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Effect Of Degree of Taper on Trueness of Endocrown Scanning Using Two Technologies

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Abstract
Background: one extracted human mandibular first molars with known dimensions was scanned inorder to create virtual preparation for conventional endocrown with different tapers eight and twelve. Each preparation of different taper was then printed 7 times to be scanned 7 times by reference desktop scanner "InEos X5" (Dentsply Sirona-Germany). Followed by scanning of each die using Active triangulation technology Omnicam intraoral scanner (Dentsply Sirona-Germany) and Confocal technology Primescan intra oral scanner (Dentsply Sirona-Germany) .
Each scan was checked for trueness using Geomagic reverse engineering software.
Results: samples with 12º taper (66.17±17.78) (µm) had significantly higher trueness than those with 8º (91.96±21.31) (µm) ($p<0.001$).
Samples scanned by confocal technology (65.23±16.44) (µm) had significantly higher accuracy than those acquired by triangulation (92.91±21.11) (µm) ($p<0.001$
Conclusion: 12 degree taper of endocrown gives more true scans than 8 degrees. Confocal IOS are more true than Active triangulation.
Key words: Endocrown, Virtual preparation, intra oral scanner, confocal, active triangulation

Introduction

Due to loss of structural integrity associated with access preparation or caries, or due to decrease moisture content endodontically treated teeth become more brittle and more liable to fractures than teeth with vital pulp. Restoration planning for these teeth will be associated with remaining tooth structure and functional requirements (1). In accordance to several studies, the remaining dentin structure is directly proportional to the strength of the tooth (2).

Only 5% of tooth stiffness is impacted by tooth structure loss after a cautious cavity preparation. The impact of subsequent canal instrumentation and obturation has little to no impact on tooth biomechanics and only slightly reduces the resistance to fracture. In fact, additional preparation linked to post preparation causes the most reduction in tooth stiffness (3).

For several years conventional post and core systems were mainly used to restore teeth with significant loss of coronal tooth structure (4). But due to additional necessary root preparation, conventional posts were associated with rooth fractures due to wedging effect (2). However, fiber reinforced posts were of similar modulus of elasticity to dentine so were more resilient, compatible and able to act as a single unit (monobloc concept) within the root (5).

The real innovation for restoration in endodontic treated teeth was introduced with the development of dentine adhesives (6).Owing to this, insertion of radicular posts became the exception instead of the rule. in fact, less invasive preparation techniques with maximum tissue preservation are now regarded as the gold standard for restoring teeth that have undergone endodontic treatment (7).

Endocrowns fit such approach perfectly as they are restoration with a central retentive feature that extends into the pulp chamber space and a circumferential butt-joint margin. Therefore, core and crown are one single unit providing the monobloc concept (8).

Endocrown is a single monobloc concept providing complete crown with intra-radicular extension that fits into the endo preparation having microretention via adhesive cements in addition to macromechanical retention adapting in to pulpal walls (9) (10).

In teeth where it is hard to apply a post due to severe curve, perforation, short, or calcified roots, endo crown can be very useful. Also, in teeth with severe loss of coronal tooth structure, short occlusogingival height with no space for metal fused to porcelain or all ceramic crowns, endo crowns are highly indicated (11).

Endocrown preparation does not have a specified or unique design. However, some studies suggest that it should contain 90° butt join with decrease in occlusal table of 2 to 3 mm. When possible, supragingival enamel finish line, flattened pulp floor, with internal taper of the pulpal walls, and smooth internal line angles are used (12).

Conventional impressions were used for years, however, were subject to volumetric changes and dental stone's expansion lead to inaccuracy of fabrication procedure (13). Therefore, Intra Oral Scanners (IOS) were developed to overcome such obstacles, impressions became digital

(14). The IOS device's implementation in dental offices occurred at the same time as CAD/CAM (computer-aided manufacturing) (computer-aided design and manufacturing) technology provides several benefits for practitioners in dentistry. Nowadays, IOS and CAD/CAM make treatment planning simpler, patient acceptance, better communication with laboratories, reduced storage requirements, operational time, and treatment intervals (15) .

