EVALUATION OF DIAGNOSTIC ACCURACY OF DIGITAL MODELS

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THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the degree of

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BRANCH V

ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS

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CERTIFICATE

This is to certify that this dissertation titled **"EVALUATION OF DIAGNOSTIC ACCURACY OF DIGITAL MODELS"** is a bonafide record work done by **Dr. RISHI.RAGHU** under my guidance during his post graduate study period 2015-2018.

This dissertation is submitted to **THE TAMILNADU Dr.M.G.R. MEDICAL UNIVERSITY,** in partial fulfillment for the degree **of MASTER OF DENTAL SURGERY in BRANCH V - ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS**. It has not been submitted (partially or fully) for the award of any other degree or diploma.

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CONTENTS

ABSTRACT

Aim:

The aim of the study is to evaluate the accuracy of non powdered digital impression by comparing mesio-distal width measurements and Bolton ratio, length of tooth, inter-canine and inter-molar width obtained through intraoral digital impression and compare it with conventional models.

Materials and Methods:

Based on the inclusion criteria All 9 patients were studied using 2 different methods and measurements were made.

Group A (study group)- the patient's dentition was scanned with the intraoral (IOS)scanner (iTero/ Cadent; invasalign, carlstad New Jersy).

Group B (control group)- maxillary and mandibular impressions were taken Using poly vinyl siloxane (PVS) material orthodontic study models was poured using orthocal without any dimensional change of the impression.

Digital Vernier caliper (Aero space, Resolution 0.01mm) was used to measure the mesio-distal width of individual teeth and the data was used to find bolton tooth ratio. Intraoral scanned model was measured using Dolphin 11.8 and both the groups were compared.

Results:

Statistical analysis were performed using statistical package for social sciences software (SPSS version 22.0). Normality of the entered data was checked statistically using Shapiro-wilk test and data comparison was done

using Independent sample t test and it was used to compare statistical significance of obtained result.

Conclusion:

It was concluded that iTero (study group) models are capable of capturing tooth size accurately along with dolphin version (11.8) as compared with manual measurement on conventional plaster model.

Keywords: **Digital models, intra-oral scanner, Plaster models, Non-powdered digital impression, Bolton ratio.**

Introduction

INTRODUCTION

Diagnosis is the single most important phase of orthodontic treatment that is dependent on accurate and reliable orthodontic records[26].To develop an orthodontic treatment plan consists of models, photographs, panoramic and lateral cephalometric radiographs and a clinical examination[12].Traditionally in orthodontics and orthognathic surgery, the use of accurate Plaster models is an essential prerequisite for establishing suitable diagnosis and treatment planning as well as for monitoring treatment progress[24].The techniques used for impression making with elastomers and creating plaster casts have been used since 1937.

However the problem of space for long term storage of study models is inevitable. Hence the same information can be obtained from study models stored electronically problems of space, cost of storage and use of damage are avoided.[20]

Digital impressions and scanning spectrums were introduced in dentistry in the mid 1980.[42] In Orthodontics, digital impression taking has been used successfully for several years with systems like cadent, IOC/orthoCAD,Dentsply/GAC's orthoflex, stiates/orametrixsure smile and EMS rapid form.[12]

CAD-CAM(computer aided design and computer aided manufacturing) systems available today are capable of feeding data through

accurate digital scan made from plaster models directly to manufacturing systems that can operate without the need for a physical copy of the teeth. Two types of systems are available in market today CAD/CAM system and there dimensions digital impression system (3D).[31]

Digital impression system eliminate several dental office tests such as selecting trays, preparing and mixing materials , disinfecting impressions and sending impressions to lab. Moreover lab time is reduced by not having to pour up, plaster , and replicas etc. Additionally they enhance patient comfort, improve patient acceptance and understanding of the care. Digital scans can be stored on hard disk indefinitely while conventional models can break or chip must be physically stored and requires office space.[21]

However , until now conventional plaster casts and traditional impression making techniques with elastomers remain the gold standard and it is even now being practiced extensively in many places and is always more cost effective than any digital method.[51]

CEREC used the light's reflection of angled surfaces to acquire the tooth image was developed based on the principle of triangulation, For uniform light dispersion an opaque titanium dioxide powder coating is applied over the area to be scanned then the margins of the preparation are virtually identified and the impression is complete.[31]

Digital models can also be used for the production of laboratory appliances and computer-aided bracket placement as well as for virtual treatment simulations[43].

