do not inhibit polymerization (Noonan, Goldfogel, & Lambert, 1986).

Type I Silicones and polysulfide rubber have a lower dimensional stability as they usually produce ethyl alcohol and water respectively, volatile by-products that cause the distortion of set impression when they evaporate from its surface. They should therefore not exceed more than half an hour before they are poured after removal. Polyether's, on the other hand, absorb atmospheric water vapor causing swelling as others shrink as a factor in the release of volatile compounds and polymerization which all result in distortion. It is therefore often recommended that for polyether impression materials, for instance, they have to be poured within an hour after removal (Donovan & Chee, 2004).

Most of the modern PVS materials are thixotropic which means that they have good flow and flexibility. Polyethers are however a little bit more rigid making it hard when making thin preparations of periodontaly involved teeth, particularly when patients had existent crowns or bridges and wide gingival embrasures from the recession and bone loss. As a result, some of the common problems from this rigidity have included the fracture of gypsum dies and the tearing of the polyethers when being removed. In such kinds of situations, it was therefore often advised that more flexible materials be used and that the undercuts be blocked with utility wax before the impressions are made. Although PVS materials are also rigid, they meet the recommended threshold below problems with dies and fractures. These are therefore significant when making dual arch impressions (Christensen, 1994).

PVS materials are also hydrophilic but not as much as polyethers. On cost, in comparison to other elastomers, PVS and polyethers are the most expensive. However, this should be disregarded as costs have minimal consequence on impression making (Donovan & Chee, 2004).

Reversible Hydrocolloids

In comparison to PVS materials, reversible hydrocolloids (RHs) are the worst at meeting the ADA specification #19 as they can only meet the accuracy 25 micrometers (Ragain, Grosko, Raj, Ryan, & Johnston, 2000). They, however, have a higher dimensional accuracy in comparison to elastomers (Federick & Caputo, 1997). RHs also have a poor dimensional stability meaning that they have to be poured within 10 minutes' after removal. This is because they are made of 80% water making them subject to water absorption which distort impressions (Donovan & Chee, 2004).

On flow and flexibility, reversible hydrocolloids are the least rigid materials used for impression and are therefore often recommended for multiple periodontal teeth. They are additionally hydrophilic and can make accurate impressions when moist. This property makes them effective as they flow into the gingival sulcus hence capturing the prepared subgingival margins. RHs are usually more economical than elastomeric materials, but there are usually other costs associated with the use of water cooled trays for purposes of tempering baths and conditioning (Donovan & Chee, 2004).

1.2.2 Impression Trays

The conventional impression has enabled the use of custom trays (Figure 4) that are more efficient and comfortable for use by patients; this is because most of the contemporary materials are essentially tasteless, odorless and colorless. The old polysulfide rubber materials and some reversible hydrocolloids required the use of bulky water cooled trays (Christensen, 1994).

Because impression materials have to flow readily unto cavities and capture the minute details of grooves, cervical margins, and pinholes, heavy body tray materials have to be used to force materials with lower viscosities like PVS and polyethers to effectively flow into the gingival sulcus (Donovan & Chee, 2004).

Custom trays have been particularly recommended when making full-arch impressions with multiple preparations as opposed to dual arch impressions using triple tray which use minimal amounts of impression materials and limits the need for opposing arch impressions. Custom trays are also more accurate than stock trays as well as more comfortable for use on patients. Custom trays are furthermore more cost effective as they use sufficiently less material making significant savings while reducing the number of remakes. Plastic stock trays (Figure 5), metal trays (Figure 6), full or partial trays have been associated with numerous deficiencies in impression making due to minimal control of bulky materials. Therefore, dual arch techniques using triple trays should only be used when required, while custom trays should be used when making full-arch impressions (Donovan & Chee, 2004).

Figure 4: Custom tray

Figure 5: A- Plastic Stock Tray

Figure 5: B- Triple Tray

Figure 6: Metal Stock Tray

Well-sized stock trays are used to provide a cross-sectional thickness of 4-6 mm to water based reversible and irreversible hydrocolloids. This is important as different impression materials require different cross-sectional thickness for optimal accuracy (Rudd, Morrow, & Strunk, 1969). Custom trays on the other hand help to provide the required cross-sectional thickness of 2 mm used on elastomeric impressions (Eames, Sieweke, Wallace & Rogers, 1979).

PVS materials produce better results when used with custom trays as compared to stock trays. This difference in accuracy and precision can be explained by the fact that materials in stock trays are thicker by 1.5 to 2 mm than in custom trays, warranting the need for precision in the fabrication of custom trays (Ceyhan, Johnson, Lepe, & Phillips, 2003).

Triple trays (Figure 5) are usually flexible and are especially used when making dual arch impressions while using rigid and thixotropic polyethers and PVS materials. To work well, impression materials must adhere well to the impression tray to allow for the effective shrinking of material towards the tray during polymerization. Special chemical tray adhesives that match with the impression materials are often used (Cho, Donovan, Chee, & White, 1995). The use of tray adhesive with custom trays is very important and critical as it is the only way impression material will retain to tray.

1.2.3 Retraction

For the purpose of making a high-quality impression, preparation margins have to be visually clear, capturing supragingival margins is simple. Margins are however often subgingivally located making capturing a challenge. There are a number of retraction

techniques that are available with the most common being the use of retraction cords, laser, chemical agents, and electrosurgery (Figure 7) (Prasad, Hedge, Agrawal & Shetty, 2011).

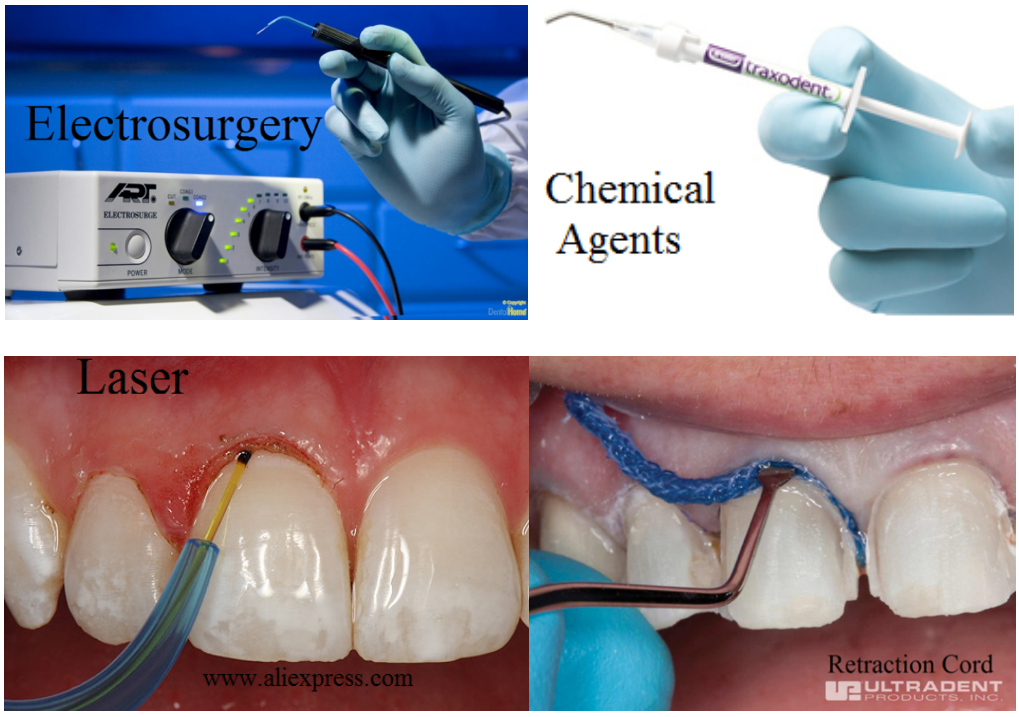

Figure 7: Methods of Soft Tissue Retraction

Retraction is done before impressions are taken particularly in cases where gums are an impediment to the effective record of the complete tooth surface. Gingival retraction is hence use to temporarily move the gums. The most prevalent method of retraction is the use of retraction cords, cords are available in different sizes, and they could be used as a single or double cords. Retraction cords have to be removed from the sulci before the injection of impression materials around the tray.

When chemical retraction is used, careful attention has to be considered to prevent contamination of impressions material with sulfur containing gingival retraction chemicals as they will promote the inhibition of polymerization (Phillips, 1991). This mechanism of polymerization inhibition is thought to result from the reaction of chloroplatinic acid catalyst from PVS material with sulfur. Therefore, profuse washing of chemical is necessary before impression making (Cook & Thomas, 1986).

1.2.4 Impression Techniques

The transfer of accurate impressions of the patients' soft and hard tissue for processing in dental laboratory is an important process (Christensen, 1994). There are some impressions techniques used in the making of fixed prosthesis (Winstanley, Carrotte, & Johnson, 1997). For instance, the single-step technique which is currently mostly used where impression materials of two different viscosities applied and allowed to set at the same time, the double step technique where impression is made in two stages using materials of different viscosities, the monophase technique whereby the impression materials used have single viscosity, and the single copper band technique (Federick, Caputo, 1997). Because impressions records both the soft tissue and teeth, it is also based on an understanding of the anatomy of soft tissues for the purpose of effective tissue preparation. This helps in the creation of decipherable and accurate impression (Klooster, Logan, & Tjan, 1991).

Putty/Wash Impression Techniques

Putty/wash techniques could be done through three different approaches and its either done in two steps or one step (figure 8):

The first approach is the most acceptable and appropriate as the second has some potential drawbacks while the third is unacceptable. The first and best approach requires the need for using putty materials for the fabrication of the custom trays with polymethylmethacrylate (PMM) and light-cure materials. Putty impressions are often made in stock trays to make customized PVS trays. Often, a layer of base plate wax is used as a spacer over the diagnostic cast. Wax removal from non-functioning cusps on the other hand allows for the provision of occlusal stops (Chee & Donovan, 1992).

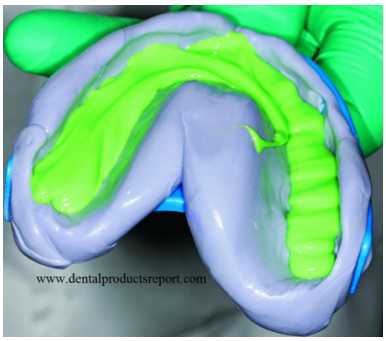

Figure 8: Putty/Wash Technique

Putty materials are advised to be used in control and in appropriate manners to create impressions with optimal accuracy. Putty materials are often unable to reproduce fine details as they do not have the necessary required low viscosities to record fine details of up to the 25-μm level, they are instead only able to record required only to record detail of 75 μm. Another deficiency of putty materials is that they record critical areas of tooth

preparation like cervical margins which have a deleterious effect on the gypsum dye (Chee & Donovan, 1992).

The second approach uses a relieved pre-operative putty impression made intra-orally. Plastic sheets have to be placed on teeth to prevent the enclosing of impression material into gingival embrasures. Impression materials are removed with a scalpel or a bar in the regions where the teeth are to be prepared as the impression is refined with PVS materials of lower viscosities or 'washed'.

The approach is often never quite successful as it has two drawbacks, first, limiting wash materials to the region of relieved impression is difficult as well as the fact that some wash materials often enter unrelieved impressions causing inaccurate occlusal patterns on the resultant cast. The 'washing' of the entire impression may hence be recommended which in essence poses the potential problem of the hydraulic distortion of the used putty material hence a deleterious effect on the precision of the impression (Chee & Donovan, 1992).

The third approach is also referred to as 'simultaneous' or as the 'squash' technique. It involves the loading of a stock tray with putty material as the injectable material is squirted on prepared teeth. Putty trays are then pressed on the injected materials to set the putty material. This third approach is not preferred as it is difficult to control the thickness of the impression material. It is also impossible to control which material should record the margin details of the preparation (Chee & Donovan, 1992).

Dual-Arch Impression Technique

The dual arch or double-bite impression techniques (using triple tray) are recommended for use when one or two posterior teeth have to be prepared for indirect restorations (Donovan & Chee, 1989). The dual-arch impression techniques capture the prepared teeth, the occlusal articulation in MIP (maximum intercuspation) and the opposing arch simultaneously (Bremner, 1958). By some studies, it has been demonstrated that this technique can provide accurate fabrication restorations through the use of confirmation maxilla-mandibular relation (Getz, 1971). Its advantages include accurate recording of the MIP position and clinical simplicity. It can also be used with the closed-mouth technique to eliminate mandibular flexure associated with opening. Despite the fact that its laboratory procedures are a little bit complicated, technicians can handle once understood (Gates & Nicholls, 1981).

The dual-arch impression technique is also appropriate as it is comfortable for use on patients and it also uses a minimum amount of material while avoiding the need for opposing arch impressions. This is why in cases of full-arch impressions, custom trays are always advocated for (Donovan & Chee, 1989).

Segmental Impression Technique (SIT)

This is used for the preparation of simultaneous impressions of many teeth. The SIT can make successful impressions of multiple prepared teeth despite the inherent limits of moisture control maintenance and working time which make the process difficult in spite of the progress made on auto-mix systems and materials used (Gardner & Loft 1981). It can be used with any impression material, but auto-mixed PVS materials are

recommended. The technique breaks down the arch to be impressed into smaller segments that are easily managed with the diagnostic casts in each segment fabricated with their own individual customized trays. A wax relief of 1 mm is provided as the trays are allowed to go past the 3 mm of the gingival margin of the teeth that have been prepared. This is significant because the gingival tissues have to prevent the over-seating of the trays and also because it has no occlusal stops (Donovan & Chee, 1989).

The trays are made using PVS putty material and PMM acrylic resin, these can be individually made or as a single tray sectioned with a scalpel or disc. The individual trays should be able to simultaneously seat on the cast. Low viscosity materials are then loaded onto syringes and a segmental tray. This procedure is usually repeated for each of the different segments till all the segmental impressions are in place. SIT has proven effective particularly in cases where moisture control is tasking (Donovan & Chee, 1989).

1.2.5 Benefits and Drawbacks of Conventional Impressions

The moderate costs and success of Conventional impressions together with their ability to communicate the soft and hard tissue landmarks to laboratory technicians have enabled the proliferation over time (Derbabian & Chee, 2003).

There are however a number of disadvantages of Conventional impressions like dimensional change of impression materials which is a major issue. The probability of bubbles, tears, drags, and distortion are some of the other disadvantages. There is also the brittleness of stone models that necessitate repairs which jeopardize the accuracy of it (Samet, Shohat, Livny & Weiss, 2005).

Some other issues with Conventional impressions is the fact that they are cumbersome and time-consuming. It is also uncomfortable to patients as well as messy with constant mixing, pouring of impressions, basing, trimming and dying as well as well as clean-ups. In Conventional impressions, the capture of finer details can only be made after the plaster model stage making it difficult to make early quality analyses. This is in comparison with digital impression where the use of physical casts is eliminated through the use of digital records of the intraoral condition using 3D acquisition devices and acquired information that enables the generation of virtual models. In Conventional impressions, the possibility for early qualitative analysis is hindered as this can only be achieved later on at the plaster modeling stage. This is in comparison to Digital impression whereby diagnoses can be made on the computer monitor both during and after the scanning procedure (Donovan & Chee, 1989).

