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Review Article

Digitalization And Its Future In Prosthodontics

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A R T I C L E I N F O

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A B S T R A C T

Aim: Dentistry can be dated back to eighteenth century, when impressions meant use of waxes and plaster of Paris and the dental equipment consisted of hand driven and later water driven motors. From then there's been a long journey to achieve the contemporary paraphernalia. Along with limited materials and equipment there were selective treatment options but, with the passing years and the endless growth in research, emerged a gamut of options in dentistry. Digitilization started to influence dental fraternity with the form of audio-visual aids in both teaching and patient education. It was in 1980s that advances in computerisation, optics, miniaturisation and laser technologies enabled capture of dental impressions.
Dental impressions are an important step in restorative dentistry. Extensive conventional impression making and cast pouring procedures may lead to distortions. To overcome these deficiencies researchers have used the CAD/CAM technologies to develop intra oral scanners to make 3D virtual impressions without time lapse and of high accuracy known as the digital impressions

INTRODUCTION

The first dental impressioning digital scanners were introduced in the1980s. The digital scanners that are used presently were invented by Hart in early 2000's when he was working on seeding fluids with particles and scanning them.

Principle of working:

Basically this digital scanner for impression work on 2 principle

1) Triangulation of light
2) Active (optical) wavefront sampling

''Triangulation of Light'', where intersection of three linear light beams is used to locate a given point in three dimensional (3D) space. This concept has been used in a variety of industrial measuring devices, but surfaces that disperse light irregularly or do not reflect it evenly, and surfaces that are not continuous, adversely affect the accuracy of scans based on triangulation, consequently an opaque powder coating (titanium dioxide) is used to provide uniform light dispersion and enhance the accuracy of the scan.

"Active Wavefront Sampling" The LavaTM Chairside Oral Scanner (Lava C.O.S.) was recently introduced (3M Lexington, USA). This intraoral scanner is based on the principle of active (optical) wavefront sampling. Active wavefront sampling refers to getting 3D information from a single lens imaging system by measuring depth based on the defocus of the primary optical system. Three sensors capture the clinical situation from different perspectives. With these three images captured simultaneously, 3D surface patches are generated in real time by means of proprietary image processing algorithms using the in-focus and out-offocus information. Twenty 3D datasets per second can be captured with over 10,000 data points in each, resulting in over 2400 datasets (or 24 million

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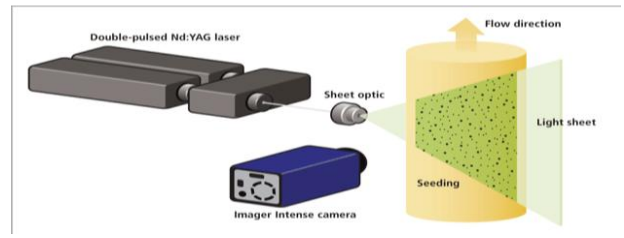
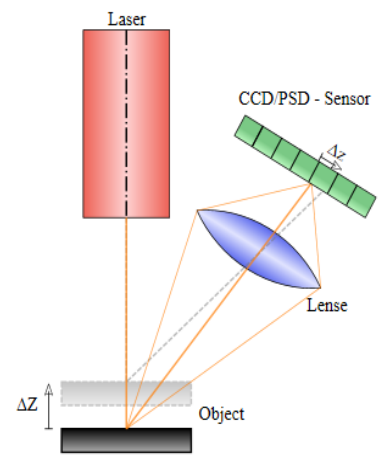
data points) for an accurate scan. According to the manufacturer the high data redundancy resulting from many overlapping pictures together with special image processing algorithms ensures excellent image quality and consequently high accuracy. However, there are no published clinical studies on the in vivo performance of this intraoral scanner. Marginal fit as well as fracture resistance and aesthetics are some of the most important criteria for long-term success of all-ceramic crowns. Sizable marginal discrepancies can expose the luting material to the oral environment, leading to a more aggressive rate of cement dissolution, caused by oral fluids and chemo-mechanical forces. Marginal gaps can promote plaque accumulation which may result in inflammation of the periodontal tissues as well as secondary caries at the crown margin. The aim of this randomized controlled examiner-blinded clinical trial was to test the accuracy of Lava C.O.S. by comparing the fit of all-ceramic zirconia crowns resulting from Lava C.O.S. scans with the fit of all-ceramic zirconia crowns fabricated from silicone impression. Marginal fit was chosen as the primary endpoint as marginal accuracy of a ceramic crown cannot be adjusted once the crown is finished. Occlusal and interproximal fit were chosen as secondary endpoints. The null hypothesis was that there is no difference in marginal fit between crowns fabricated from digital and silicone impressions.





