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A COMPARATIVE EVALUATION OF DIRECT AND INDIRECT 3D DIGITATIZATION TECHNIQUES FOR DIGITAL CAD/CAM DATA USING DIFFERENT IMPRESSION MATERIALS

Dental Science

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ABSTRACT

Aim: The aim of this invitro study was to evaluate and compare the accuracy of digital impression fabricated by direct and indirect 3D digitization conducted at various stages of prosthesis fabrication using different impression materials.

Material and Method: Master model was fabricated from acrylic resin using 3D printing technique to mimic an all ceramic FPD preparation for missing mandibular molar. Master model was scanned with high resolution industrial scanner to obtain a highly precise reference dataset. 10 digital impressions of master model were made with intraoral scanning system. Subsequently, 10 polyether and 10 polyvinyl siloxane impressions were made. Impressions were poured and dies were obtained. These impressions and dies were scanned with extraoral scanning system to produce datasets. Datasets were superimposed on reference dataset to calculate the mean positive, negative and absolute deviation.

Results: The deviation with the reference datasets were minimum for direct digital impression followed by polyvinyl siloxane impression, polyether impression and dies prepared from polyvinyl siloxane and maximum was for dies made from polyether impression material.

Conclusion: Within the limitations of this in vitro study, it can be stated that direct digital impression were more accurate than indirect digital technique. In indirect digital technique polyvinylsiloxane impression and die were more accurate than polyether impression and die.

KEYWORDS

Direct Digitalization, Indirect Digitalization, Intraoral Scanner, Extraoral Scanner.

INTRODUCTION

A key determinant of the quality of any fixed prosthesis is intimate internal and marginal adaptation of the crowns. Fit accuracy is one of the main factors for the success of fixed restorations.[1] Unless an accurate reproduction of the dental tissue is obtained with the impression materials the laboratory technician cannot fabricate an accurate prosthesis.[2] Elastomeric impression materials was considered as the material of choice for a variety of reasons including excellent reproducibility and dimensional stability. In last few years the application of computer-aided design/computer-aided manufacturing (CAD/CAM) restorations provides innovative, state-of-the-art dental service has increased significantly.[3]

Digital scanning offer speed, efficiency, ability of storing captured information indefinitely and transferring digital images between the dental office and the laboratory.[4] Improving patient acceptance, reducing the distortion of impression materials, 3D pre-visualization of tooth preparations, and potential cost- and time-effectiveness are the advantage for digital impression and scanning system.[5]

Direct 3D digitalization of tooth preparation is not feasible in every clinical setup. Therefore indirect method of data capturing of impression or die is most commonly used in practice.[6]

The comprehensive objective of the evolving direct digital impression technique is to avoid the errors in multiple stage and therefore volatile process includes conventional impression, plaster cast and extra oral indirect digitalization, by a more standardized, reliable and predictable approach. However, this means the new digital impression technologies and innovative devices have to be compared to the current standard procedures, to evaluate their reliability and competitiveness.[7]

Therefore the present study has been taken up to find the accuracy of direct and indirect 3D digitization made at different stages of prosthesis fabrication and with different impression materials.

MATERIALS AND METHOD

Master model was fabricated from acrylic resin using 3D printing technique to mimic an all ceramic FPD preparation for missing mandibular molar with second premolar and second molar as abutment. The specifications for all ceramic tooth preparation were followed. Heavy chamfer margin(1 mm) was located at the cervical area of the labial, lingual, mesial, and distal surfaces and occlusal surface was reduced by 2 mm.[2,3] Facial, lingual, mesial, and distal surfaces were prepared at 6 degrees taper with the axial wall. The line and point angles were rounded. 3D acrylic resin model was prepared to minimize the abrasion of the abutment tooth surface while making the impression and to ensure the accuracy of the impression.[2,8]