1.3 Digital Impression Overview

Computerization, laser technologies, optics, and miniaturization technological advances have enabled the capturing of dental impressions. Three-dimensional (3D) digitizing scanners have been in use for more than 20 years for the acquisition of virtual impressions. Computer-Aided Design/Computer-Aided Manufacture (CAD/CAM), a special dental technique is responsible for the transfer of digital scans of the intraoral cavities to the milling unit. These systems can carve restorations from blocks of different materials without the need to obtain physical impression of target and opposing arch (Reicha, Vollbornb, Mehlc, & Zimmermannd, 2013).

Currently, new esthetic and high-strength ceramic restorative materials like zirconia are developed in laboratories whereby master casts are poured from conventional impressions and then digitally scanned for the creation of stereo lithic models for the construction of restorations, replacing the conventional layering technique (Reicha et al., 2013). A review of some of the common scanning systems used in Dental Digital Impression are described in (Figure 9).

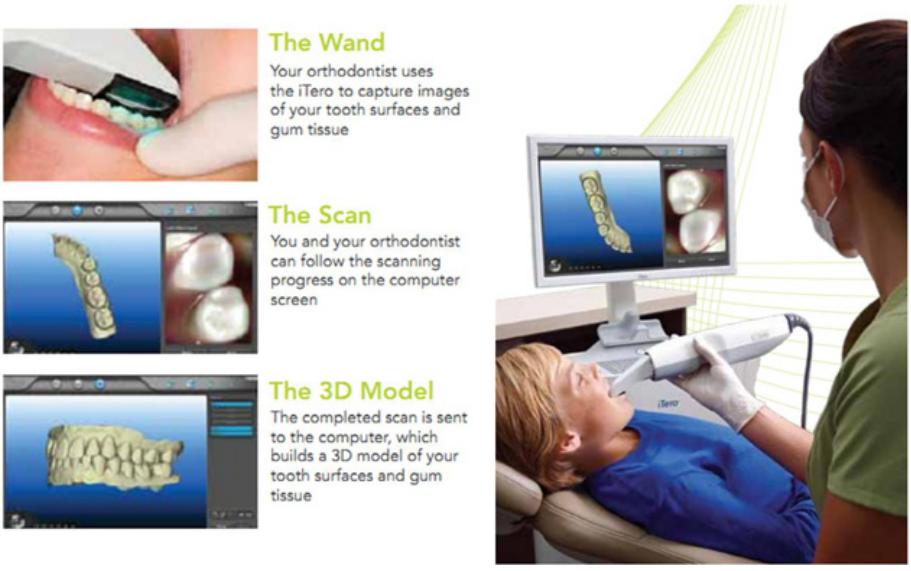

Figure 9: An Illustrative Review of Scanning Process (Reicha et al., 2013).

1.3.1 Scanning Systems

Four major types of scanning systems are present in the market today; these include 3M ESPE, iTero, 3Shape, and CEREC by Sirona.

The 3M ESPE Intraoral Scanner

The 3M ESPE machine operates by producing models through wave front sampling which are later sent to dental laboratories. The SLA model from the scan data is responsible for constructing restorations using a LED scanning system to produce a video-type format, this relies on the use of powder. The 3M ESPE however does not produce high quality colored images. Its configuration is made up of a trolley and a touchscreen. It does not have a clinical milling unit which immediately fabricates the final restoration chairside and therefore the intraoral scan data is transferred via STL file to 3M Connection Center (Reicha et al., 2013).

The True Definition Scanner (3M ESPE)

THE 3M True Definition Scanner (Figure 10) is a development of the Lava C.O.S Chairside Oral Scanner. It uses the active wavefront sampling and optical measuring method which requires powder conditioning, also referred to as 'dusting.' This powder helps to provide a random pattern that enables the extraction of height and density data for sufficient sampling points. Occlusal surfaces are always scanned first, followed by lingual and buccal surfaces (Zimmermanna et al., 2015).

Monochrome non-colored digital datasets are produced and displayed as video sequences. It has an established lab side workflow with its chairside option still in the planning stage. Acquired 2-D are exported in STL format to the Lava 3M systems. This data export process uses the Dental Wings Open Software (Reicha et al., 2013).

Figure 10: The True Definition Scanner (3M ESPE)

The iTero Intraoral Scanner

The iTero uses the confocal laser scanning microscopy which offers a powder-free scanning operation that is optically aided. It operates as a digital impression system with its configuration made up of the touchscreen with a tabletop version (Figure 11).

The optic used in this scanning system allows for real-time imaging by producing high-resolution images and videos through parallel confocal microscopy (Zimmermann, Mehlb, Mörmannc, & Reichd, 2015). Once target teeth are well defined, the system can direct the user to the areas that require scanning. The patient and doctor can, therefore, see as the model is being built throughout the scanning process. These images are acquired and achieved through different positions for high accuracy. It eventually produces a milled model which allows for the eventual fabrication of the different restorative requirements (Reicha et al., 2013).

The scanner size is 40% smaller with a 6,000 rather than 800 fps scanning at a speed of 20 scans for every second, 20 times faster than the normal scanning fees. The iTero has a special webcam feature that allows for live feedback. Its labside milling system is dependent n the CAD and CAM systems. The scanner also produces 2-D colored images

of the intraoral cavity. Its chairside CAM/CAD technology is still in planning (Reich, Wolfart & Vollborn, 2012).

Figure 11: The Itero Intraoral Scanner

The 3Shape TRIOS

The 3Shape TRIOS offers different variations of the TRIOS intraoral impression system. It is a spray-free scanning system that has two distinct color versions, the TRIOS Color Pod, and the TRIOS Color Cart as well as two non-color standard versions (the TRIOS Standard Pod and the TRIOS Standard Cart). This type of colored scanning is advantageous as it allows for better representation and preparation of teeth margins (Reicha et al., 2013). TRIOS systems can handle up to five different units of bridgework or crowns with just one or two adjacent pontics. The TRIOS furthermore has an image cropping tool able to eliminate redundant parts as well as replace those of insufficient quality. It is important to note that this scanning system also relies on the use of powder spraying. Data is captured using the confocal laser technology with the possibility of video recording rather than individual images only. The confocal laser processes 3D visualizations. It particularly has

a incorporated shade matching and selection within its system together with a blocking function for surfaces (Zimmermanna et al., 2015).

There are two available versions of the 3Shape TRIOS; these include the pistol-shaped handle (Figure 12-A) and the pen-grip handle (Figure 12-B). Its special feature is the provision of real scanner scans as mentioned; this is accompanied by the production of HD images with automatic artifact elimination and digital shade determination (Reicha et al., 2013).

Figure 12-A: 3Shape TRIOS with pistol-shaped handle

Figure 12-B: 3Shape TRIOS pen-grip handle

The CEREC Bluecam

The Bluecam AC by Sirona (Figure 13) operates on the principle of active triangulation which relies on titanium dioxide powder dusting to create a uniform reflective surface. Three non-colored dimensional images are produced through the use of the stripe scanning pattern. It operates on a single trolley configuration and has established chairside and labside systems that allow for milling options for final restorations (Reicha et al., 2013).

Figure 13: The CEREC Bluecam

The CEREC Omnicam

The CEREC Omnicam does not depend on the use of powder and produces true color images. Its digital workflow is complete with a chairside treatment and scans can be transferred to lab tech through the cloud-based platform called Cerec Connect. It is distinct as it can record intraoral data not only as individual images but also as video recordings. This video recording is enabled through the exposure time per scan data which eliminates camera shakes. The CEREC Omnican has a unique feature that cuts out and rescans errors. Its configuration is made up of a tabletop version (AF) and a trolley (AC) (Figure 14), it

also relies on the use of the triangulation data capture method. The Omnican furthermore allows for clinical milling as it has an established labside system that relies on the CAD/CAM technology (Zimmermanna et al., 2015).

Figure 14: The CEREC Omnicam

The above-mentioned scanners are but a portion of the wide array of intra-oral scanners in the market today. Some of the others being used include The Appollo Digital impression, PlanScan, Carestream – CS 3500 Intraoral Scanner, BlueScan I, Lythos, Intrascan and DigImprint just to mention a few.

The number of intraoral optical impression systems available have clearly increased over the years with significant innovations like the IDS 2013. It is now undisputed that the use of optical impression systems has a significant level of potential for growth and precision. It will be exciting to see when digital impression systems will become a natural part of everyday life like other now-established digital applications, such as the smartphone, which we cannot imagine living without. Considering the pace of innovation seen at the IDS 2013, it can be concluded that this will very probably occur shortly (Reicha et al., 2013).

1.3.2 Materials

The material requirements for Digital impression is simple. The major items needed are usually a scanning system and the titanium dioxide powder in specific scanning systems.

1.3.3 Technique and Milling Options

Tissue management and tooth preparation in Digital impression are similar to Conventional impressions in some ways. Reflective powders are often applied only when indicated by the scanning system before the state of the scanning of prepared tooth. The scanning system used determine whether or not prepared teeth can be scanned and restored by milling machines.

Systems with milling units are referred to as Chairside. The opposing arch, quadrant, and occlusal registration have to all be scanned. In cases where the scanning system and the milling machine is not available, the digital scans are often sent to the dental laboratory through specific software for designing and milling (Christensen, 2011).

1.3.4 Benefits and Drawbacks of Digital Impression Systems

Compared to the conventional impression techniques that have been used in the past, Digital impression making has numerous distinct advantages in some respects (Stimmelmayr, Güth, Erdelt, Edelhoff, & Beuer, 2012). More specifically, Digital impression's versatile and flexible integration in diagnostic and treatment systems of "health care packages" for individual patients is especially noteworthy and has a promising future. This versatile integration into dental diagnostic and treatment options furthermore provide a customized healthcare system that is not only effective but also efficient for

patients and doctors. Its possibilities, therefore, go beyond single-tooth restorations (Reicha et al., 2013).

Intraoral scanning systems and the creation of digital datasets when compared to physical impression method has its advantages. The success of scanning systems such as iTero, CEREC by Sirona and 3M ESPE True Definition Scanner has convinced many dentists worldwide to engage in and develop such technologies (Zimmermanna et al., 2015).

Some of these advantages of Digital impression over the Conventional impressions include the improvement of patient comfort and acceptance, the potential for the provision of 3D pre-visualizations of the prepared teeth, a reduction in the number of distortions of impression materials together with time and cost effectiveness (Seelbach, Brueckel, & Wöstmann, 2013).

Digital impressions are also electronically transferred through either flash drives, disks, dedicated software or the electronic mail. There is also a reduced risk for the transfer of diseases and infection between the technician and patient as there is a little tangible impression. In Digital impression, real-time visualizations allow for early qualitative analysis from the digital models on the computer monitor during both the scanning operation and after as opposed to Conventional impressions whereby the significant critical details can only be examined after pouring the impression (Zimmermanna et al., 2015).

Digital impression also has easy repeatability because, in the case of unsatisfactory results, the scanning procedure can be easily and quickly repeated without the need for constant mixing of impression materials and the use of impression trays. It is also flexible and can allow for selective repeatability and assessment of all the relevant and affected areas, for

instance in cases of bleeding at prepared margins which can be digitally rescanned when cutting out (Reicha et al., 2013).

Since in Digital impression no trays are necessary, there is little need for impression tray disinfection. Intraoral scanners can be cleaned and disinfected easily, and the scanner tips can be sterilized and autoclaved like other dental instruments. Disposable plastic protective sleeves are also alternatives that can be used (Zimmermanna et al., 2015).

Effective analysis options for preparation and restoration can also be used for Digital impression through monitoring and checking of the significant preparation parameters like distances from antagonist teeth and places of insertion on computer screens. In the same way, restoration parameters like the functionality of restorations like wall thickness, for instance, can be evaluated digitally (Ender & Mehl, 2013).

Models in Digital impression are additionally durable as it they are always available in their original quality in comparison to Conventional impressions which is subject to wearing when fits are being checked for restoration. Digital impression models therefore rarely wear out giving them an added advantage (Reicha et al., 2013).

Digital impression making furthermore allow for fast communication and availability as it requires minimal time consumption because the digital data is transferred through cloud-based systems that save on transport costs. Digital impression models in comparison to Conventional impressions models are simple to store as they can be easily and effectively archived in the computer and the cloud systems saving on space. Retrieval of data is also easy only requiring the need to access patients' dental record files (Zimmermanna et al., 2015).

Digital impression is additionally economical and sustainable as it does not produce waste products and hence conserves resources (Reiz, Neugebauer, Karapetian, & Ritter, 2014). Besides the advantages of saving time and single-visits for treatment, other perks include adhesive stabilization of residual tooth substances (which prevents the influence of temporary cement) and the sealing of dentin wounds preventing bacterial infections. True color representation furthermore allows for the capture of elements like the gingival texture and dental structures and hence enabling an analysis of color changes in oral structures like the gingiva and the teeth. There are also systems that allow for measurements that are selective based on teeth shades (Zimmermanna et al., 2015).

Digital impressions are therefore in essence considered viable alternatives to Conventional impressions for providing accurate single or fixed prostheses. However, some of the factors that are preventing dentists from migrating to Digital impression is the fear of the learning curve which is great and extremely flat at the very beginning. This is because beginners have to first learn and understand complex scanning paths and measurement techniques (Brawek, Wolfart, Endres, Kirsten, & Reich, 2013).

Intraoral scans are furthermore expensive and require some users to pay for scanning fees. In closed systems, scans have to be sent to owner companies first, then to cloud-based storage systems as the information acquired is usually in encoded file formats. Open systems like the intraoral scanners, however, allow for direct exports. Together with some other factors like the diverse systems of scanning and scan paths for different scanners make the use of Digital impression almost technical for use. All these are some of the reasons that have slowed down the paradigm shift (Zimmermanna et al., 2015).

1.4 Purpose of the Study

The purpose of this study is to evaluate the quality of conventional or digital final impressions of indirect restorations in general and particularly in the USA to help dentists pay more attention to the most common errors that exist in final impressions. It also seeks to enable dentists to judge the quality of the impression and to know if digital impression allows fewer errors than the conventional one.

Its long-term goal is to improve the quality of impressions sent to dental labs with the objective of collecting information that will guide the development of awareness among dentists and encourage them to try new and innovated impression methods that could help them provide the dental lab with better quality impressions. The research is based on the need to identify the best impression method that will guarantee better quality impressions as well as identify the most common errors so they can be avoided.

1.5 Specific Aims and Hypotheses

Patients today have very high expectations regarding their dental treatments and are more concerned about how the dental restoration would look like, how it will function and for how long it will survive. In some clinical situations either for the reason of function or better esthetics, tooth needs to be reduced (prepared) (Fig 15) to be replaced by a restoration that gets processed in the lab.

Figure 15: Picture showing a prepared tooth

After finishing the preparation, a copy of the site should be made and sent to the laboratory, and this is what we refer to as the final impression (Fig 16). The dental lab technician will be able to make a replica of the patients' teeth including the prepared tooth out of the final impression which is called the cast model (Fig 17), which will enable the lab technician to fabricate the restoration.

Figure 16: The Final Impression "Conventional".

Figure 17: Restoration Made out of the Final Impression and on the Cast.

There is a direct relation between the accuracy of the impression and the quality of the produced restoration, which makes it impossible to get a high-quality restoration out of a poor impression. Which makes the final impression procedure an important element in getting a good quality restoration. And according to dental lab technicians' their top challenge with dentists is their skills in impression making (Fig 18). For this reason, Carrotte PV, W. R., Green JR. (1993) Published an article "A study of the quality of impressions for anterior crowns received at a commercial laboratory". Br Dent J, 174.