Triangulation of Light

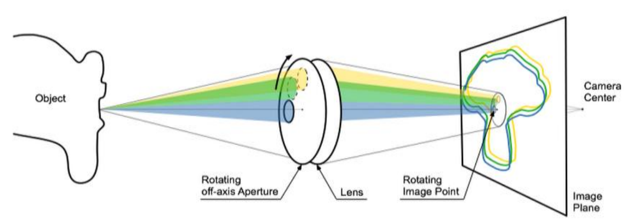


Illustration of the active wavefront sampling approach (AWS). Here a single off-axis aperture is rotated around the optical axis. Thus, a target point's image will appear to rotate on the image plane.
The diameter of the target point's image rotation is used to calculate the depth information.

Active Wavefront Sampling

APPLICATIONS

Digital impression systems with CAD/CAM technologies have applications in the fields of Prosthodontics, Restorative dentistry, Implant dentistry, Orthodontics.

- In implant dentistry: Digital scans are used to calculate implant diameter, implant position, abutment design and the emergence profile.
- In Prosthodontics: It captures 3D virtual images of tooth preparations, restorations may be fabricated

directly using CAD/CAM systems or fabricated indirectly by creating an accurate master models(of epoxy resin)

- In orthodontics: guide bracket placement , virtual planning of tooth movement, produces customized arch wires and plastic aligners(using CAD/CAM)

ADVANTAGES

There are many clinical factors, besides impression material and technique, which influence the quality of an impression, including: location of the finish line, periodontal health, sulcus bleeding during impression taking or saliva flow rate, and patient compliance. In addition, if the impression is taken by means of an intraoral scanner, the accessibility of the preparation for the scanner wand becomes critical for the success of the impression. Accessibility can be limited especially in the retromolar region of patients with limited to the buccal surface of the last molar. Therefore a clinical design was chosen to evaluate the performance of Lava C.O.S., although for a straightforward scanner accuracy analysis a laboratory study would have been sufficient. The clinical approach had the disadvantage that evaluation of crown fit was more difficult compared to an in vitro study, where for instance direct measurement of marginal discrepancies by means of microscopy would have been possible. To overcome this, a replica technique for determination of the marginal gap size was adopted in addition to a clinical evaluation with dental probes. The replica technique is accepted as a reliable and non-invasive means to determine the in vivo adaptation of crown-to-tooth surfaces. Besides its reliability of this method, the replica technique has several other advantages that make it a method of choice for the evaluation of marginal fit20:

- The technique allows accurate in vivo measurement of marginal adaptation just prior to cementation and thus reflects clinical reality. This is important because many clinical situations (e.g. subgingival margins, posterior teeth) may create difficult working conditions that compromise the quality of the final restoration.
- The technique is ethically acceptable as the data collected is of direct clinical benefit to the patient without deleterious effects.
- The technique is easy and efficient to carry out, and relatively inexpensive.
- Eliminate goopy, gagging impression procedures
- Rotation of 3-D images
- Computer generated epoxy models. Unlike stone the epoxy model does not chip or destroy
- Relaxing, interactive and educational for the patient
- Easy and relaxing for the doctors and staff
- Improves efficiency
- Coast-to-coast transfer of digital data to the labs
- no die trims
- no distorted impressions
- no delay in seat appointments
- Approxiately 99.84% Fit Rate of the restorations
- Better marginal fit
- Better inter proximal contact points
- Comparision With The Conventional technique
- Recent studies evaluated
- Distortion of the digital models.
- Lower precision compared to conventional impressions.
- Lack scan speed.
- Highly accurate but limited to small measurement fields such as single tooth or quadrants