Master model fabricated with acrylic resin was scanned with high resolution industrial scanner (CMM, Comet 5 1.4M Steinbichler) to serve as reference (control group). The industrial CT-system used the helical method to obtain a highly precise reference dataset. The accuracy of the used CT system was estimated by a calibration scan of a ball bar model, and comparison with data from a standardized CMM showed a difference of the diameters of 0.003 mm. However, the size of the isotropic voxels in each measurement could be entered accurately. The voxel size after correction was 16.03 µm, which means that the accuracy of the surface measurement can be estimated about 5 µm over the entire model. To receive a surface model from the volume data, data were post-processed using a special software developed by the Fraunhofer Institute (Furth) as commercially available products are not able to handle such an enormous amount of data. To generate a STL surface, the position of the corner points of the triangles was determined using the marching cubes method. Irrelevant surface areas and manifolds were deleted using Geomagic Qualify 10.0 (Geomagic; Morrisville, NC, USA). The resulting STL dataset was exported and defined as the control group for this study.[8]

Master model was scanned with intraoral scanner(CS3600,Carestream dental) to mimic direct digital impression. Scanning process was

carried out according to the manufacturer's recommendations. With intraoral scanning system, 10 scans were performed and the corresponding surface tessellation language(STL)datasets were postprocessed and exported.[3]

Twenty conventional monophasic impression of master model were made with polyvinyl siloxane(PVS)(Aquasil ultra Monophase regular set Dentsply sirona, US) and polyether elastomer (PE)(Impregum ™ soft, 3M ESPE, Germany) impression material(n=10). To ensure homogeneity, material was mixed by using mixing gun. The manufacturer's recommended polymerization times were doubled to compensate for the impression not being made at mouth temperature. After the material was set, the impression were carefully removed from master model and visually evaluated. Impressions with voids were discarded. Extraoral scanner (Medit T500, Medit) was used to scan all the impression. The dataset was recorded in STL format and exported.[8]

All PVS and PE impressions were poured using type IV gypsum product (die material, Kalabhai Karson Pvt Ltd, Mumbai, India) within 2 hr of making impressions. Boxing was done for all the impression. Distilled water was used for die stone mixing, in accordance with manufacturer's instructions. The mixing was carried out in a ratio of 100 g to 22 ml water, initially by hand to incorporate the water, and then mechanically under vacuum for 20s. The mechanical vibrator Were used to pour impressions with operating at 6000 cycles/min and at amplitude of 0.4 mm. The die stone casts were allowed to set for 1 hr and then removed from the impressions and trimmed. All models were captured using the extraoral scanner and all gathered data were exported in STL file format.

The study was divided into three groups Control Group, Group I (direct scanning), Group II (indirect scanning of impression), Group III (indirect scanning of die) and further divided into subgroup Group IIa (PVS impression), Group IIb (PE impression), Group IIIa(Dies made from PVS impressions) and Group IIIb (Dies made from PE impressions). All 3D data acquired in STL format was transported to geomagic qualify software. To ensure a precise superimposition, the datasets were reduced to the field of interest. Therefore, all artefacts and not relevant areas below the preparation line were eliminated. Each dataset was compared with control group. Positive, negative and absolute deviation was calculated for each specimen and subjected to one way ANOVA followed by post hoc Student Newmans Keul test for pairwise comparison. Statistical analysis was performed with SPSS software. Level of significance was set as $p \leq 0.05$.

RESULTS

Table I shows mean positive, negative and absolute deviation of all test groups from control group after 3D superimposition of datasets. On statistical evaluation of all deviations it was found that direct digitization and impressions with PVS exhibited least deviation from the control group when compared with PE impression and dies made from PVS and PE. Among impression of PVS and PE, PVS was exhibited least discrepany. Among dies, PVS dies were more accurate then PE dies.

Table 1: Summary table of mean positive, negative and absolute deviation of all test groups from control group after 3D superimposition of datasets

Group	Mean Positive Deviation(mm)(Mean±S.D)	Mean Negative Deviation(mm) (Mean±S.D)	Absolute Deviation(mm) (Mean±S.D)
I	0.061±0.089[a]	-0.055±0.0123[c]	0.058±0.0621[f]
IIa	0.082±0.041[a]	-0.112±0.039[c]	0.098±0.0422[f,g]
IIb	0.178±0.126[b]	-0.153±0.031[c]	0.166±0.0905[g]
IIIa	0.097±0.042[a]	-0.270±0.105[d]	0.184±0.1184[g]
IIIb	0.229±0.216[a,b]	-0.382±0.230[e]	0.306±0.2311[h]