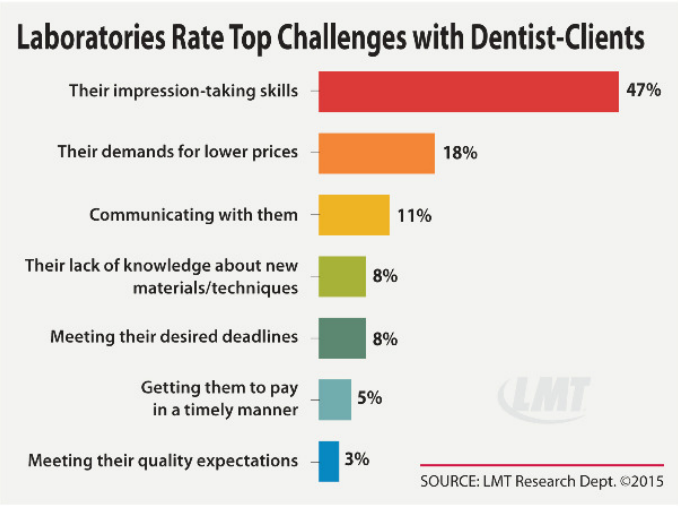

Figure 18: Top Challenges in Dental Laboratories.

Investigating the standards of anterior crowns impressions in a commercial laboratory in Britain, where they examined 50 cases and assigned each one to a category of three, depending on the level of satisfaction.

In 1997 Winstanley RB, C. P., Johnson A., followed up with a similar study, "The quality of impressions for crowns and bridges received at commercial dental laboratories", (Br Dent J, 183), where they investigated the final impressions of crowns and fixed partial dentures. 290 cases were examined and assigned to a category of four depending on the level of satisfaction. Also, in 2005, Samet, Shohat, Livny, & Weiss published their study, "A clinical evaluation of fixed partial denture impressions" in The Journal of Prosthetic Dentistry, 94.

With a similar idea, they evaluated 193 fixed partial denture impressions and recorded all the data related to material, technique and errors, then they stated the frequency of errors and they correlated between observations. Digital impression making in the dental market for the past twenty years has proven effective in making single unit fabrications (Chiche & Caudill, 1994).

The digital impression has become an alternative method to conventional impression where the patient's teeth are electronically scanned and the images or video of the scan can be processed through a special computerized system where the dentist can validate their preparation electronically before sending the digital scan or impression to the dental laboratory through the same system. Besides producing confirmed good quality impressions, this process saves the dentist and the lab technician a lot of work, time and materials (Spear, Puri, & Manji, 2009).

According to dental labs, the percentage of restoration remake related to digital impression is much less than conventional impression and this can be related to the fact that the system ensures that the dentists have accurate details and valid preparation, the casts made out of digital impression are also very accurate allowing the technician to produce a precise and high quality restoration. In order to ensure long lasting restorations with better quality, there is need to evaluate whether the quality of impressions sent to the lab are of a satisfactory quality as well as find the best impression method that will help the Dentist provide the dental lab with a good quality impression and identify the most common types of errors noticed on impressions sent to the lab.

The long-term goal of this project is to improve the quality of impressions sent to dental labs. The objective of this prospective investigation is to collect information about the quality of impressions sent to dental labs; that will guide in the development of awareness among dentists and encourage them to try new and innovated impression methods that could help them provide the dental lab with better quality impressions. The proposed research is based on the need to identify the best impression method that will guarantee better quality impression as well as identify the most common errors that will help in finding ways to avoid these errors.

Research questions:

- Are the conventional final impressions of single unit restorations being sent to the laboratory of a satisfying quality?
- Are the final digital impressions of single unit restorations being sent to the laboratory of a satisfying quality?
- What are the most frequent errors in final impressions of single unit restorations for both digital and conventional?
- Do dental lab technicians' find digital impressions of single unit restorations sent to the lab to be of a better quality than conventional impressions?

Specific Aims and Hypotheses

The Hypothesis

Do digital impressions aid dentists to obtain better impressions with less errors compared to conventional impressions.

The Null Hypothesis

Digital impressions do not aid dentists to obtain better impressions with less errors compared to conventional impressions.

The First Aim

To assess the conventional final impressions quality of single-unit restoration using a 3-point Likert scale: Satisfactory, Questionable, or Unsatisfactory.

The Second Aim

To assess the digital final impressions quality of single-unit restoration using a 2-point Likert scale: Satisfactory, and Unsatisfactory.

The Third Aim

To detect the most common types of errors in conventional and digital final impressions of single unit restorations.

The Fourth Aim

To determine whether Digital impressions of single unit restorations sent to lab are different from Conventional impressions in in the perspective of the dental lab technicians'.

1.6 Location of the Study

This study was conducted in the USA. At DSG Laboratories in Clearwater, Florida.

CHAPTER TWO: MATERIALS AND METHODS

2.1 Sample size calculation

For the evaluation of conventional impressions:

The sample size was conducted from previous studies, and a total of 5% more were included in the sample number (approximately 230 impressions). To calculate sample size, the G Power Software was used. A power analysis was conducted using data from:

- Nachum Samet, et al. (2005)
- Storey D, et al. (2013)
- Winstanley RB, et al. (1997)
- $p<0.05$

A simple random sampling method was used which resulted in at least 230 impressions for the study, for the purpose of this study a total of 259 impressions were evaluated and errors were noted. Impressions for single unit restorations were acquired from a commercial lab. Impressions were randomly selected and divided into three groups (full tray, partial tray, triple tray) (Figure 19) which are all separately evaluated. Furthermore, the type of tray and arch were correlated with impression ranking using Chi Square Analysis.

For the evaluation of Digital impressions:

Since the literature lacks similar studies, the sample size was intended to be a minimum of 50 digital impressions to be evaluated, for the purpose of this study 74 Digital impressions were evaluated. The type of system, arch, and restoration type were correlated with impression ranking using Chi Square Analysis.

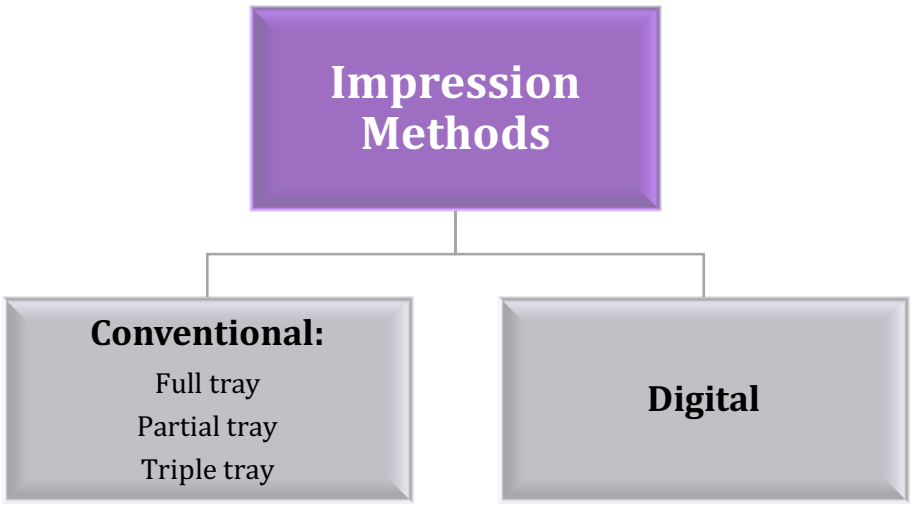

Figure 19: Impression Techniques.

Inclusion / exclusion criteria

The study included final impressions of single unit indirect restorations: single unit crowns, inlays, onlays and veneers from a commercial lab. The quality of the preparation and un-clinically detectable errors were excluded from the evaluations together with the impressions of multiple single units and fixed partial prosthesis.

External validity

The results obtained from this study have the potential of affecting the decisions of dental practitioners on the type of impression-making method. However, this is a limited observational study that reveals results from a limited number of laboratories and the need for broader studies is required before generalizing.

2.2 Methods

Instrumentation

A calibrated examiner who is the Independent variable evaluated each impression, selected the types of errors presented and established the ranking procedure which is the Dependent variable (Figure 20).

Independent variable	**The examiner evaluation**
Dependent variable	**Type of errors detected** **Rank of impression**

Figure 20: Dependent and Independent Variables.

The calibrated examiner had a checklist of errors; using a modified quality assurance form of NSU-CDM to control the consistency of the evaluation.

Design and procedures

This study conducted observations, descriptive, and randomized studies with the impression evaluated by a calibrated examiner, the examiner detected errors in different impressions and ranked them accordingly.

Statistical Analysis

A total of 259 PVS impressions were evaluated, by a calibrated examiner, immediately after arrival at a large dental laboratory. The type of tray, arch, and type of required restoration was recorded. Information related to errors and defects was registered and assessed and the data analyzed with the Chi-square test. Beside the Chi-square test, Fisher's

exact test was used to cross tab and connect dependent variable and one or more independent.

Chi-square "tests null hypotheses stating that the frequency distribution of certain events that are observed in a sample are consistent with particular theoretical distribution. These events have to be mutually exclusive with total probability" (Plackett, 1983); that's why it was chosen for this study. These same methods were used to analyze all the aims.

For quality control, a modified NSU-CDM quality assurance form was used. All the results were stored and processed using Excel spreadsheet. The statistical analysis was then transferred to SPSS for Windows statistical software to have access to customize tables and analysis outcomes.

Ethical issue

Due to the blind nature of the study, all of the impressions were identified through a laboratory procedure, no human or animal tissue was involved to prevent any ethical issues.

2.3 Conventional impression evaluation process

2.3.1 Impression criteria

PVS final impressions taken by full, partial and triple trays of single unit indirect restorations from a commercial US dental lab were evaluated for their quality. The figure 259 was dependent on the number of impressions available. Impressions were evaluated for their quality before any manipulation by the lab technician. The sample included: single unit crowns, inlays, onlays, and veneers. Impressions of multiple units were excluded (Samet, Shohat, Livny & Elvin, 2005). The quality of the preparation it self-was not assessed. The evaluation procedure was conducted by a calibrated examiner. The subject impressions were given a number before the examination procedure for de-identification purposes (blind study). This was followed by a recording of the type of tray, arch, and required restoration.

2.3.2 Evaluation criteria

The evaluation procedure was conducted using a calibrated examiner (principle investigator). Each of impressions was graded using a modified NSU-CDM quality assurance evaluation form for conventional impressions and Rubric Grading system, a scoring method representing the performance anticipations for specific tasks (in this study, they are the impressions being evaluated). Each impression was evaluated first and then ranked. Information relating to errors and defects were registered and assessed using magnification loops. Each impression was evaluated for the following (Figures 21): defects related to prepared tooth and finish line (i.e. bubbles, voids, tears, clarity of finish line, and retraction cord left in impression) (Figures 22, 23, and 24). Defects in material setting,

distortion (Figure 25), defects in contralateral side affecting occlusion, and no retention to tray (Figure 26). Each of the impressions were then ranked using a 3-point Likert scale that relayed the various satisfaction levels of the impression.

These are:

1. Satisfactory.
2. Questionable.
3. Unsatisfactory.

- The impression was rated as **Satisfactory** when no errors existed (figure 27), or a single error existed in the category "Errors related to prepared tooth" or "General impression."
- The impression was rated as **Questionable** when there was a Single error in the Category "Clarity of finish line", or more than one error in the category "Errors related to prepared tooth" or "General impression."
- The impression was rated as **Unsatisfactory** when an error existed in the Category "Clarity of finish line" with an error in Category "Errors related to prepared tooth" or "General impression."

{Please refer to Conventional Impression evaluation form in APPENDIX A}

Category I: CLARITY OF FINISH LINE
Bubbles/Voids/ unclear margin
Tears
Retraction cord left in impression
Category II: ERRORS RELATED TO PREPARED TOOTH
Bubbles/Voids
Tears
Category III: GENERAL IMPRESSION NOT INCLUDING PREPARED TOOTH
No Retention to tray
Material distortion
Defect in contralateral side affecting occlusion

Figure 21: Errors in Conventional Impressions.

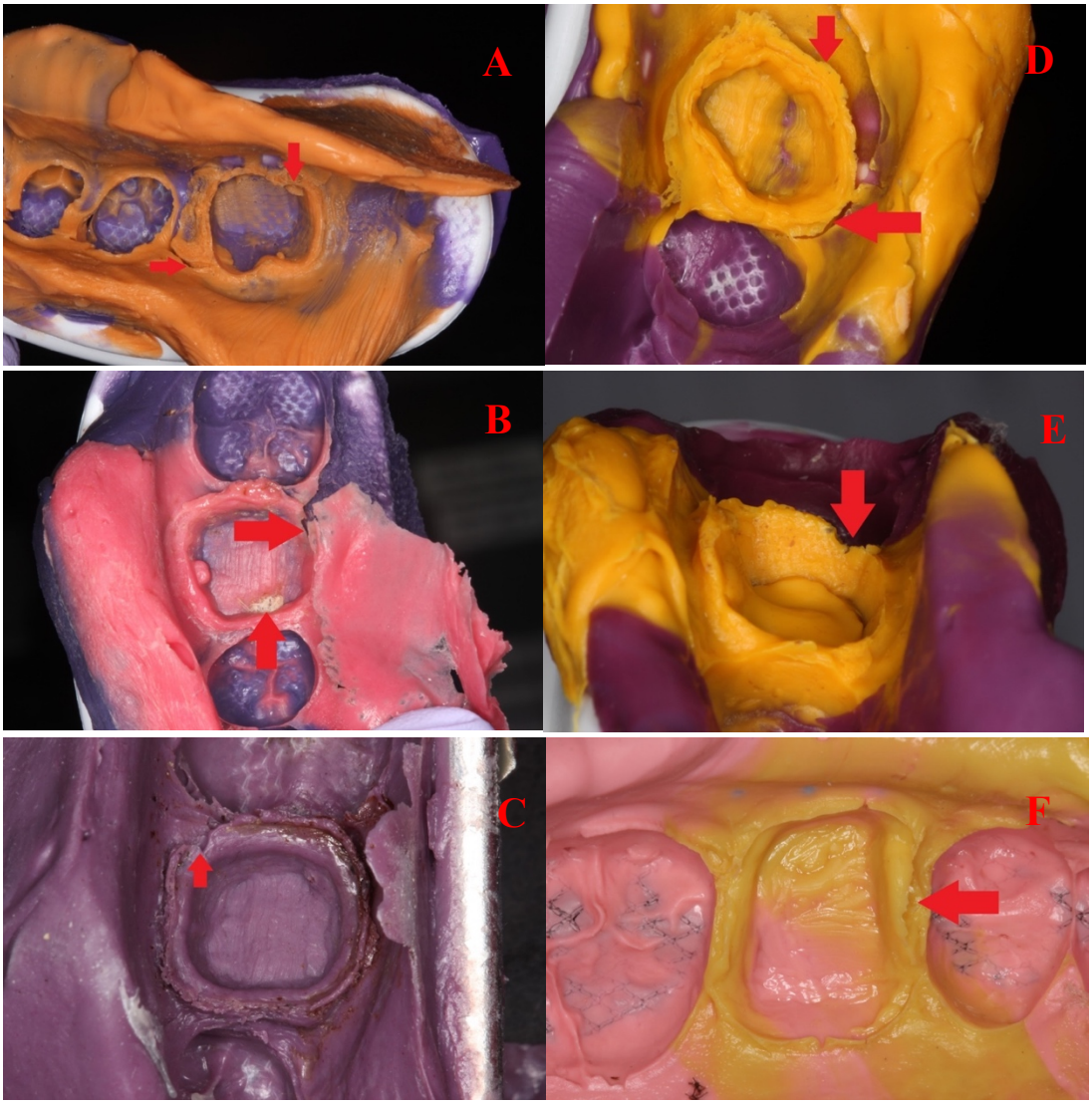

Figure 22: Errors in Conventional Impression: Voids, Bubbles, and Tears. A. Tears within finish line and prepared tooth, B. Tear within finish line and tray show through, C. Void in finish line, D. Void and tear in finish line, E. Void in finish line, F. Bubble in finish line.