IOS is a medical gadget made up of a computer, software, and a portable camera (hardware). IOS aims to precisely capture the three-dimensional geometry of an object. The open STL and closed STL are the most used digital format (Standard Tessellation Language). This style, which is already in use in many industrial domains, represents a series of triangulated surfaces, each of which is made up of three points and a normal surface. Other file types, however, have been created to capture the color, transparency, or texture of tooth tissues (such as Polygon File Format, PLY files). All cameras need to project light, which is subsequently recorded as separate photos or videos and assembled by the software after the POI is recognized, regardless of the type of imaging technology used by IOS (points of interest). Each point's x and y coordinates are evaluated on the image, and the third coordinate (z) is then determined using each camera's distance-to-object technologies (16).

There are several scanning technologies available owing to the fact that the scanner itself must move in the small oral cavity as opposed to a desktop scanner. Examples of scanning technologies are active triangulation and Parallel Confocal Imaging Technique (17).

One of the most widely used and significant technologies in the area of 3D imaging is active triangulation. It is based on the incredibly straightforward triangulation method, which measures distance using trigonometry and fundamental algebra. Triangulation is the name given to the process since the camera, the light source, and the object point being seen all form a triangle. Based on a given distance between the camera and the light source, a fixed angle of the light source, and a quantifiable viewing angle, trigonometry is used to compute the distance between the object and the camera. While passive triangulation use numerous cameras and unstructured light, active triangulation makes use of a structured light source and at least one camera (18).

Parallel confocal imaging technique’s foundation is the same technology used in confocal microscopy. It is based on a system that only gathers and contains light that is in focus and is reflected off the specimen, excluding light that is out of focus. In a nutshell, the surface to be scanned is illuminated by a light source that projects a number of parallel laser beams with known (x,y) coordinates that are positioned in the scanner head in various focus planes. Focusing optics are used as part of the lens assembly in the scanner system to achieve this. A charged coupled device (CCD) camera measures the light intensity of the reflected light at different focal planes (in the z dimension) that can be adjusted by the scanner system. This CCD camera has a collection of light sensor elements, each of which corresponds to a pixel in the image (x,y coordinates). For each point of reflected light, a processor determines the spot-specific position (SSP). The focal plane (z dimension) where the light spot produces the most intensity is represented by this (i.e. in- focus). The 3D coordinates of the scanned surface are made up of the x, y, and z coordinates of all the SSPs. Additionally, this scanner records colour image data and displays a real-time coloured 3D model as it scans in 3D. (MHT) as well as TRIOs (3Shape) are additional instances of IOSs that use parallel confocal imaging technology as a component of their image acquisition process (19) (20).

Since elastomeric impressions are an unavoidable step in routine conventional dentistry that may result in some inaccurate results for the dental laboratories due to human error, such tooth defects or voids at important areas of the impression .Because of this, the adoption of desktop scanners in the field of dentistry, particularly prosthodontics, is a logical transition (21).

With five Axis technology, a robotic arm, and automatic model positioning, the InEos X5 is a blue light stripe scanner. It takes about 60 seconds to scan the entire jaw and the output was exported to an open STL file. The two scanning modes are manual and automatic; manual scanning is used for simple procedures, and automatic scanning is used for complex procedures (22).

Among the most important evaluation criteria for the clinical use of the digital impression technology are trueness and precision. These concepts cannot be used similarly because of their established mathematical meanings (23).

ISO 12836 defines the "trueness" of the impression technique as the difference in measurements between the reference model and the intraoral scan model, and the "precision" of the impression technique as the difference in measurements between digital models of the same intraoral scanner (24).

The tested impression method's divergence from the original geometry serves as a measure of the trueness. As a result, a scanner with high trueness will produce a result that is quite similar to or identical to the real dimensions of the object being scanned (25).

The precision measures the differences in impressions within a test group. As a result, a more precise scanner results in a more reliable and consistent scan (25).

Measurement of trueness can be done using Geomagic Xontrol X 2018 reverse engineering software as it compares the images takes by IOS to the reference desktop scanner InEos X5 (26).

Endodontically treated teeth are more liable to fracture. Endocrowns are more conservative especially with advancements in adhesion technology. Preperation of endocrown with different degree of taper has an impact on accuracy of scanning for CAD/CAM restoration. However, no suffiecient data is available on the effect of scanning technology on the accuracy of CAD CAM restoration is available.