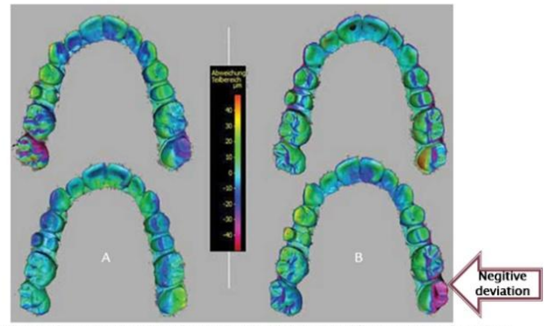
- Do not accurately measure fissure lines and interproximal areas because of the geometric size and shape of the tip of the stylus (probe).

Conventional Impression

Five conventional impressions (CI) were made with a vinyl siloxanether impression material (Identium; Kettenbach, Eschenburg, Germany) and metal stock trays (ASA PermaLock; ASA Dental SpA, Bozzano, Italy) by using a double mix technique. Polymerization time was 10 minutes and the impression was removed from the model by lifting the tray from the anterior to the posterior. After 8 hours storage at ambient humidity and 23°C room temperature and in a dark environment, the impression was poured with Type IV gypsum (CAM-base; Dentona AG, Dortmund, Germany) and allowed to set without inverting the impression. After 40 minutes, the casts were removed from the impression and stored for 48 hours at room temperature and ambient humidity before scanning with the reference scanner. The casts were scanned with the reference scanner as described in section Ref_Prec To obtain the CI_Prec (Precision) data, the cast scans were compared to each other to determine the precision of the conventional impression (n=10). To obtain the CI_True (Trueness) data, the cast scans were compared to the scan of the reference model to determine the trueness of the conventional impression method (n=5). The difference analysis was performed in the same way as described above.

Digital Impression

Five digital impressions (DI) of the reference model were made with the CEREC AC System (Sirona Dental Systems, Bensheim, Germany) by using the CEREC Connect Software 3.82. The reference model was coated with OptiSpray (Sirona Dental Systems) and

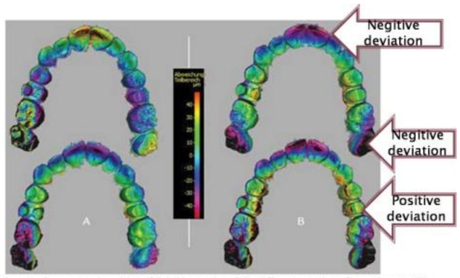


4 Difference images of trueness and precision of conventional impressions. Color difference map is set from -50 μm to +50 μm. Yellow to red color indicates positive deviations, blue to violet shows negative deviation between 2 superimposed models. (A) Precision: Difference map of 2 repeated scans. Anterior regions show minimal deviations of up to 20 μm. Distal end of arch shows irregularly occurring deformations of up to 50 μm. (B) Trueness: Gypsum casts show increasing deviation to distal end of dental arch. Distortion in region of second molar of second quadrant is visible.

Conventional Impression

approximately 20 optical impressions were made to acquire the

entire dental arch. The resulting model was exported to a standard triangulation language file (STL) describing the 3D object surface and imported into the Alicona IFM Software for comparison to the reference model scanned with the Alicona IFM device. To obtain the DI_Prec (Precision) data, the digital impressions were superimposed on each other and the differences showed their precision. The superimposition of the digital impressions on the reference model provided the basis for the trueness of the digital impression method and the DI_True (Trueness) data. The difference analysis was performed in the same way as described for Ref_Prec. To analyze the differences of the mean value, the independent sample t test was used in a pairwise comparison of the testing groups. The Levene test was used to assess the equality of variances among the test groups (=.05).No significant differences for all compared groups were found. Statistical differences between the mean values in pairwise comparison of Ref_Prec to CI_Prec, Ref_Prec to DI_Prec, and CI_Prec to DI_Prec for precision and Ref αTrue to CI_True, Ref_True to DI_True,and CI_True to DI_True for trueness were analyzed with software at α =.05 Chicago, Ill). To analyze the differences of the mean value, the