Same alphabet represent statistically significant

DISCUSSION

Dental impression is a routine procedure that is required in many disciplines of dentistry to record the oral tissues. The generated casts are used for diagnostic purpose, treatment planning, or prosthesis and appliance fabrication.[9] Impression with inaccuracy will lead to prosthesis misfit which will ultimately cause cement dissolution, loss of prosthesis retention and rendering the tooth prone to biological problems such as caries.[2,10]

Although the conventional impression has been the standard of practice for many decades, it is associated with material preparation, ongoing cost, technical time, potential patient discomfort and requirements of high clinical skills.[11,12] A comparatively new approach employs Computer-Aided Design/ Computer-Aided Manufacturing (CAD/CAM) technology to take a digital impression intra orally, fabricate the master model, and design as well as produce the final restoration. This process aims to prevail over certain physical limitations of conventional means, such as the dimensional changes of impression materials, the expansion of dental stone, and human errors associated with final restoration fabrication, thus reducing processing time as well as cost. Regardless of the digitizing mode applied clinical parameters such as movements of the patient, saliva or blood or can affect the accurate reproduction of teeth. Another CAD/CAM method does not involve intraoral scanning, but it allows dental laboratory technicians to produce restorations using conventional impressions without the need for stone master models.[13]

Besides laboratory scanners; intraoral scanners in particular constantly gain importance since in contrast to the laboratory scan their application positively simplifies the workflow and avoids inaccuracies linked to the conventional impression and model casting. Some studies have shown a higher marginal accuracy of restorations derived from an intraoral scanner in comparison to conventional impressions.[11,14]

The comfort in treatment of the intraoral scan also needs to be discussed, as a lot of patients dislike conventional impressions for different reasons. Initial first studies on this topic indicate that patients tend to favor digital intraoral impressions. Despite the positive aspects of digital intraoral impression procedures, one fundamental clinical problem remains: Optical systems of all the scanner is that theyonly can record visible areas. Thus, blood and especially saliva, combined with subgingivally located finish lines, substantially complicate the scanning process.[15]

The master model used in the present study was fabricated to mimic the clinical scenario for FPD similar to studies conducted by Frederik J et al[2] and Guth JF et al[8] 3D acrylic resin was used to fabricate master model mimicking 3 unit all ceramic prosthesis with 36 missing and 35& 37 as abutments. Preparation parameters were kept as per Rosenstiel et al.[13] Previous studies used metal-based, PMMA or ceramic reference models [2,7,15]. Indeed, a metal-based model has a reliable durability and is resistant against mechanical irritations, but there is still the problem of optical surface reflections that may lead to scanning artifacts with all applied scanners. Seelbach et al overcame this problem by sandblasting the surfaces. This 3D acrylic resin material represents a specially developed material for high-precision dental applications. To minimize the risk of water-uptake- or temperature related distortions of the model and consequently of the datasets, all measurements were performed within the same day under similar conditions. Thus, the model dimensions were stable during the scanning processes.[15]

The master model was scanned with CMM scanner to serve as reference scan for all the datasets to compare with it. In the present study direct digitalization of the mater model was done with intraoral scanner. Indirect digitalization of impression and die stone model was done with extraoral scanner and comparison was done. The scanners used in the study were powder free.[13]

The precision of digital impressions depends on two different parameters. First, the resolution of the optical scanning system, and second, precision of the matching algorithm which maybe decisive for the conduction of full arch scans. In order to minimize the effect of matching artifacts, only small parts of the dental arch in close vicinity of the tooth model were scanned.[9]

Two types of impression materials were used in the study. The impressions of dentulous and edentulous arches, duplication of casts and bite registrations was done with Polyvinyl Siloxane (PVS) impression materials which represent the state of the art in prosthodontics and restorative dentistry. Polyether elastomeric impression materials with very high elastic recovery and high tear strength have been introduced. Their main advantages are low polymerization shrinkage, hydrophilic nature, long-lasting dimensional stability and endurance, and an absence of toxic or allergenic behaviors. Impression detail is influenced by factors such as

viscosity, wettability, handling properties and the presence of voids. Two principal characteristics of the impression material are accuracy and dimensional stability.[4,5]

Various studies conducted on accuracy of PVS and PE conventional impressions have found no significant difference between accuracy and dimensional stability of these materials.[7,11,15] There were no previous studies done showing the comparison between digital polyether and polyvinyl siloxane elastomeric impression and dies prepared from these materials for fixed prosthodontics. Studies conducted by Paul et al, Hiba Al-Iman et al and Persson SKA et al[3] evaluated only digital PVS elastomeric impressions and Guth JF et al[8] evaluated only digital PE elastomeric impression material.