Aim of the study:

This research studies the effect of two preparation tapers (different dregrees)

1)8

2)12

On the trueness of two CAD CAM scanning technologies

1) Active Triangulation (Omnicam)
2) Confocal (Primescan)

Materials and methods

Sample Preparation: An extracted human lower mandibular first molar was used in this study by being scanned by "Ineos X5 " (Dentsply Sirona-Germany).

and virtually prepared to desired different tapers. Virtual models with prepared teeth were printed and scanned using two different scanning technologies to measure the effect of endocrown taper and on trueness of different intra oral scanners.

STL generated from the Ineos X5 was imported into Autodesk mesh mixer (Autodesk, Inc. USA) to receive virtual occlusal preparation of 2mm and create virtual butt joint margin by plane cut tool. In order to create a cavity with the desired taper, autodesk mesh mixer was also used by selecting cube shape and using plane cut tool to prepare the edges of the cube according to the required taper of the cavity preparation taper. Two virtual cubes were created with taper of 8 and 12 to be later used.

STLS files of endocrown with virtually created butt joint margin, cube of 8 degree taper, and cube of 12 degree taper were exported separately to be used by ExoCad CAD software (Exocad GmbH Align Technology, Inc. Company, Germany). Exocad model creator module was used to re-import the stl file of tooth with virtual occlusal clearance. Preset of FormLabs2 hollowing 50 um as the model type to be created and stl was aligned (SCAN DATA, OBJECT) on base axis.

On exocad exper mode, plateless model design was selected in order to change the scan data into a virtual modelling object (Modelling object was generated). Two meshes were then imported, first mesh was the original scan of the lower 6 prior to any virtual prep second mesh STL with virtual clearance.

Free form model was selected in order to add an attachment as subtraction option. Then cube shape of 8 degree taper was imported. The cube was aligned onto the modeled object. In this step cavity of 2mm depth and 8 degree taper was created. A model base was created to ease handling during scanning.

Cavity parameters were verified using exocad 2D cross section option and measuring tool of the software. Cavity depth was measured using 2D cross section tool of exocad from the bottom of the cavity of the modelled object to the virtually created object added as a mesh before.Taper was measured via angle tool. After model with desired virtually created taper was finalized the model was exported from ExoCad as STL File for printing.

Halot BOX printing software(Shenzhen Creality 3D Technology **Co**., Ltd) was used by importing STLS of endocrowns with taper 8 and taper 12 created by exocad. Cloning of each taper 7 times to have 7 models of each taper was done. Model were positioned on building plate of printer, printing supports were added and then slicing of models to be finally exported to the Creality 3D printer (Creality Halot 3D Printer Shenzhen Creality 3D Technology Co, Ltd. China).

Total of 14 models were printed. They were then divided into two groups 1(A-G) and 2(A-G) according to degree of taper 1 was the 8 degree and 2 was the 12 degree. Each model in each group was scanned 3 times. Once with Omnicam, secondly with Prime scan and then via Ineos X5 as a refrence scanner.

. Wear measurement

A reverse engineering software (control X 2018, Geomagic, 3Dsystems, NC, USA) was employed to superimpose the reference STL file obtained from the InEos X5 desktop scanner which is the baseline scan to the STL file obtained from each intra-oral scanner.

1 Import and align datasets

The reference data was imported and trimmed to remove any data that is not related to the desired scan, then the measured data was imported and trimmed too.

The transform alignment feature was applied with 4 fixed points to align between the 2 datasets then the best fit alignment was selected to ensure the 2 models data sets are positioned in one common coordinate system with the least possible mean deviation.

2 Resegmenting

The reference model was resegmented according to planes to thousands of segments then the area of interest which is the opposing enamel to the cemented restoration was merged with the merge tool to ensure a precise superimposition

3 3D compare

The 3D compare was done only for the merged area which is the area of interest with the shortest projection of deviation and auto maximum deviation.

$$\text{RMS} = \sqrt{\frac{\sum_{m=1}^{n}(x_{1,m} - x_{2,m})^2}{n}}$$

Results

Null hypothesis was rejected in our study. Samples scanned by confocal technology (65.23±16.44) (µm) had significantly higher accuracy than those acquired by triangulation (92.91±21.11) (µm) ($p<0.001$). Comparisons and summary statistics of different technologies are presented in figure (1) and in table (1). As samples with 12º taper (66.17±17.78) (µm) had significantly higher trueness than those with 8º (91.96±21.31) (µm) ($p<0.001$) Comparisons and summary statistics of trueness (RMS) (µm) for different taper degrees are presented in Table (2) and in Figure 2).