5 Difference images of trueness and precision of digital impression. Color difference map is set from -50 μm to +50 μm. (A) Precision: Difference image of 2 repeated digital impressions. Irregularly occurring deviations are visible across entire dental arch. Highest differences are located at distal end. Wavelike distortion of dental arch with alternating positive and negative deviations together with rotation of anterior region is visible. (B) Trueness: Systematic distortion along sagittal and transversal axes is visible. Negative deviations are located in anterior and molar region and positive deviations in premolar regions up to 50 μm. Distal end of dental arch differs up to 170 μm.

Digital Impression

independent sample t test was used. The Levene test was used to assess the equality of variances among the test groups (α =.05).

Accuracy of Conventional Impression Technique

Conventional impressions showed a mean precision (CI_Prec) of 12.5 }2.5 µm (median 11.0 µm) and a trueness (CI_True) of 20.4}2.2µm (median 21.5 µm) (Fig. 2). The low standard deviation showed high reliability for the conventional impression in this in vitro experiment. The independent sample t test revealed a statistically significant difference compared to the accuracy of the reference scanner (P<.001). The visual evaluation of the precision measurement showed small deviations in the anterior and premolar regions of around 10 µm and higher, irregularly occurring discrepancies on the second molar with maximum values of up to 50 µm (Fig. 4A). Trueness difference images showed low deviations in the anterior region. Premolar and molar regions differed more from the reference model. At the distal end of the dental arch, irregular deviations of up to 50 µm occurred.

Accuracy of Digital Impression

The digital impressions showed a precision (DI_Prec) of 32.4 ±9.6 µm (median 31.7 µm) and a trueness (DI_True) of 58.6 ±15.8 µm (median 50 µm). The independent sample t test showed statistically significant differences from group CI_Prec and CI_True (P<.001). The differences of the precision measurements showed an irregular deviation pattern. The anterior region was more precise than the posterior, and the highest posterior deviations were located only at 1 side of the model. The visual analysis of the trueness showed a systematic deviation of the virtual 3D models to the reference model, with negative values in the anterior and molar region and positive values in the canine and premolar region. Maximum differences of up to 170 µm occurred in the second molar area. The model was distorted along the sagittal and transversal axes on both sides.

According to the results of these in vitro analyses, the precision (1.6 µm) and trueness (5.3 µm) of the new reference scanner are high for scanning the dental morphologies of a complete-arch model. In comparison, the use of a laser triangulation system as a reference yielded a trueness of about 15 µm when scanning a quadrant (Laserscan 3D Pro).9,22 No other systems that have the ability to scan morphologically shaped tooth surfaces with such high trueness

and precision over an area up to 6 cm2 and 2 cm in height have been reported. Other studies used geometric forms to verify CMMs and showed high trueness and precision for these devices. However, these CMMs acquire only a small number of points from the model surface. Additionally, for a precise model with CMM, knowledge of the surface shape before scanning is necessary. Also the tip of the tactile probe has a certain diameter, meaning small morphological structures such as fissure lines and gingival margins cannot be detected with these systems. With the new reference scanner, acquiring the dental surface without prior knowledge of the morphology is possible.

CONCLUSION

The quality of final impressions plays a major role in the success of the prosthetic rehabilitation. A number of impression materials are available on the market. Their selection must be based on the knowledge of their physical properties and possible interactions with other products commonly used during clinical procedures. During the preprosthetic phase, the preparation of an ideal environment for final impressions is of paramount importance. The quality and stability of soft tissues must be preserved during the intracrevicular placement of crown margins required for esthetics—and the impression phase.

Digital technology has provided a boom not only for the prosthodontics but in all sectors of dentistry. Although a lot more researches are to be undertaken for improving and standardizing digital dentistry the day is not far when virtual imaging is going to be a reality of every day practice.

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