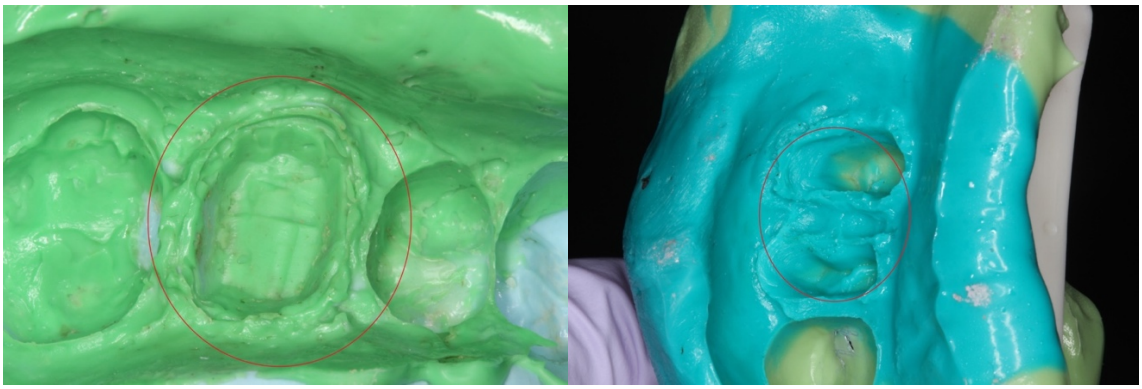

Figure 23: Errors in Conventional Impression: Unclear Margins.

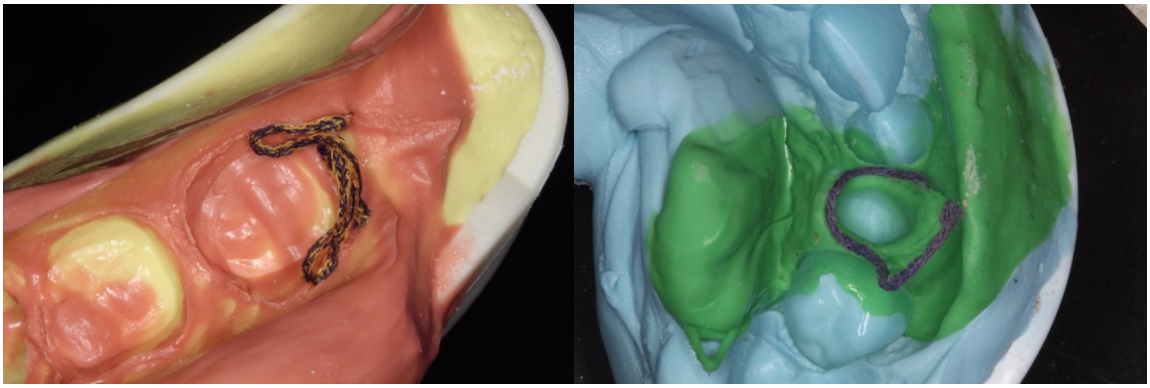

Figure 24: Errors in Conventional Impression: Retraction Cord Left in the Impression.

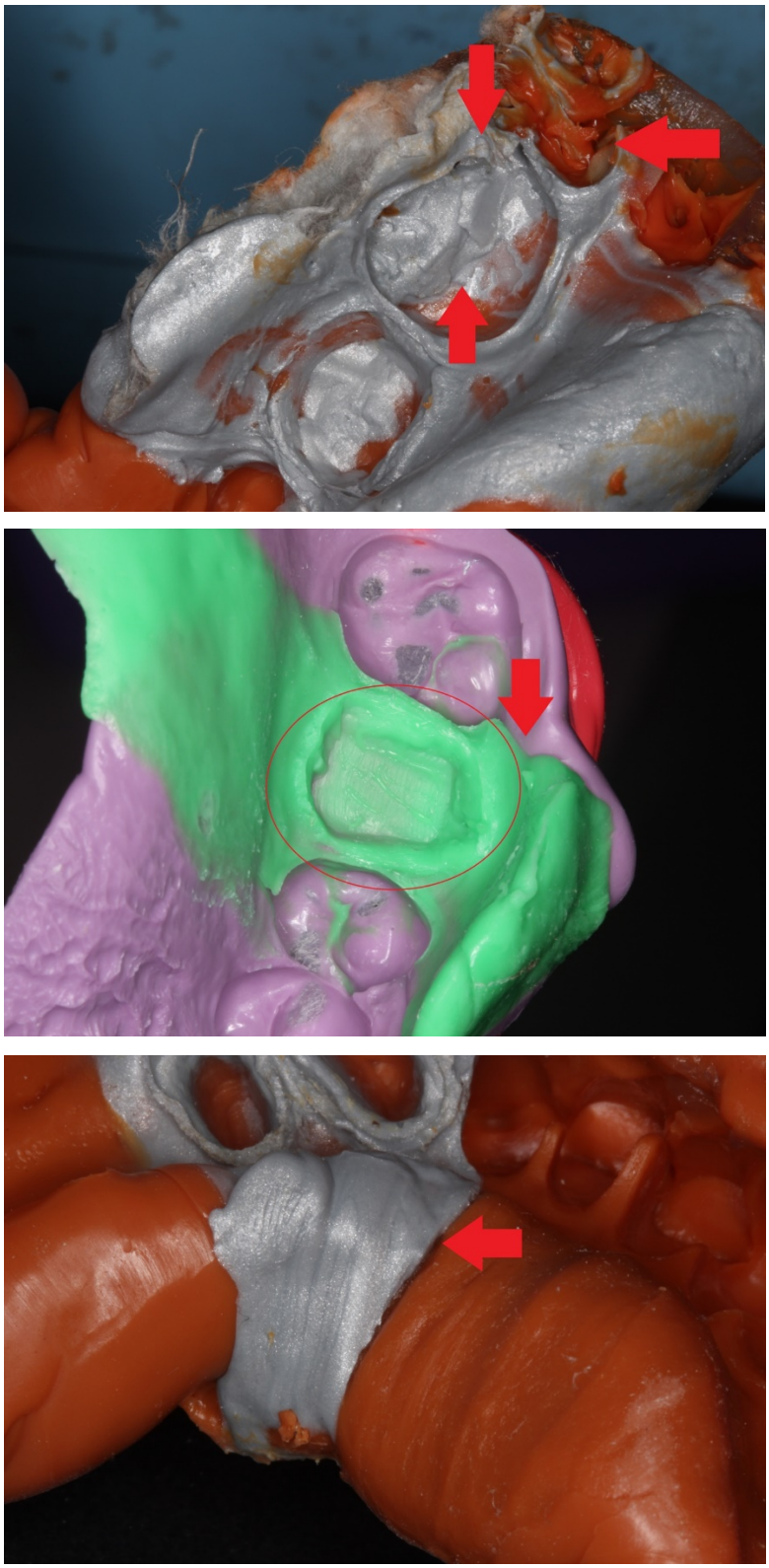

Figure 25: Errors in Conventional Impression: Distortion and Material Setting Problem.

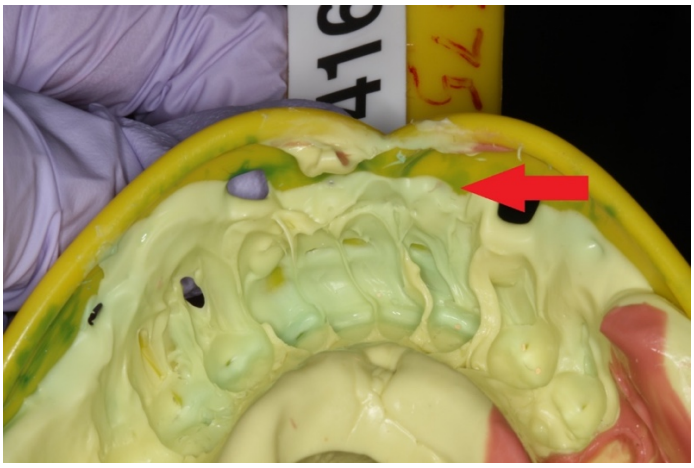

Figure 26: Errors in Conventional Impression: No retention to tray.

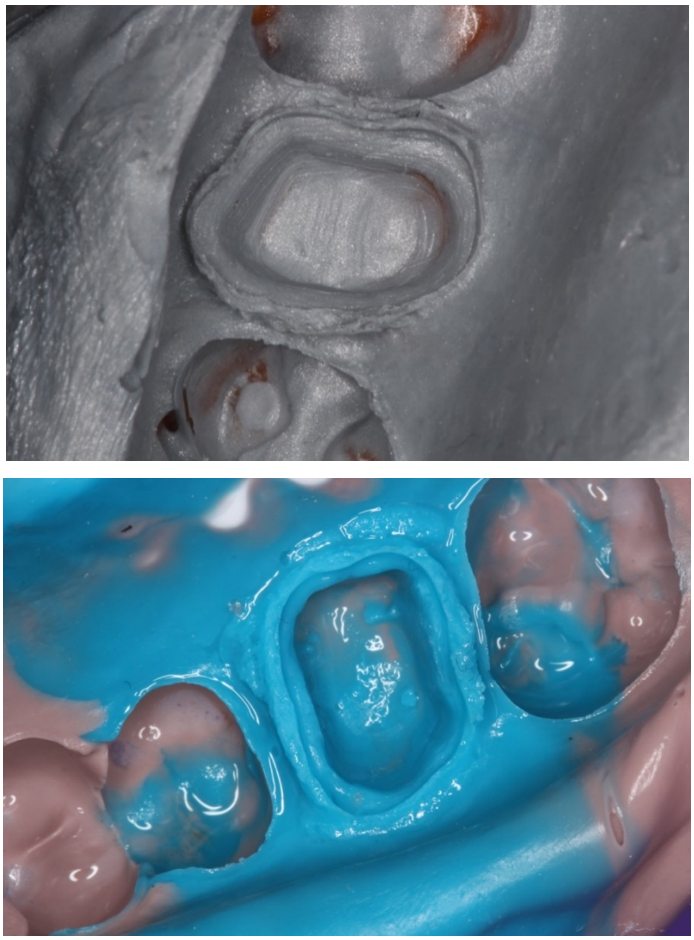

Figure 27: Ideal Conventional Impression.

Errors relating to material setting and distortion occur during the impression making (pressure points caused by flexure of tray, poor adaptation between different bodies of impression, arch details not fully captured as a result of material setting before impression making, wiped out impression caused by removal of impression before full setting occurs and material impression softness due to faulty mixing in impression tube). Distortion that happens after impression making, i.e., the shrinkage was not assessed in the study.

Frequencies of the assessed errors were also recorded and efffectively statistically analyzed using Chi Square Analysis. The data from the evaluation forms was then transferred to a Microsoft Excel sheet for statistical analysis by Dr. Patrick Hrdigan. Only clinically noticed defects were reported in this study (See APPENDIX D).

2.4 Digital impression evaluation process

2.4.1 Impression Criteria

In regards to digital impression, 74 digital impressions of single unit indirect restorations from a commercial US dental lab were evaluated for their quality using a similar evaluation form by a calibrated examiner (principle investigator) with the help of a dental lab technician who routinely receives the digital impressions and processes them for assessment. The subject impressions were given a number before the examination procedure for de-identification purposes (blind study).

The type of required restoration, type of digital system and arch were also recorded. The quality of the preparations and impressions of multiple units were not evaluated.

2.4.2 Evaluation Criteria

Each impression was evaluated for the following: inadequate scanned data, improper tooth preparation, unclear margins, improper powder application, lack of moisture control, improper occlusal registration, and the presence of an obstruction. Each impression was ranked using a 2-point Likert scale, relaying on the level of satisfaction of the impression: Satisfactory or Unsatisfactory.

The frequency of the assessed criteria/errors of both types of impressions were recorded and statistically analyzed using Chi Square Analysis. Each impression was evaluated for the following defects:

- *Inadequate scanned data* was defined as an incomplete scan where necessary parts of the impression were not fully scanned in instances where the impression had a cropped out appearance (Figure 28).

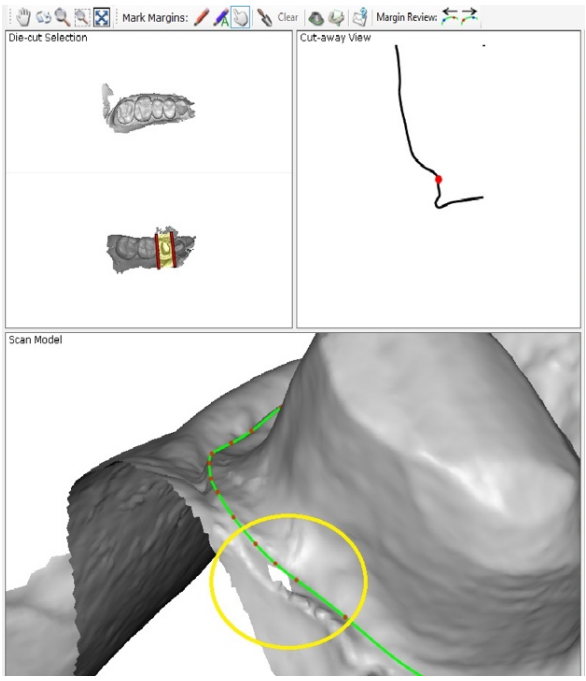

Figure 28: Errors in Digital impression: Missing Data.

- *Improper tooth preparation* in cases where margins were unclear and the system was unable to locate a well-defined finish line and margins (Figure 29).

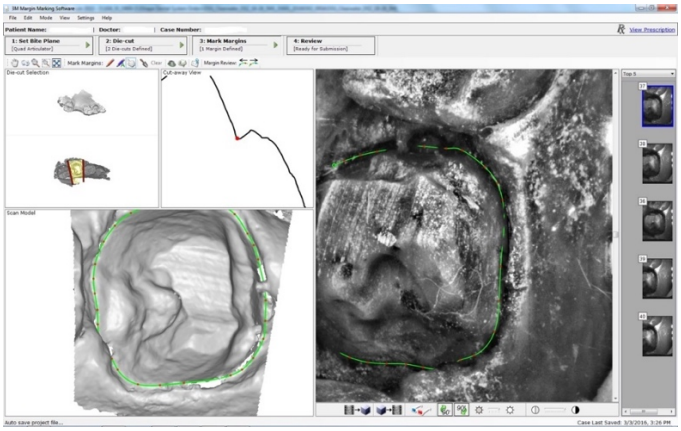

Figure 29: Errors in Digital Impression: Improper tooth preparation, Deep margins cannot be captured by scanner, and the presence of an obstruction.

- *Lack of moisture control and improper powder application* was described as when the excessive or minimal amount of powder was applied or when the saliva wiped out or clotted the applied powder decreasing the visibility and quality of the scan (Figure 30, and 31).