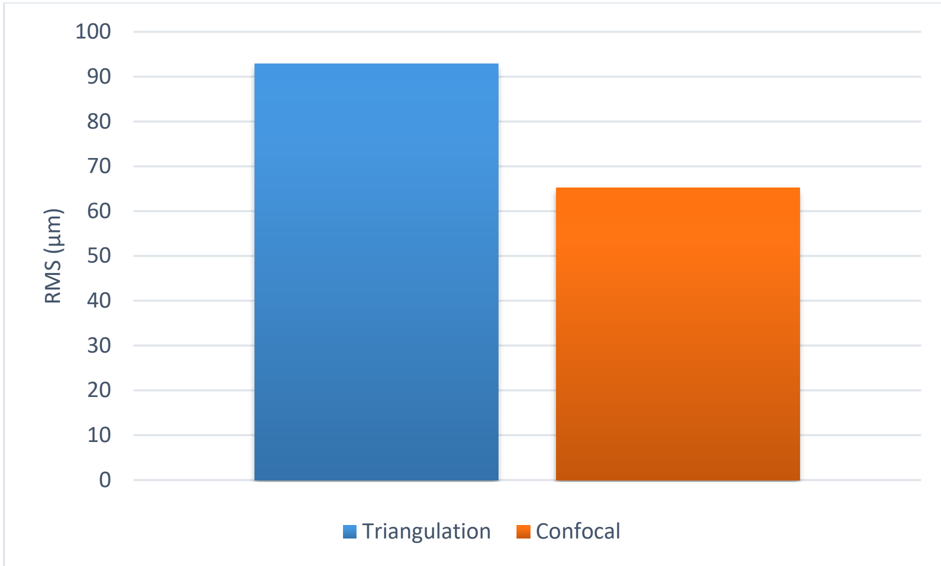

Figure (1):

Bar chart showing average trueness (RMS) (µm) for different scanning technologies.

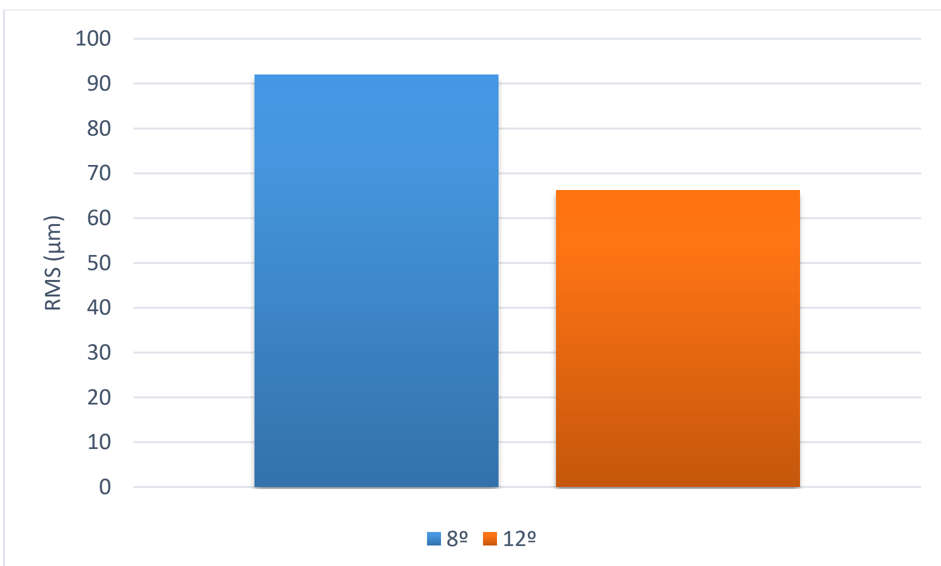

Figure (2): Bar chart showing average trueness (RMS) (µm) for different taper degrees.

Table (1): Comparisons and summary statistics of trueness (RMS) (µm) for different scanning technologies.

Trueness (RMS) (µm) (Mean±SD)		p-value
Triangulation	Confocal	
92.91±21.11	65.23±16.44	**<0.001***

(27)

Table (2): Comparisons and summary statistics of trueness (RMS) (µm) for different taper degrees.