The results of the present study show that direct and indirect digitalization revealed different accuracies of the obtained 3D datasets when compared to a highly accurate reference dataset. Differences in accuracy were found among the 5 investigated groups. Direct digitalization resulted in higher accuracy than indirect digitalization. There was no significant difference between direct digitalization and indirect digitalization at impression level. Further indirect digitization of dies prepared from PVS and PE impressions were significantly different from direct digitalization. This result was in consensus with studies conducted by Guth et al.[8] This result can be attributed to elimination of multiple steps involved in indirect digitalization which might lead to shrinkage of the impresssion material that is compensated by the expansion of the gypsum model. As well, the scanning software might filter out possible outliers and therefore smoothens the surface of the construction datasets. This means that these factors could influence the precision of the single datasets captured. The higher inaccuracy of the conventional way based on conventional impression, gypsum master cast and extraoral digitalization can be explained by the numerous potential sources of errors and the long process chain related with that procedure, until a construction dataset is obtained. Previous studies have shown quality of impression to be a cause for concern.[8,10]

Indirect digitalization at impression level showed better result than die level because of discrepancies and irregularities of the stone replicas. Indirect digitalization of PVS impressions and dies were more accurate than indirect digitalization of PE impressions and dies. Indirect digitalization of PE dies exhibited least accuracy and were significantly different from all other groups. Currently there is no literature available about the comparison of digital impression and dies prepared from PVS and PE. Various researches conducted on conventional impressions of PVS and PE has concluded that both the materials are similar as FPD impression materials based on dimensional accuracy and stability. The differences in accuracy of digital impression of both the materials might be attributable to their optical properties.[13]

The results of the present in vitro study should be interpreted with caution that scanning accuracy is one of the important factor in the whole process of fabricating prosthesis but must not be over estimated. There are many other influencing factors during the fabrication of each prosthesis like milling and sintering; rapid prototyping, etc which might affect accuracy of prosthesis. Still, in the in vitro study trueness of a scanning method is important to know, as trueness parameters cannot be evaluated in vivo yet due to missing reference structures.[12] Additionally, in vitro trueness data can be combined with in vivo evaluation of the reproducibility (precision), which can give a good picture about the performance of the scanners.[6] All tested digital impression techniques are feasible to produce datasets of three unit FDPs within a clinical acceptable range. All over, the digital workflow offers the possibility for compensation of measuring inaccuracies by the adaptation of the interfaces between single working steps.[4] This is one of the advantages of digital dentistry and comprises the potential of higher standardization of the clinical and technical processes.

These in vitro results can give a first hint that direct data capturing technology can offer comparable results like conventional methods. Further in vivo studies must show that this holds true for clinical application as impression procedure and digitalisation are influenced by a variety of factors in the oral cavity. But these studies have to compare the full production process (fig 1 &2).

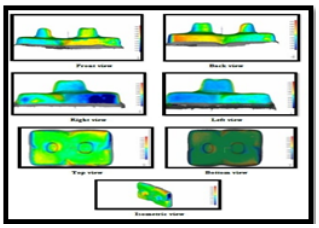

Fig 1: 3D superimposition if datasets

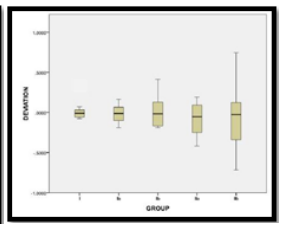

Fig 2: Boxplot for deviation

CONCLUSION

- Within the limitation of the present study following conclusions can be drawn:
- Direct and indirect digitalization revealed different accuracies of the obtained 3D datasets when compared to a highly accurate reference dataset. Direct digitalization resulted in higher accuracy than indirect digitalization.
- There was no significant difference between direct digitalization and indirect digitalization at impression level. Further indirect digitization of dies prepared from PVS and PE impressions were significantly different from direct digitalization.
- Indirect digitalization at impression level showed better result then die level scanning of impressions produces more accuracy when compare to die.

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