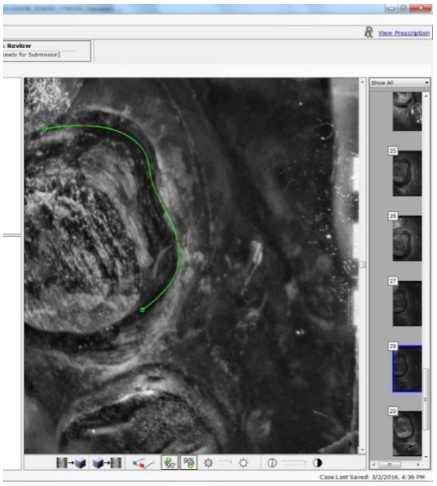

Figure 30: Errors in Digital Impression: Light powder that results in dark images.

Figure 31: Errors in Digital Impression: Too much powder, resulting in over exposed image.

- *The presence of an obstruction* was defined when shadows developed in the scan leading to lose of necessary information.
- *Improper occlusal registration* which occurs when occlusion is recorded in non centric occlusions (Figure 32).

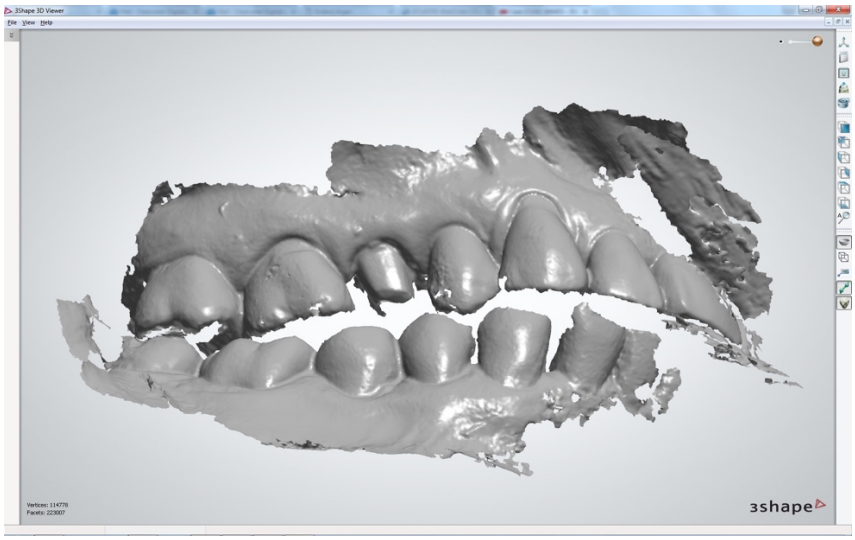

Figure 32: Errors in Digital Impression: Poor occlusal alignment.

Satisfactory impressions should have clear margins with no missing data nor obstructions, and even powder application, this will allow dental lab technician to locate and trace margins easily and start designing the restoration either to be milled or layered (Figure 33). Each of the impressions were then ranked using the 2-point Likert scale, relaying the different levels of satisfaction of the impression. This was also based on whether either the lab technician was able to proceed and mill the restoration/cast or the impression scan was not sufficient to produce the restoration/cast and hence the need for the dentist to remake the impression. These included:

1. Satisfactory. (Able to mill: none of the defects was present)
2. Unsatisfactory. (Not Able to mill: any of defects was present)

{Please refer to Digital impression evaluation form APPENDIX B}

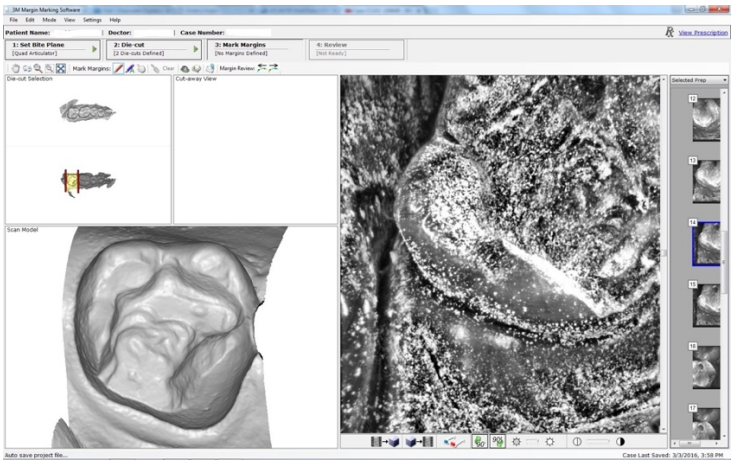

Figure 33: Ideal Digital Impression, all margins are clear, no missing data, and Ideal powder application

The frequency of the assessed criteria/deficiency was recorded and statistically analyzed using Chi Square Analysis. Data from the evaluation forms was transferred to a Microsoft Excel sheet for statistical analysis by Dr. Patrick Hardigan (See APPENDIX E).

2.5 Survey

2.5.1 Survey Target and Subject

A survey on the quality of digital impressions of single unit restorations sent to the lab was made in comparison to the conventional impressions that were also sent to the lab with the same criteria. The survey was carried out on dental lab technicians' working with both methods of impression making, 52 questionnaires were collected. The survey included questions comparing the frequency of errors, ease of procedure, frequency of remake, and the preferences of the dental technician between conventional and digital impressions {Please refer to survey questions and results attached in APPENDIX C and F respectively}.

CHAPTER THREE: RESULTS

3.1 Conventional impressions

3.1.1 Type of tray in relation to number of errors and impression quality

Table 1: Chi Square Analysis – Impression Tray

		Rank		
		Satisfactory	Questionable	Unsatisfactory
Impression	Full Tray	40 (83.3%)	3 (6.3%)	5 (10.4%)
	Partial Tray	7 (53.8%)	3 (23.1%)	3 (23.1%)
	Partial Triple Tray	102 (52.0%)	62 (31.6%)	32 (16.3%)

Using a Fisher's exact test we find a significant difference between the groups $c^2(4, n= 257)=17.36$, $p < 0.001$. We find the following:

- More full tray impression were rated satisfactory than all other groups
- More triple tray impression were rated questionable than all other groups

The Fisher's exact test analysis of the errors related to the use of specific types of trays found a significant difference between the groups $c^2(4, n= 257)=17.36$, $p < 0.001$. Full tray impressions were rated as 'satisfactory' at 83.3% as compared to other groups. Partial trays had a 53.8% satisfactory level, while partial triple trays were at 52%. More triple tray impression, on the other hand, were rated as 'questionable' (31.6%) when compared to the other groups. Only 6.3% of full trays and 23.1% of partial trays were rated 'questionable' respectively. This suggests that full trays are more accurate and reliable for use in impression making when compared to the other.

3.1.2 Arch position in relation to number of errors and impression quality

Table 2: Chi Square Analysis - Arch

		Rank		
		Satisfactory	Questionable	Unsatisfactory
Arch	Lower	66 (53.7%)	32 (26.0%)	25 (20.3%)
	Upper	84 (61.8%)	37 (27.2%)	15 (11.0%)

Using a chi-square test we find no significant difference between the groups $c^2(2, n= 259)=4.38, p < 0.112$.

Analyses on the type of errors related to arch position using the chi-square test found no significant difference between the groups $c^2(2, n= 259)=4.38, p < 0.112$. Impressions of the lower arch had a satisfactory level of 53.7% while those of the upper arch had a 61.8% satisfaction. Unsatisfactory lower arch impressions were at 20.3% while upper arch impressions were at 11%. This indicated that the quality of impressions was not affected by the arch whether lower or the upper.

3.1.3 Errors frequency

Table 3: Conventional Impressions Descriptive Statistics

Variable	Outcome
Type of Tray	Count (Percent)
Full tray	48 (18.5%)
Full triple tray	2 (0.8%)
Partial tray	13 (5.0%)
Partial triple tray	196 (75.7%)
Arch:	Count (Percent)
Lower	123 (47.5%)
Upper	136 (52.5%)
Type of Restoration	Count (Percent)
Crown	257 (99.2%)
Inlay/Onlay	2 (0.8%)
FINISH LINE: existence of bubbles, voids or unclear margin	Count (Percent)
No	165 (63.7%)
Yes	94 (36.3%)
FINISH LINE: existence of Tears	Count (Percent)
No	165 (63.7%)
Yes	94 (36.3%)
PREPARED TOOTH: existence of bubbles or voids	Count (Percent)
No	241 (93.1%)
Yes	18 (6.9%)
PREPARED TOOTH: existence of Tears	Count (Percent)
No	217 (83.8%)
Yes	42 (16.2%)
GENERAL IMPRESSION ERRORS: No Retention to tray	Count (Percent)
No	255 (98.5%)
Yes	4 (1.5%)
FINISH LINE: Retraction cord left in impression	Count (Percent)
No	250 (96.5%)
Yes	9 (3.5%)

Table 3. Conventional Descriptive Statistics (Continued)

Variable	Outcome
GENERAL IMPRESSION ERRORS: Material distortion	Count (Percent)
No	250 (96.5%)
Yes	9 (3.5%)
GENERAL IMPRESSION ERRORS: Defect in contralateral side affecting occlusion	Count (Percent)
No	48 (18.5%)
Not Applicable	210 (81.1%)
Yes	1 (0.4%)

3.1.4 Impressions quality

Table 3. Conventional Descriptive Statistics (Continued)

Impression Rank:	Count (Percent)
Satisfactory.	150 (57.9%)
Questionable.	69 (26.6%)
Unsatisfactory.	40 (15.4%)

An analysis on the frequency or errors found the following results: Partial triple trays were mostly used at 75.7% while full trays were 18.5%, partial trays 5%. Lower and upper arches had correlating error values at 47.5% one 52.5% with little statistical difference. Within the evaluated sample crowns group, represented the majority of it 99.2%, inlay/onlay presented 0.8% of the sample.

Analyses on the frequency of errors on finish lines were as follows; 36.3% percent of the finish lines had bubbles, and voids resulting in unclear margins, while 63.7% did not. Finish lines with tears were also 36.6% while impressions with retraction cords left in them were 3.5%. A total 6.9% of prepared teeth had tears and bubbles while 93.1% did not. Prepared teeth with tears were 16.2% while 83.3% did not have. These statistics indicate

that the amount of errors associated with unclear margins in Conventional impressions are considerably high.

General impression errors were as follows: There was minimal material distortion at 3.5%, on defects in the contralateral side that affects occlusion, a larger percentage of the sample (81.1%) was not applicable as the majority of the evaluated sample was partial trays, to 18.5% recording no errors and a minimal number of 0.4% had errors. The samples were ranked as 57.9% satisfactory, 26.6% questionable and 15.4% unsatisfactory. A general conclusion is that Conventional impressions have a considerable number of errors as classified by the calibrated examiner.

3.2 Digital Impression

3.2.1 Digital system brand in relation to number of errors and impression quality

Table 4: Chi Square Analysis - Digital System

		Rank	
		Satisfactory	Unsatisfactory
System	3-Shape	5 (83.3%)	1 (16.7%)
	3M	52 (53.8%)	13 (23.1%)
	Sirona	1 (52.0%)	2 (16.3%)

Using a Fisher's exact test we find no significant difference between the groups $c^2(2, n = 74)=2.98$, $p =0.168$.

Three significant digital scanning systems were in the evaluated sample; the 3Shape, Sirona, and 3M. An analysis of the digital system brand in relation to a number of errors and impression quality using the Fisher's exact test found no significant difference between the groups $c^2(2, n = 74)=2.98$, $p =0.168$. The 3-Shape Intraoral Scanner had a leading

satisfactory level of 83.3%, while 3-M had 53.8% and Sirona 52%. Few impressions were ranked unsatisfactory, 3M 23.1%, 3Shape 16.7% and Sirona at 16.3%. These data indicate that the operational quality of the different scanners is almost similar with considerably higher levels of satisfactory levels.

3.2.2 Arch position in relation to number of errors and impression quality

Table 5: Chi Square Analysis - Arch

		Rank	
		Satisfactory	Unsatisfactory
Arch	Lower	29 (80.6%)	7 (19.4%)
	Upper	29 (76.3%)	9 (23.7%)

Using a chi-square test we find no significant difference between the groups $c^2(1, n = 74)=0.19$, $p =0.658$.

Analyses were carried out on the number of errors and impression quality in relation to the position of the arch. Using the chi-square test, there was no statistical difference found among the two Arches groups $c^2(1, n = 74)=0.19$, $p =0.658$. Lower and upper arch Digital impressions had 80.6% and 76.3% satisfactory levels respectively. Unsatisfactory levels were at 19.4% and 23.7% for lower and upper arcs respectively.

3.2.3 Type of restoration in relation to number of errors and impression quality

Table 6: Chi Square Analysis – Type of Restoration

		Rank	
		Satisfactory	Unsatisfactory
Restoration	Crown	29 (80.6%)	7 (19.4%)
	Inlay/Onlay	29 (76.3%)	9 (23.7%)

Using a Fisher's exact test we find no significant difference between the groups $c^2(1, n = 74)=1.16$, $p =0.571$.

Regarding the errors and impression quality in relation to the type of restoration, no significant difference was found between crown and inlay/onlays restorations, $c^2(1, n = 74)=1.16$, $p =0.571$. Crown restoration had a satisfactory level of 80.6% while inlays/onlays had 76.3%. This indicates that neither restoration type has more error frequency than the other.

3.2.4 Errors frequency

Table 7: Digital Impressions Descriptive Statistics

Variable	Outcome
Digital System Brand:	Count (Percent)
3 shape	6 (8.1)
3M	65 (87.8)
sirona	3 (4.1)
Arch:	Count (Percent)
Lower	36 (48.7)
Upper	38 (51.4)
Type of Restoration	Count (Percent)

Crown	70 (94.6)
Inlay/Onlay	4 (5.4)
Type of material requested:	Count (Percent)
Emax	24 (32.4)
Metal	1 (1.4)
PFM	5 (6.8)
Zirconia	44 (59.5)
Inadequate scanned data (missing data):	Count (Percent)
No	60 (81.1)
Yes	14 (18.9)
Unclear margins (improper tooth preparation):	Count (Percent)
No	63 (85.1)
Yes	11 (14.9)
Improper powder application-heavy:	Count (Percent)
No	63 (85.1)
Yes	11 (14.9)
Improper powder application-light:	Count (Percent)
No	66 (89.2)
Yes	8 (10.8)
Improper moisture control:	Count (Percent)
No	71 (96.0)
Yes	3 (4.1)

Improper occlusal registration:	Count (Percent)
No	67 (90.5)
Yes	7 (9.5)
Presence of an obstruction:	Count (Percent)
No	70 (94.6)
Yes	4 (5.4)

The evaluated impression systems were 87.8% 3M, 8.1% 3Shape and 4.1%Sirona. Analyses on the frequency of errors had the following results; there was no statistical difference between the errors found in the lower and upper archs (48.7% and 51.4%). On the type of materials used, Zirconia was the most requested material 59.5%, followed by Emax 32.4% while metal and PFM had 1.4% and 6.8% respectively. Errors from missing data recorded an 18.9% value while 81.1% of the restorations did not have inadequate data. A clear observation here is that the number of errors in the Digital impressions were considerably lower. The same was observed for other errors associated with digital impressions.

On unclear margins (improper tooth preparation) 85.1% were clear while 14.9% were unclear. Errors on improper powder application-heavy recorded that 14.9% had heavy powder application, improper powder application-light 10.8% had light powder application, improper moisture control 4.1% had reduced visibility due to saliva and moisture existence, improper occlusal registration (90.5% accurate, 9.5% had errors) and for presence of an obstruction (94.6% were clear, 5.4% had obstructions). These indicate the general accuracy of final digital Impressions as illustrated by the values. However, most errors resulted from cases of inadequate scanned data 18.9%.