Trueness (RMS) (µm) (Mean±SD)		p-value
8º	12º	
91.96±21.31	66.17±17.78	**<0.001***

Discussion

The objective of this study was to evaluate the effect different degrees of endocrown tapers have on different scanning technologies.

The two tapers were selected according to different material such as Emax Cad which is very widely spread in the dental market, requires more degree of taper inorder to compensate for its stiffness (28) (29). While materials such as hybrid resin nanoceramics are known for their resiliency, therefore, they require less taper and are considered more conservative (30) (31) .

Standardisation is necessary to ensure the reliability and repeatability of study findings. It is challenging to keep this consistency when dealing with natural teeth, which can vary significantly even across individuals. Such variables as tooth preparation and size can be eliminated with CAD software, guaranteeing uniformity. Thus, to generate a virtual preparation of endocrowns of various taper, CAD software was employed (27) .

In order, to create a 3D printed model from the generated STLS from CAD software a 3D printed was used (32). The 3D printed models were then scanned using Prime scan (Confocal technology) (33) and OmniCam (Active triangulation)(34).

The data processing algorithm, scanning technology, use of powder, and image acquisition method (35) are some of the aspects that impact an IOS's reproducibility. To obtain accurate results, we therefore concentrated on standardising the factors as much as possible in our study.

All operating rooms were lit with LED white light using light bulbs of identical intensity, and all scanning times were averaged to eliminate the influence of time on the accuracy of the scanners (36).

The direct intraoral scanning method was selected for scanning since it is widely used in the market and doesn't require powder, even if there is considerable debate regarding its impact on trueness (37) (38) .

Expressing the accuracy in terms of trueness and precision is a common method, applied in several studies (39) (40). Since the InEos X5 has an accuracy of less than 15 µm—is regarded by literature as a minimum deviation—it was selected as the reference scanner (41).

Superimposition of the STL files was done using the reverse engineering 3D analysis program "Geomagic control X, 2018 (3D systems, Morsiville, NC)" (36) (42) . The "best fit alignment" method was used to superimpose the test and reference datasets. This was the best methodological trade-off to achieve the study's goals because there were no reference shapes available (41).

Null hypothesis was rejected in our study. As samples with 12º taper (66.17±17.78) (µm) had significantly higher trueness than those with 8º (91.96±21.31) (µm) ($p<0.001$). Samples scanned by confocal technology (65.23±16.44) (µm) had significantly higher accuracy than those acquired by triangulation (92.91±21.11) (µm) ($p<0.001$).

First null hypothesis that the degree of taper would not have an effect on trueness was rejected. This comes in accordance to Jeon et al. (43) that stated that the more the inclination of walls increased the more the accuracy of intra oral scanners. This is also in agreement with Ashraf et al. (44) that found a direct proportion between taper of cavity of intracoronal restorations and trueness of intraoral scan. In addition, Safoura et al. found better internal fit regarding lithium disilcates endocrowns at 10 degrees than at 5 degrees.

Moreover, Chan et al. (45) also found no significance regarding axial inclination of the preparation and accuracy of intraoral scanners except in the case of 0 degree which adversely affected the accuracy of IOS. Darwish et al.(46) found better internal fit at 6 degrees than at 10 degrees regarding hybrid ceramics.

Second hypothesis was also rejected, as confocal technology was found to be significantly of higher trueness than active triangulation. This comes in accordance to Nulty et al. (47) that found Confocal technology of higher trueness. Jorquera et al. (48) assesed the trueness and precision of two intra oral scanners Primescan (Confocal) and Omnicam (active triangulation) finding that Primescan (CONFOCAL) is of better trueness than omnicam, which were both the scanners used in our study. Gurpinar et al.(49) also studied the effect of endocrown depth and trueness on IOS, finding that Primescan of confocal techonology having the best trueness.

Ural et al. (50) on the other hand stated that in their study on different ios and endocrown preparation Medit i500 which is an active triangulation technology scanner had better trueness results . Explaining the findings that the nature of light the technology is using is of effect. Stating that blue light is better than white light.

Conclusion: Within the limitations of this in vitro study, the following conclusions could be drawn:

1. The more the taper of the preparation the more the trueness of intra oral scanners
2. Intra oral scanners using Confocal technology are more true than those using Active Triangulation

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