According to **RheeYe-Kyu et al** demerits of powdered scanning are discrepancies which are caused by jaw opening, saliva, blood and other factors in clinical situations. A layer of inhomogeneous powder spray on the tooth surface, may slightly transfigure the tooth outline. If the programs in the scanners is capable of taking the powder spraying into account in the algorithm, the thickness of the powder will still varied by the operator, reducing scan accuracy.[34] To overcome the demerits.

In late 1999, Ortho CAD (cadent) developed and released to market virtual design dental casts. Then in early 2000 e-models came to the market.[41]Software from the imaging companies allows orthodontist to view the image and manage it in virtual 3D environment.[21]

Optical/Scanning technology has almost took on the field today. One such technology is the Align technology which has delivered significant enhances in the field of tooth movements as evidenced by the invisalign clear aligner products. However, irrelevant of the method used accuracy plays a vital role in delivering the success of the treatment.[31]

Today, digital impressions such as there delivered by the Align iTero Tm Scanner are providing practice with superior accuracy and patient

satisfaction, restorative solutions, implant solutions and mainly orthodontist solutions as well as supporting practical use of polyurethane models.[31]

The iTero digital impressions system entered the market in 2007. It was a parallel confocal imaging system to perform fast digital scans. Major advantage of iTero scanning is in-office virtual treatment simulation which also helps in patient motivation.[21]

The Align iTero scanning technology doesn't not require any powder, dusting or accent frosting regardless of the scan required. It provides highly accurate orthodontic scanning with real time viewing in adult and adolescent patients with various mouth openings and in full and partial arches.[31]

The iTero powder free technology delivers highly accurate digital impressions of the interproximal areas and dental arch with dimensional stability. Hence, the digital scanning technology has numerous merits and a few demerits when compared to the conventional plaster model method. With this background, the **primary AIM of this study** is to measure the accuracy of the study models made using the iTero digital scanner method by comparing with the conventional plaster model.

HYPOTHESIS

The null hypothesis is that there will be a difference in accuracy between the digital model obtained by iTero scanner and conventional plaster model.

Review of Literature

REVIEW OF LITERATURE

- **Plaster models**
- **Intraoral scanners**
- **Plaster and digital models**

In 1958, **Dr. Wayne Bolton**[4] published his investigation on inter-arch tooth size discrepancies and their influence on diagnosis and treatment planning. In his study, he measured a sample of fifty five adult dentitions with no missing teeth, forty-four of which had received previous orthodontic treatment. Using three-inch needle-pointed dividers and a finely calibrated millimeter ruler, he measured the mesio-distal dimensions of the teeth in each arch from first molar to first molar. To establish an overall ratio, he summed the total value for measurements made in the respective arches and calculated the ratio of these totals for the maxillary arch to those of the mandibular arch. He also took the ratio of the summed values for the maxillary teeth from canine to canine to the summed value of their mandibular counterparts for calculation of the anterior ratio His ratios had no statistically significant difference when compared to those of the untreated, ideal occlusion. Incidentally, mean values for his sample of ideal occlusions did not differ significantly for other measurements he made, including percentage overbite, overjet, incisor angle or posterior cusp heights. The mean ratios Bolton derived also correlated very closely to ratios calculated from tooth dimensions

considered ideal for establishing the ideal restorative setup for the adult dentition Bolton's study demonstrated the clinical impact of mathematically calculating these ratios. He recommended that inter-arch tooth-size discrepancies observed in patient dentitions beyond one standard deviation from his values indicated consideration in treatment planning regarding extractions or the need for diagnostic set-ups. With respect to more contemporary orthodontic mechanics, his ratios also aid in clinical decisions regarding amount and site of interproximal reduction or restorations necessary to finish orthodontic treatments with ideal buccal occlusion, overbite and overjet. Currently, clinicians regard ratios with values in excess of two standard deviations beyond Bolton's values merit consideration as having clinical significance, although a number of studies challenge the notion that the values he derived apply universally to gender and ethnicity.

Shellhart et al[45](1995) evaluated the reliability of the analysis when performed with needle pointed dividers and Boley gauge. Four clinicians measured the teeth on 15 set of cast with 2 instruments at two session. The measurement's were use to calculate tooth size excess. Result demonstrated that clinically significant measurement error can occur when the Bolton tooth size analysis is performed on cast with at least 3mm of crowding. The boley guage demonstrated a higher frequency of significantly correlated repeated measures and thus may be somewhat more reliable for this analysis than needle-pointed dividers.