3.2.5 Impressions quality

Table 7: Digital Impressions Descriptive Statistics (continued)

Impression Rank:	Count (Percent)
Satisfactory.	58 (78.4)
Unsatisfactory.	16 (21.6)

Results on the general quality of the digital impressions were as follows; 78.4% of all the Digital impressions were ranked as satisfactory while 21.6% were unsatisfactory. This can be compared to that Conventional impression's samples that were ranked at 57.9% satisfactory, 26.6% questionable and 15.4% unsatisfactory. Digital impressions are seen to have a higher number of samples that were classified as satisfactory. An additional set of data was gathered from a survey conducted in the dental lab to gather the perceptions of the lab technicians working with the Conventional impressions and Digital impressions. This data is important as it provided an arbitrary swing to the data to indicate the impression method that is preferable for use.

3.3 Survey

Since we are mainly concerned about the opinion of technicians' who has experience in both methods, all subjects responding to question two "How do you describe your experience with digital impression for single unit restoration –with the answer - I work on digital impressions in conjunction with conventional", their answers to the following questions were connected:

- In comparison with conventional impression, number of errors noted on the single unit digital impressions are.

- In comparison with conventional impression, frequency of remakes with the single unit digital impressions.
- In comparison with conventional impression, overcoming and blocking errors in single unit digital impression.
- As a dental lab technician fabricating a single unit restoration, I would encourage dentists to.

Table 8. Survey Data Connections

In comparison with conventional impression, number of errors noted on the single unit digital impressions are:	Count (Percent)
Equal to conventional impressions	8 (21.0)
I'm not sure	2 (5.4)
Less than conventional impressions	24 (63.1)
More than conventional impressions	4 (10.5)
In comparison with conventional impression, frequency of remakes with the single unit digital impressions is:	**Count (Percent)**
Equal to conventional impressions	5 (13.1)
I'm not sure	4 (10.5)
Less than conventional impressions	27 (71.0)
More than conventional impressions	2 (5.4)
In comparison with conventional impression, overcoming and blocking errors in single unit digital impression is:	**Count (Percent)**
Easier than conventional impressions	22 (57.9)
I'm not sure	5 (13.1)
More difficult conventional impressions	1 (2.6)
Not Applicable	10 (26.4)
As a dental lab technician fabricating a single unit restoration, I would encourage dentists to	**Count (Percent)**
Adhere to conventional impression	0 (0.0)
Switch to digital impression	17 (44.7)
Case dependent	21 (55.3)
No preference	0 (0.0)

The views of the dental lab technicians working on both Conventional impressions and Digital impression were as following:

Using a chi-square goodness-of-fit test, we find a significant difference in responses for **question 4**. Subjects see fewer errors in digital vs. conventional impressions [$c^2(3, n = 38)=31.47, p < 0.001$]. A total of 63.1% of the technicians' noted decreased errors in Digital impression when compared to Conventional impressions, 21% stated that the number of errors were equal in both, 10.5% noted more errors in Digital impression while 5.4% were not sure.

Using a chi-square goodness-of-fit test, we find a significant difference in responses for **question 5**. Subjects see fewer frequency of remakes with the single unit digital impressions vs. conventional impressions [$c^2(3, n = 38)=43.47, p < 0.001$]. A total of 71% of the technicians noted less remakes in Digital impressions, 13.1% stated that the errors were equal in both, 10.5% were not sure and only 5.4% noted more remakes in Digital impression.

Using a chi-square goodness-of-fit test, we find a significant difference in responses for **question 6**. Subjects see overcoming and blocking errors in single unit digital impression is easier than conventional impressions [$c^2(3, n = 38)=26.21, p < 0.001$]. A total of 57.9% of the technicians thought it was easier to overcome and block errors in Digital impression, 26.4% of the technicians did not find the questions applicable, 13.1% were not sure and only 2.6% thought it was more difficult than in Conventional impressions.

Using a chi-square goodness-of-fit test, we find no significant difference in responses for **question 10**. The majority of dental lab technician fabricating a single unit restoration would encourage dentists to switch to digital impression or go by a case-by-case basis [$c^2(1,$

n = 38)=0.42, p = 0.516]. A total of 44.7% suggested a switch from Conventional impressions to Digital impression while 53.3% thought the choice to switch is case dependent, there were no technicians who proposed adherence to Conventional impressions, none of the technicians also had preferences.

Table 9: Descriptive Statistics – Survey Data

How many years of experience do you have as a Dental Lab Technician?	Count (Percent)
1-5 years	8 (15.4)
11-20 years	20 (38.5)
6-10 years	2 (3.9)
More than 20	22 (42.3)
How do you describe your experience with digital impression for single unit restoration?	**Count (Percent)**
Received the training but never practiced on my own	0 (0.0)
I work on digital impressions in conjunction with conventional	38 (73.08)
I work on digital impressions only	1 (1.92)
No experience	13 (25.00)
How do you describe your experience with conventional impression for single unit restoration?	**Count (Percent)**
Received the training but never practiced on my own	42 (80.77)
I work on conventional impressions in conjunction with digital	9 (17.31)
I work on digital impressions only	1 (1.92)
No experience	0 (0.0)
In comparison with conventional impression, number of errors noted on the single unit digital impressions is:	**Count (Percent)**
Equal to conventional impressions	10 (19.23)
I'm not sure	8 (15.38)
Less than conventional impressions	30 (57.69)
More than conventional impressions	4 (7.69)
In comparison with conventional impression, frequency of remakes with the single unit digital impressions is:	**Count (Percent)**
Equal to conventional impressions	7 (13.46)
I'm not sure	10 (19.23)
Less than conventional impressions	33 (63.46)
More than conventional impressions	2 (3.85)

Table 9. Descriptive Statistics – Survey Data (Continued)

In comparison with conventional impression, over coming and blocking errors in single unit digital impression is:	Count (Percent)
Easier than conventional impressions	23 (44.23)
I'm not sure	15 (28.85)
More difficult conventional impressions	1 (1.92)
Not Applicable	1 (1.92)
Same as conventional impressions	12 (23.08)
Regarding single unit digital impressions, types of errors noted are mostly related to:	**Count (Percent)**
Dentists impression- making skills	20 (38.46)
I'm not sure	12 (23.08)
Limitations of scanning machines	2 (3.85)
Local factors "Moisture control, tissue management, preparation, uneven powder …etc."	17 (32.69)
Other	1 (1.92)
Regarding single unit conventional impressions, types of errors noted are mostly related to	**Count (Percent)**
Dentists impression- making skills	39 (75.00)
Local factors "Moisture control, tissue management, …etc."	11 (21.15)
The preparation itself	2 (3.85)
Tray selection	0 (0.00)

Table 9. Descriptive Statistics – Survey Data (Continued)

Regarding single unit digital impressions, the most important advantage that could encourage us toward it, is	Count (Percent)
Easy communication	5 (9.62)
Less materials used	9 (17.31)
Less time needed	22 (42.31)
The quality of the impression	16 (30.77)
As a dental lab technician fabricating a single unit restoration, I would encourage dentists to	**Count (Percent)**
Adhere to conventional impression	0 (0.00)
Switch to digital impression	27 (51.92)
Case dependent	25 (48.08)
No preferences	0 (0.00)
As a dental lab technician fabricating a single unit restoration, regardless of any other factors, I feel more comfortable working on	**Count (Percent)**
Conventional impression	2 (3.85)
Digital impression	12 (23.08)
I like working with both	31 (59.62)
No preferences	7 (13.46)

In the Survey section, a total of 42.3% of the technicians had more than 20 years of working experience, 38.5% had 11-20 years of work experience, 15.4% had 1-5 years of experience and finally only 3.9% had 6-10 years of experience.

When questioned on their experience working with Digital impression, a total of 73.08% of the technicians stated that they work on Digital impressions in conjunction with Conventional impressions, 25% stated they had no experience, while 1.92% specialized only on Digital impression. There were no technicians who never practiced their training.

When questioned on their experience working with Conventional impressions, a total of 80.77% of the technicians stated they had received training on Conventional impressions

but never practiced on their own, 17.1% stated they work on Conventional impressions in conjunction with Digital impression while 1.92% stated they exclusively work on Digital impression, none of the technicians lacked the required experience.

From this data, it is observable that a larger population (80.77%) of the technicians working with Conventional impressions have never practiced the technique on their own in comparison to 0% of technicians trained on Digital impression who are able to work on their own. A smaller number of technicians trained on Conventional impressions (17.1%) stated they can also work with Digital impressions too in comparison to 73.08% of Digital impression technicians who stated they also work with Conventional impressions. This suggests that technicians trained on Digital impressions are more flexible and able to work on Conventional impressions too.

When questioned of the number of errors in Digital impressions in comparison to those on Conventional impressions, a total of 57.8% stated that the errors in Digital impressions are less, 19.23% stated that errors were equal, 15.38% were not sure while 7.69% stated that errors in Digital impressions were more. This points to the fact that a larger percentage of the technicians thought Digital impression had less errors when compared to Conventional impressions. 63.46% stated that the frequency of remakes in Conventional impressions is more than Digital impressions. 3.85% found the frequency of remakes in Digital impressions more.

Technicians were also asked to compare their ability to block and overcome error in Digital impressions in comparison to Conventional impressions. A total of 44.23% stated it was an easier process in Digital impression, 28.85% were not sure, 23.08% stated the processes

were similar for both Conventional impressions and Digital impression, while 1.92% found it more difficult and another 1.92% found it not applicable.

Regarding Digital impressions, the common errors noted by the technicians were as follows: 38.36% referred to the poor impression making skills of dentists as the major causes for errors while 32.69% cited local factors like moisture control, tissue management, preparation and uneven powder application as some of the major causes. A total of 23.08% were not sure as 3.85% thought the limiting factors in scanning machines were to blame as the remaining 1.92% had other reasons.

Regarding Conventional impressions, a total of 75% of the technicians cited the poor impression making skills of dentists as the major problem, 21.25% stated that local factors like tissue management and moisture control were some of the causes as the rest 3.85% mentioned that the preparation procedure itself was the problem. There were no technicians who mentioned that the selection of the tray used caused errors.

A larger percent of the technicians (75%) thought dentists working on Conventional impressions had poor skills as compared to only 38.36% who though the same for dentists working on Digital impressions.

The most significant advantage that was cited by the technicians that would encourage them to shift to using Digital impressions was the minimal amount of time spent working on them (42.31%), the quality of the impression (30.77%), minimal amount of material used (17.31%) and lastly, easy communication (9.62%).

A total of 51.92% of the technicians advised dentists to shift to Digital impression while 48.08% thought it was case dependent. None of the technicians wanted the dentists to adhere to Conventional impressions. Finally, a total of 59.62% of the technicians like

working with both, 23.08% thought Digital impressions were more comfortable, while 13.36% had no preferences, only 3.85% of the technicians thought Conventional impressions were comfortable.

From this survey analysis, it becomes evident that most technicians have a general preference to Digital impression as compared to Conventional impressions. Digital impressions are also seen to have better quality and reduced errors.

CHAPTER 4: DISCUSSION

4.1 Overview

Impression making is still one of the major challenges to dentists and lab technicians. Dentists are either lacking the skills or the time to insure a good quality impression, and dental lab technicians are struggling working with the quality of impressions that are being sent, the main victim in this process would be the patient receiving the restoration. This study consisted of an evaluation and analysis of 259 Final PVS impressions taken with disposable partial or full trays of single unit indirect restorations from a commercial US dental lab. These were evaluated for errors related to prepared tooth and finish line (i.e. bubbles, voids, tears, clarity of finish line, and retraction cord left in impression) also, defects in material setting and distortion. Each of these impressions were evaluated and ranked using a 3-point Likert scale, relaying on the level of satisfaction of the impression. These were: Satisfactory, Questionable, and Unsatisfactory.

With a similar evaluation, 74 digital impressions were evaluated on the following errors; inadequate scanned data, unclear margins, improper moisture control, improper powder application, improper occlusal registration, and presence of obstructions. Each of the impressions were then ranked using a 2-point Likert scale, relaying on the level of satisfaction of the impression, these are: Satisfactory or Unsatisfactory. In accordance to the results, the following assertions can be made.

4.1.1 Conventional Impressions

Regarding conventional impressions, the indications of an ideal impression are: a stable impression tray, a firm adhesion between impression and tray, a complete and uniform mix of impression material also uniform bonding between the two impression materials, no show throw or pressure points, and clear margins with no voids, bubbles, or tears. This could be insured by the use of effective retraction methods and moisture control, appropriate tray selection, the use of denture adhesive, bleeding impression material before use to avoid bubbles and to insure homogenous mix, avoiding the use of latex gloves as they could inhibit the material setting, avoiding bubbles when applying wash material intraorally by keeping the tip of the syringe dipped into the material, keep in mind the setting and working times, carefully inserting the tray with no too much pressure and avoiding lateral shifts, also careful removal of the tray, then the evaluation of the impression thoroughly insuring that preparation margins are clear and fully captured, lastly make sure you disinfect the impression before sending it to the laboratory (3M, 2015).

Trays

Full tray impressions are more 'satisfactory' in comparison to partial and partial triple trays while triple tray impression, have 'questionable' satisfactory levels. The amount of errors associated with unclear finish lines in Conventional impressions are generally also considerably high. These results are related to those found in similar studies carried out on fixed partial denture impressions by Samet et al., 2005 and Winstanley, Carrotte, & Green, 1997. It was noted that full trays are much more suitable and 'acceptable' for use in Conventional impressions.

Type of Arch

The type of arch impression whether the lower or the upper arches does not affect the quality of Conventional impressions.

Types of Errors in Conventional impressions and Solutions

Results from this study are in coherence to the findings of the research that was done by Storey, D., 2013, on the '*The quality of impressions for crowns and bridges*'. A significant number of errors was recorded as the authors suggested the need for dentists to re-evaluate their impressions before sending them to the lab. Some of the common errors in Conventional impressions include bubbles, unclear margins, tears, and voids and unclear finish lines which are all considerably high. Other errors like material distortion and defects in the contralateral side that affects occlusion are minimal but still evident.

To prevent the decline in impressions quality, dentists have the responsibility of re-making their impressions when critical errors are noted, this will ensure that precise impressions are sent to the lab instead and prevent guess work depending on the judgment of the technicians when making final restorations (Storey, 2013). Conclusive observations indicate a general high number of errors in Conventional impressions.

4.1.2 Digital Impressions

Digital scanning systems like the 3Shape, Sirona, and 3M have a high level of approval.

Type of Arch/Restoration Type

Just as in the case of Conventional impressions, Digital Impressions quality is not affected by the type of the arch impression, whether lower and upper. The same observation can be made on the errors related to the type of restoration, there are no significant differences between crown and inlay/outlays restorations in Digital Impressions.

Types of Errors in Digital Impressions and Solutions

The common types of errors in Digital Impressions include missing data, unclear margins, improper powder application-heavy and light, improper moisture control, improper occlusal registration and presence of an obstruction. These errors however have lower values when compared to Conventional impressions. Significant errors in Digital Impressions result from cases of missing data. The general quality of Digital Impressions is therefore higher than that of Conventional impressions.

In the literature only one similar study was done in this matter, carried out by Kim et al., 2015. They explored the errors arising from Digital Impressions in an in-office CAD/CAM CEREC AC system for dental restorations. In their study, similar errors on insufficient scanned data and improper powder application were observed. The Improper Powder Application was a recurrent error recorded at 21.1% of the total data (Kim et al. 2015). The use of powder (TiO_2) is important as teeth are only reflective partially. The precision of the Digital Impression is compromised when more or less of the powder is applied as

already observed in this study. This results in an improper and unclear dental reconstruction. To prevent this types of error, there is need for better skilled and experienced dentists and technicians. Powder-free scanners like the latest version of CEREC Omnicam and iTero have also been developed to deal with this type of problem.

Errors on Insufficient Scanned Data represented a total of 16.9% of the total results in the study by Kim et al., 2015. To prevent these error, dentists and technicians should acquire sufficient information regarding both the adjacent and abutment teeth. This well enable the acquisition of ideal, precise and complete reconstruction data.

A number of other errors in Digital impressions can be supplemented or modified using the repair menu in the CEREC system software for instance. In addition, new Digital impressions can be taken in instances when errors have been detected.

Survey Perspective

In her article, "*Some Things Never Change: Inadequate Impressions Still Labs' Biggest Client Headache"* (2015) in the Dental Magazine, LMT, Maribeth Marsico recounts the plight of laboratory respondents who still rank the impression- making skills of dentists as their most disturbing challenge. In accordance to the document, approximately a quarter of all the impressions taken to the laboratory are usually inadequate. Also (Christensen, 2007) stated in his article titled "Laboratories Want Better Impressions" if you look at impressions sent to standard labs in the US you will reach the conclusion that few impressions are considered adequate.

The views of dental lab technicians is very significant in the study as a measure of their expansive experience working on both Digital Impressions and Conventional impressions.

With regard to all of the errors associated with Conventional impressions, a larger percentage suggest the need for dentists to shift to Digital Impressions. Some of the reasons they have include the fact that Digital Impressions have lesser errors, are easier to manipulate and have less restoration remakes. The Digital Impressions is efficient because the system ensures dentists have accurate details and valid preparation. Casts made from Digital Impressions are very accurate and precise producing high quality restorations. Technicians find Digital Impressions, time and material effective as well more comfortable and easy to communicate with.

Despite the fact that Conventional impressions techniques are cost effective and have also enabled a successful communication of soft and hard tissue landmarks to laboratory technicians, their disadvantages against Digital Impressions are numerous (Derbabian & Chee, 2003). The probability of errors like bubbles, tears, drags, and distortion during impression making is additionally common. There is also the brittleness of stone models that necessitate repairs which jeopardizes accuracy (Samet, Shohat, Livny, & Weiss, 2005). Conventional impressions are also time-consuming and cumbersome, it is often uncomfortable to patients and messy with the need for repetitive mixing, pouring of impressions, basing, trimming and dying as well as well as clean-ups. In Conventional impressions, the capture of finer details can only be made after the plaster model stage making it difficult to make early quality analyses (Donovan & Chee, 1989). This is in comparison with Digital impression which does not require the use of physical casts but instead operates on virtual models acquired through the use of digital records of the intraoral conditioning using 3D acquisition devices. However, although Digital impressions are regarded as superior, they also have errors and they are still unable to

capture subgingival margins. Their only distinguishing factor is that they have few errors (Donovan & Chee, 1989).

4.2 Limitations of the study

The major limitation of this study was the limited number of labs, which might affect a true representation of the truth about all dentists. Final restorations and their survival were also not evaluated, this preventing the opportunity to understand effects to the impression quality. Another limitation is the fact that the distortion that happens after impression making, i.e., the shrinkage and the quality of the preparation itself were also not assessed in the study. The impressions of fixed partial prosthesis and multiple single units were also excluded from this study.

4.3 Future research

Some of the key recommendation for future research is the need for a keen understanding of the transfer process of accurate patient's hard and soft tissue to the dental laboratory. Evaluations should be performed on the quality of impressions sent to the lab that are of satisfactory qualities. Such a consideration will allow for the establishment of the best impression method that will enable dentists to provide good quality impressions to the dental lab. Identification of the most common types of errors on impressions should also be made. This is very significant and hence the need for a much more critical evaluation of Conventional impressions and Digital impressions to ensure accuracy and efficiency in its empirical content. This will help dentists to tackle the many challenges they face in terms of quality assurance. More attention should finally also be given to innovative planning on

manufacturing investment to make much faster, easier, accurate and cost effective systems. Dental clinics should also aim at moving to the in-office milling that is that is efficient and profitable.

CHAPTER 5: CONCLUSIONS

5.1 Conclusions and Summary

In this paper, some of the significant problems faced by lab technicians when working on final impressions have been highlighted. These include: errors like bubbles, voids, tears, clarity of finish line, and retraction cord left in impression together with defects in material setting and distortion in Conventional impressions. Errors in Digital impressions include missing data, unclear margins, improper powder application-heavy and light, improper moisture control, improper occlusal registration and presence of an obstruction. These are all problems frequently noted by dental laboratory technicians. However, apart from these observations, there are other areas in fixed prosthodontics that still require attention. To promote an increased level of precision and accuracy, a general improvement in the quality of the procedures used in creating fixed prostheses is needed. The statement of dental lab technicians suggesting the need for improving the clinical procedure of impression making are important because they are responsible for observing the quality of impressions, interoccausal records and tooth preparations that are sent to them by dentists whom they work with. Dentists have the professional responsibility of upgrading their clinical techniques to enable them to produce impressions of high quality that can be effectively used for the transfer intraoral and interocclusal information to lab technicians as well as for adequate tooth preparations.

A large percentage of the indirect restorations currently being made in the country are from Conventional impressions with materials like PVS and polyethers. Lab technicians are

relied upon to make the final restorations (Christensen & Child, 2011). The rapid shift to Digital impression or in-office milling cannot be predicted yet, there are however a number of dentists who have already made this shift and are sending their impressions to special laboratories for milling. This represents the group of dentists who are satisfied with the results of Digital impressions and are willing to make the necessary shift. It has been anticipated that the concept of Digital impression will gradually develop to the level of market dominance. Currently most practitioners choose to use either Conventional or Digital Impressions depending on their preferences. With regard to the number of errors observed in Conventional impressions when compared to Digital ones together with the fact that a larger percentage of lab technicians prefers Digital Impression, it seems that Digital Impression has a positive future. Its use will ensure more accurate, precise and time efficient impression making.

5.2 Clinical Significance

There is a direct relation between impressions accuracy and produced restoration quality, which makes it impossible to acquire high-quality restorations out of a poor impression. It will additionally aid in the reduction of substandard impressions. Most dentists, technicians' and patients are usually frustrated by the results of substandard impressions together with the fact that the processes waste a lot of time, effort, and recourses. For the fabrication of a high quality and accurate indirect restorations, copy "impression" of the dental preparation and the neighboring soft and hard tissue structure should be taken, and the resultant copy should carry all the fine details without any distortion.

This study is unique because it has compared the level of human error in both the Conventional and Digital impression systems while attempting to identify the technique that is most suitable for the production of a better quality impression. There are limited studies that have explored this particular element yet as focus has instead been placed on the comparison of the accuracy of Conventional impression and Digital impression. In such studies, the material errors of Conventional impression and the technological errors of Digital impression systems are instead compared.

The process of recording a high-quality impression and the production of high-quality restoration depends on multiple factors. These factors include, cautious and suitable manipulation of the soft tissue, assurance of clear finish lines of the prepared tooth that are continuant and detectible as well as a confirmation that the surfaces of the prepared tooth are within set standards and carry no undercuts. The most important factor is that dentists should provide a thorough impression evaluation of before sending it to the laboratory. This can only be achieved when dentists are able to detect errors and judge the quality of the resultant impression, with prior knowledge of when remakes are needed.

The literature lacks studies that evaluate the quality of final impressions of indirect restorations in general and particularly in the USA, this study will, therefore, help dentists to pay more attention to the most common errors that exist in final impressions and be able to judge the quality of the impression accordingly, consequently resulting in the high quality final impression that is sent to the lab ensuring high quality of final restoration. Finally, this study will provide a clear comparison between the quality of Conventional impressions and Digital impressions of single restorations sent to the lab based on the dental lab technicians' perspective. The results of the survey may additionally help in

changing the perspectives of dentists when choosing the method of making their final impression.

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APPENDICES

APPENDIX A: CONVENTIONAL IMPRESSIONS EVALUATION FORM

Impression #

Lab name:

Type of tray: [__] full [__] partial [__] triple tray p [__] triple tray f

Arch: [__] Upper [__] Lower

Type of restoration: [__] Crown [__] Inlay/Onlay [__] Veneer

	YES	NO	Not Applicable
Category I: CLARITY OF FINISH LINE			
Bubbles/Voids/ unclear margin			
Tears			
Retraction cord left in impression			
Category II: ERRORS RELATED TO PREPARED TOOTH			
Bubbles/Voids			
Tears			
Category III: GENERAL IMPRESSION NOT INCLUDING PREPARED TOOTH			
No Retention to tray			
Material distortion			
Defect in contralateral side affecting occlusion			

Impression Rank:

○ Satisfactory. (No errors exists, single error in II or III)

○ Questionable. (Single error exists in Category I, or more than one error in II and/or III)

○ Unsatisfactory. (An error exists in Category I with an error in Category II and/or III)

APPENDIX B: DIGITAL IMPRESSIONS EVALUATION FORM

Impression #

Lab name: _____

Digital System Brand: _____

Arch: [__] Upper [__] Lower

Type of restoration: [__] Crown [__] Inlay/Onlay [__] Veneer

Type of material requested: [__] zirconia [__] PFM [__] Emax [__] metal

IMPRESSION ERROR	YES	NO	Not Applicable
Inadequate scanned data(missing data)			
Unclear margins (imp tooth prep)			
Improper powder application-heavy			
Improper powder application-light			
Improper moisture control			
Improper occlusal registration			
Presence of an obstruction			

Impression Rank:

○ Satisfactory. (No critical deficiencies in impression, restoration/cast will be milled)

○ Unsatisfactory. (Deficiencies in impression exist, milling is not possible)

Criteria Description:

INADEQUATE SCANNED DATA: incomplete scan where necessary parts of the impression are not fully scanned where the impression has a cropped out appearance.

IMPROPER TOOTH PREPARATION: margins are unclear and the system is unable locate a well-defined finish line and margins.

IMPROPER POWDER APPLICATION OR MOISTURE CONTROL (if applicable): excessive amount of powder was applied causing brightness of the image, minimal amount of powder was applied causing darkness in the image, or when the saliva wipes out or clots the applied powder which decreases the visibility and quality of the scan.

IMPROPER OCCLUSAL REGISTRATION: occlusion is recorded with incomplete or deviated occlusion.

PRESENCE OF AN OBSTRUCTION: the presence of and an object or artifact obscuring critical areas in the scan.

APPENDIX C: SURVEY QUESTIONS

1. How many years of experience do you have as a Dental Lab Technician?

A. 1-5 years
B. 6-10 years
C. 11-20 years
D. More than 20

2. How do you describe your <u>experience with digital impression</u> for single unit restoration?

A. No experience
B. Received the training but never practiced on my own
C. I work on digital impressions in conjunction with conventional
D. I work on digital impressions only

3. How do you describe your <u>experience with conventional impression</u> for single unit restoration?

A. No experience
B. Received the training but never practiced on my own
C. I work on conventional impressions in conjunction with digital
D. I work on conventional impressions only

4. In comparison with conventional impression, <u>number of errors</u> noted on the single unit digital impressions is:

A. Less than conventional impressions
B. Equal to conventional impressions
C. More than conventional impressions
D. I'm not sure

5. In comparison with conventional impression, <u>frequency of remakes</u> with the single unit digital impressions is:

A. Less than conventional impressions
B. Equal to conventional impressions
C. More than conventional impressions
D. I'm not sure

6. In comparison with conventional impression, over coming and blocking errors in single unit digital impression is:

A. Easier than conventional impressions
B. Same as conventional impressions
C. More difficult than conventional impressions
D. I'm not sure

7. Regarding single unit digital impressions, types of errors noted are mostly related to:

A. Limitations of scanning machines
B. Dentist's lack of experience "poor scan"
C. Local factors "Moisture control, tissue management, preparation, uneven powder …etc."
D. I'm not sure

8. Regarding single unit conventional impressions, types of errors noted are mostly related to:

A. Dentists impression-making skills
B. The preparation itself
C. Local factors "Moisture control, tissue management, …etc."
D. Tray selection

9. Regarding single unit digital impressions, the most important advantage that could encourage us toward it, is:

A. Less materials used
B. Less time needed
C. Easy communication
D. The quality of impression

10. As a dental lab technician fabricating a single unit restoration, I would encourage dentists to:

A. Adhere to conventional impression
B. Switch to digital impression
C. Case dependent
D. No preferences

11. As a dental lab technician fabricating a single unit restoration, regardless of any other factors, I feel more comfortable working on:

A. Conventional impression
B. Digital impression
C. I like working with both
D. No preferences

APPENDIX D: RAW DATA OF CONVENTIONAL IMPRESSION EVALUATIONS

Type of tray:	Arch:	Type of restoration:	FINISH LINE: existence of bubbles, voids or unclear margin	FINISH LINE: existence of Tears	PREPARED TOOTH: existence of bubbles or voids	PREPARED TOOTH: existence of Tears	GENERAL IMPRESSION ERRORS: No Retention to tray	FINISH LINE: Retraction cord left in impression	GENERAL IMPRESSION ERRORS: Material distortion	GENERAL IMPRESSION ERRORS: Defect in contralateral side affecting occlusion	Impression Rank:
Partial triple tray	Lower	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	Yes	Yes	No	No	Yes	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Full tray	Upper	Crown	Yes	No	Yes	No	No	No	No	Yes	Unsatisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial tray	Upper	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	Yes	No	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	Yes	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	Yes	No	No	No	No	Yes	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	Yes	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	Yes	Yes	No	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	Yes	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.

Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	Yes	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	Yes	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	Yes	No	Yes	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial tray	Upper	Crown	No	Yes	No	Yes	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	Yes	No	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Lower	Crown	No	Yes	No	No	No	No	No	No	Questionable.
Full tray	Upper	Crown	No	No	Yes	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial triple tray	Lower	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Full tray	Lower	Crown	Yes	No	Yes	No	No	No	No	No	Unsatisfactory.
Full tray	Lower	Crown	Yes	No	Yes	No	No	No	No	No	Unsatisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.

Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial triple tray	Lower	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	Yes	No	No	No	Yes	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	Yes	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	No	Yes	No	No	No	Yes	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	Yes	No	No	No	Yes	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	Yes	Yes	No	Yes	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	Yes	Yes	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	Yes	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	Yes	No	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	Yes	Yes	No	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Full triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Full triple tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial tray	Lower	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	Yes	No	Not Applicable	Questionable.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial tray	Upper	Crown	Yes	No	No	No	No	No	Yes	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	Yes	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.

Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	Yes	Yes	No	No	No	No	Not Applicable	Unsatisfactory .
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Upper	Crown	No	No	Yes	No	No	No	No	No	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory .
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory .
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	Yes	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	Yes	No	No	No	No	No	Not Applicable	Unsatisfactory .
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	Yes	Yes	No	No	No	No	Not Applicable	Unsatisfactory .
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.

Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	Yes	No	No	No	Yes	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	Yes	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	Yes	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	Yes	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	Yes	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Inlay/Onlay	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Inlay/Onlay	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	Yes	No	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.

Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	Yes	No	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	Yes	Yes	No	No	No	Yes	No	Not Applicable	Unsatisfactory.
Partial triple tray	Lower	Crown	No	No	Yes	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Lower	Crown	Yes	No	No	No	No	No	No	No	Questionable.
Full tray	Lower	Crown	Yes	No	No	No	No	No	No	No	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	No	No	Yes	No	No	No	No	No	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	Yes	Yes	No	No	Yes	No	Yes	No	Unsatisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Lower	Crown	No	No	Yes	No	No	No	No	No	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.

Partial tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Full tray	Upper	Crown	No	No	No	No	No	No	No	No	Satisfactory.
Full tray	Upper	Crown	Yes	No	Yes	No	No	No	No	No	Unsatisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.
Partial tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	Yes	No	Not Applicable	Questionable.
Partial triple tray	Lower	Crown	No	No	No	No	No	Yes	No	Not Applicable	Questionable.
Partial tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	Yes	No	Yes	No	No	No	No	Not Applicable	Unsatisfactory.
Partial triple tray	Upper	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Lower	Crown	No	No	No	No	No	No	No	Not Applicable	Satisfactory.
Partial triple tray	Upper	Crown	Yes	No	No	No	No	No	No	Not Applicable	Questionable.

APPENDIX E: RAW DATA OF DIGITAL IMPRESSION EVALUATIONS

Digital System Brand:	Arch:	Type of restoration:	Type of material requested:	Inadequate scanned data(missing data):	Unclear margins (improper tooth preparation):	Improper powder application-heavy:	Improper powder application-light:	Improper moisture control:	Improper bite registration:	Presence of an obstruction:	Impression Rank:
sirona	Lower	Crown	Zirconia	No	No	No	No	Yes	No	No	Unsatisfactory.
3M	Lower	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Zirconia	No	No	No	No	No	Yes	No	Unsatisfactory.
3M	Upper	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Zirconia	Yes	Yes	Yes	No	No	Yes	No	Unsatisfactory.
3M	Upper	Crown	Zirconia	No	No	No	No	No	Yes	No	Unsatisfactory.
3M	Upper	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	PFM	Yes	No	No	No	Yes	No	No	Satisfactory.
3M	Lower	Inlay/Onlay	Metal	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	Yes	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	Yes	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	Yes	No	Yes	No	No	No	No	Unsatisfactory.
3M	Upper	Crown	Emax	No	No	Yes	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	Yes	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	Yes	No	No	No	No	Satisfactory.
3 shape	Upper	Crown	Zirconia	No	Yes	Yes	No	No	Yes	No	Unsatisfactory.
3 shape	Lower	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3 shape	Lower	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3 shape	Upper	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3 shape	Upper	Crown	Zirconia	No	No	No	No	No	Yes	No	Satisfactory.
3 shape	Upper	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	No	Yes	No	No	No	Satisfactory.
3M	Upper	Crown	PFM	No	No	No	No	No	No	Yes	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	No	No	No	Yes	No	Satisfactory.
3M	Lower	Crown	PFM	Yes	No	No	Yes	No	No	No	Unsatisfactory.
3M	Lower	Crown	PFM	No	No	No	Yes	No	No	No	Satisfactory.
3M	Upper	Crown	Zirconia	No	Yes	No	No	No	No	No	Unsatisfactory.
3M	Lower	Crown	Zirconia	Yes	No	Yes	No	No	No	No	Unsatisfactory.
3M	Lower	Crown	Zirconia	Yes	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	No	No	No	No	Yes	Satisfactory.
3M	Upper	Crown	Zirconia	No	No	No	No	Yes	No	Yes	Unsatisfactory.

3M	Lower	Crown	Zirconia	No	No	No	Yes	No	No	No	Satisfactory.
3M	Upper	Crown	Zirconia	No	No	No	Yes	No	No	No	Satisfactory.
3M	Upper	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	Yes	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	No	Yes	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	Yes	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	No	No	No	Yes	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
sirona	Upper	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
sirona	Upper	Crown	Zirconia	No	Yes	No	No	No	No	No	Unsatisfactory.
3M	Upper	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Inlay/Onlay	Zirconia	Yes	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	Yes	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	Yes	No	No	No	No	No	No	Unsatisfactory.
3M	Upper	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	Yes	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	Yes	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Inlay/Onlay	Emax	Yes	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	Yes	Yes	No	Yes	No	No	No	Unsatisfactory.
3M	Lower	Crown	Zirconia	No	Yes	No	No	No	No	No	Unsatisfactory.
3M	Lower	Crown	PFM	No	Yes	No	Yes	No	No	No	Satisfactory.
3M	Lower	Inlay/Onlay	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	Yes	No	No	No	No	No	No	Unsatisfactory.
3M	Upper	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	No	Yes	No	No	No	No	No	Satisfactory.
3M	Upper	Crown	Emax	No	No	No	No	No	No	No	Satisfactory.
3M	Lower	Crown	Zirconia	Yes	Yes	No	No	No	No	Yes	Unsatisfactory.
3M	Upper	Crown	Zirconia	No	Yes	No	No	No	No	No	Satisfactory.

APPENDIX F: RAW DATA OF SURVEY

1. How many years of experience do you have as a Dental Lab Technician?	2. How do you describe your experience with digital impression for single unit restoration?	3. How do you describe your experience with conventional impression for single unit restoration?	4. In comparison with conventional impression, number of errors noted on the single unit digital impressions is:	5. In comparison with conventional impression, frequency of remakes with the single unit digital impressions is:	6. In comparison with conventional impression, over coming and blocking errors in single unit digital impression is:	7. Regarding single unit digital impressions, types of errors noted are mostly related to:	8. Regarding single unit conventional impressions, types of errors noted are mostly related to:	9. Regarding single unit digital impressions, the most important advantage that could encourage us toward it, is:	10. As a dental lab technician fabricating a single unit restoration, I would encourage dentists to:	11. As a dental lab technician fabricating a single unit restoration, regardless of any other factors, I feel more comfortable working on:
1-5 years	No experience	I work on conventional impressions only	I'm not sure	I'm not sure	Not Applicable	Other,,,	Dentists impression-taking skills	Less materials used	Switch to digital impression	Digital impression
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Dentist's lack of experience "poor scan"	Dentists impression-taking skills	The quality of the impression	Switch to digital impression	I like working with Both
More than 20	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	I'm not sure	Local factors "Moisture control, tissue management, …etc."	Less time needed	Switch to digital impression	I like working with Both
More than 20	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Limitations of scanning machines Local factors "Moisture control, tissue management, preparation, uneven powder …etc."	Dentists impression-taking skills	Less time needed	Switch to digital impression	I like working with Both
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	More than conventional impressions	More than conventional impressions	Same as conventional impressions		Local factors "Moisture control, tissue management, …etc."	Easy communication	Case dependent	I like working with Both
More than 20	No experience	I work on conventional impressions only	I'm not sure	I'm not sure	I'm not sure	I'm not sure	Dentists impression-taking skills	Less materials used	Switch to digital impression	No preferences
6-10 years	No experience	Received the training but never practiced on my own	I'm not sure	I'm not sure	I'm not sure	I'm not sure	Dentists impression-taking skills	The quality of the impression	Case dependent	No preferences
More than 20	No experience	I work on conventional impressions only	I'm not sure	I'm not sure	I'm not sure	I'm not sure	Local factors "Moisture control, tissue	The quality of the impression	Case dependent	No preferences

							management, …etc.”			
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Same as conventional impressions	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Local factors “Moisture control, tissue management, …etc.”	Easy communication	Switch to digital impression	Digital impression
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Dentist’s lack of experience “poor scan”	Dentists impression-taking skills	Less time needed	Switch to digital impression	Conventional impression
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	More than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Dentists impression-taking skills	Less time needed	Switch to digital impression	Digital impression
11-20 years	I work on digital impressions only	I work on conventional impressions only	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Dentists impression-taking skills	Less time needed	Switch to digital impression	Digital impression
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	I’m not sure	Same as conventional impressions	Dentist’s lack of experience “poor scan”	The preparation itself	Less materials used	Case dependent	I like working with Both
1-5 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions only	Equal to conventional impressions	Less than conventional impressions	Same as conventional impressions	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Dentists impression-taking skills	Less time needed	Switch to digital impression	I like working with Both
More than 20	No experience	I work on conventional impressions only	I’m not sure	I’m not sure	I'm not sure	I'm not sure	Dentists impression-taking skills	Less time needed	Case dependent	No preferences
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	More difficult than conventional impressions	Dentist’s lack of experience “poor scan”	Local factors “Moisture control, tissue management, …etc.”	Less time needed	Switch to digital impression	Digital impression
More than 20	I work on digital impressions in	I work on conventional impressions	Equal to conventional	Equal to conventional	Same as conventional	Dentist’s lack of experien	Dentists impression-taking skills	The quality of the impression	Case dependent	I like working with Both

	conjunction with conventional	in conjunction with digital	impressions	impressions	impressions	ce “poor scan”				
6-10 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	I'm not sure	Dentist’s lack of experience “poor scan”	Dentists impression-taking skills	Less time needed	Case dependent	I like working with Both
More than 20		I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	I'm not sure	Dentist’s lack of experience “poor scan”	Dentists impression-taking skills	The quality of the impression	Switch to digital impression	Digital impression
1-5 years		I work on conventional impressions in conjunction with digital	Equal to conventional impressions	Less than conventional impressions	Easier than conventional impressions	I'm not sure	Dentists impression-taking skills	Less materials used	Case dependent	I like working with Both
1-5 years	No experience	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Equal to conventional impressions	Easier than conventional impressions	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Dentists impression-taking skills	Less materials used	Case dependent	I like working with Both
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Dentists impression-taking skills	Less time needed	Switch to digital impression	Digital impression
More than 20	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Local factors “Moisture control, tissue management, …etc.”	Less time needed	Switch to digital impression	I like working with Both
More than 20	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	I’m not sure	I’m not sure	I'm not sure	I'm not sure	Dentists impression-taking skills	Less time needed	Case dependent	I like working with Both
More than 20	No experience	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Same as conventional impressions	Dentist’s lack of experience “poor scan”	Dentists impression-taking skills	The quality of the impression	Case dependent	I like working with Both
11-20 years	I work on digital impressions in conjunction with	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Dentist’s lack of experience “poor scan”	Dentists impression-taking skills	The quality of the impression	Switch to digital impression	I like working with Both

	conventional									
More than 20	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	I'm not sure	Local factors "Moisture control, tissue management, preparation, uneven powder …etc."	Dentists impression-taking skills	The quality of the impression	Case dependent	I like working with Both
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	I'm not sure	I'm not sure	I'm not sure	Dentist's lack of experience "poor scan"	Dentists impression-taking skills	Less materials used	Case dependent	I like working with Both
More than 20	No experience	I work on conventional impressions only	Equal to conventional impressions	Equal to conventional impressions	I'm not sure	I'm not sure	Dentists impression-taking skills	Less time needed	Case dependent	No preferences
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Equal to conventional impressions	Equal to conventional impressions	Easier than conventional impressions	Dentist's lack of experience "poor scan"	Local factors "Moisture control, tissue management, …etc."	The quality of the impression	Case dependent	I like working with Both
More than 20	No experience	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	I'm not sure	Dentist's lack of experience "poor scan"	Dentists impression-taking skills	The quality of the impression	Switch to digital impression	Digital impression
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Same as conventional impressions	Local factors "Moisture control, tissue management, preparation, uneven powder …etc."	Local factors "Moisture control, tissue management, …etc."	Easy communication	Switch to digital impression	Digital impression
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	More than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Local factors "Moisture control, tissue management, preparation, uneven powder …etc."	Dentists impression-taking skills	Less time needed	Switch to digital impression	Digital impression
1-5 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Equal to conventional impressions	Less than conventional impressions	Easier than conventional impressions	Dentist's lack of experience "poor scan"	Dentists impression-taking skills	Easy communication	Case dependent	I like working with Both
1-5 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Equal to conventional impressions	Easier than conventional impressions	Local factors "Moisture control, tissue management, preparation,	Dentists impression-taking skills	Less materials used	Case dependent	I like working with Both

						uneven powder …etc.”				
More than 20	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Local factors “Moisture control, tissue management, …etc.”	Less time needed	Switch to digital impression	I like working with Both
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	I’m not sure	Same as conventional impressions	Dentist’s lack of experience “poor scan”	The preparation itself	Less materials used	Case dependent	I like working with Both
More than 20	No experience	I work on conventional impressions only	I’m not sure	I’m not sure	I'm not sure	I'm not sure	Dentists impression-taking skills	Less time needed	Case dependent	No preferences
More than 20	No experience	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Same as conventional impressions	Dentist’s lack of experience “poor scan”	Dentists impression-taking skills	The quality of the impression	Case dependent	I like working with Both
More than 20	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	I'm not sure	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Dentists impression-taking skills	The quality of the impression	Case dependent	I like working with Both
More than 20	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Equal to conventional impressions	Equal to conventional impressions	Same as conventional impressions	Dentist’s lack of experience “poor scan”	Dentists impression-taking skills	The quality of the impression	Case dependent	I like working with Both
More than 20	No experience	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	I'm not sure	Dentist’s lack of experience “poor scan”	Dentists impression-taking skills	The quality of the impression	Switch to digital impression	Digital impression
More than 20	No experience	I work on conventional impressions only	Equal to conventional impressions	Equal to conventional impressions	I'm not sure	I'm not sure	Dentists impression-taking skills	Less time needed	Case dependent	No preferences
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	More than conventional impressions	More than conventional impressions	Same as conventional impressions	Local factors “Moisture control, tissue management, preparation, uneven powder …etc.”	Local factors “Moisture control, tissue management, …etc.”	Easy communication	Case dependent	I like working with Both
More than 20	I work on digital impressions in conjunction	I work on conventional impressions in	Less than conventional impressions	Less than conventional impressions	Easier than conventional	Limitations of scanning machines	Dentists impression-taking skills	Less time needed	Switch to digital impression	I like working with Both

	with conventional	conjunction with digital			impressions					
More than 20	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	I'm not sure	Local factors "Moisture control, tissue management, …etc."	Less time needed	Switch to digital impression	I like working with Both
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Dentist's lack of experience "poor scan"	Dentists impression-taking skills	The quality of the impression	Switch to digital impression	I like working with Both
1-5 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Equal to conventional impressions	Less than conventional impressions	Easier than conventional impressions	I'm not sure	Dentists impression-taking skills	Less materials used	Case dependent	I like working with Both
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Local factors "Moisture control, tissue management, preparation, uneven powder …etc."	Dentists impression-taking skills	Less time needed	Switch to digital impression	Digital impression
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Dentist's lack of experience "poor scan"	Dentists impression-taking skills	The quality of the impression	Switch to digital impression	I like working with Both
1-5 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Equal to conventional impressions	Less than conventional impressions	Same as conventional impressions	Local factors "Moisture control, tissue management, preparation, uneven powder …etc."	Dentists impression-taking skills	Less time needed	Switch to digital impression	I like working with Both
11-20 years	I work on digital impressions in conjunction with conventional	I work on conventional impressions in conjunction with digital	Less than conventional impressions	Less than conventional impressions	Easier than conventional impressions	Dentist's lack of experience "poor scan"	Dentists impression-taking skills	Less time needed	Switch to digital impression	Conventional impression