Santoro M etal[41](2003)evaluated the reliability of the OrthoCAD system. Two independent examiners measured tooth size, overbite, and overjet on both digital and plaster models. The results were compared, and interexaminer reliability was assessed. The results showed a statistically significant difference between the 2 groups for tooth size and overbite, with the digital measurements smaller than the manual measurements. No difference was found between the 2 groups in the measurement of overjet. Interexaminer reliability was consistent for both the plaster and the digital models.

Quimby et al, (2004)[32] evaluated accuracy, reproducibility, efficacy, and effectiveness of measurements made on computer-based models and Found that those measurements appeared to be generally as accurate and reliable as measurements from plaster models. Recently, electronic storage of models became available, allowing users to store and view 3D models on a computer. This concept could eliminate the problem of model storage in an orthodontic office and shorten the time necessary to perform space analyses.

Redlich M,**et al[33](2007)** evaluate the reliability of a new technique for measuring 3D-scanned orthodontic cast models with cross-section planes using TELEDENT, a new software, developed at Technion The results of this study show that using cross-section planes for measuring tooth width and arch

length does not differ from using the caliper on plaster models and can therefore be employed for clinical purposes. They concluded that The accuracy of the technique of cross-section planes measurement of 3D-scanned cast models does not differ from manual caliper measurement of casts. Cross-section plane measurements are more accurate than linear measurements. Linear measurements may cause clinical inaccuracy when calculating space analysis in a crowded dentition.

Mullen et al[25](2007)accuracy and speed of measuring the overall arch length and the Bolton ratio, and the time to perform a Bolton analysis for each patient by using software (emodel, version 6.0, GeoDigm Corp, Chanhassen, Minn) compared with hand-held plaster models. And the results suggested that, when performing a Bolton analysis, the emodel can be as accurate as, and significantly faster than, the traditional method of digital calipers and plaster models. A clinician who has switched to using emodel software can be confident in his or her diagnoses using it

Othman et al[39](2006)analysed the Bolton's TSD with specific attention to the prevalence of TSD and the influence of different classes of malocclusion, gender and of racial group and examine methods of measurement of TSD and their reproducibility. They concluded that Bolton standard deviation is probably not a good guide to the prevalence of a clinically significant tooth-size discrepancy. Investigators should focus more

on the actual size of the discrepancy, rather than the Bolton ratios alone. Gender and racial group are unlikely to have a clinically significant effect on TSD. And Class III malocclusions probably have higher average ratios. The advent of computer programs and electronic calipers greatly facilitates the measurement of Bolton ratios and should greatly increase the use of measurement of TSD in clinical practice. and Reproducibility of measurement of TSD has been poorly investigated.

Stevens R D et al[44](2006)compare the current gold-standard plaster model with the digital counterpart of emodel for the analysis of tooth sizes and occlusal relationships—specifically the Bolton analysis and the peer assessment rating (PAR) index and their components. Concluded that No measurement associated with Bolton analysis or PAR index made on plaster vs digital models showed a clinically significant difference. Digital models are a clinically acceptable replacement for plaster casts for the routine measurements made in most orthodontic practices. Because the PAR analysis and its constituent measurement are not significantly different clinically between plaster and emodel media, and preliminary results gave no indication that digital models would cause an orthodontist to make a different diagnosis of malocclusion than with plaster models, digital models are not a compromised choice for treatment planning and diagnosis.

Malik et al[22](2009) evaluated whether the same orthodontic information can be obtained from study models and photographs of study

models for the purposes of medico-legal reporting. Thirty sets of study models were used for the study. Photographs of the study models were taken: anterior and right and left buccal views in occlusion and upper and lower occlusal views. Three examiners assessed the study models and photographs of the models in a random order. They concluded that the same orthodontic information can be obtained from study models and photographs of study models for the purposes of medico-legal reporting.

Torassian et al[48](2010) compared the dimensional stability of four impression materials over time compared OraMetrix digital models vs traditional plaster models. However, with digital model services, turn around time can be about 7 days. When the plaster and digital models were compared, overall the digital model measurements were smaller compared with the plaster model measurements. Differences between the measurements were greater than 0.5 mm; therefore a clinically significant difference is seen between plaster and digital models. Digital models measured with OraMetrixsoftware showed a clinically significant difference compared with traditional plaster models.

Horton heatheret al[19](2010) Overall, digital techniques tend to slightly over estimate actual stone cast measurements, indicated by their positive bias values. The Occlusal technique, measuring each mesial distal tooth width from the standard occlusal aspect, is the best combination of accuracy, repeatability, and speed of measurement and therefore the best

choice for routine digital measurement of mesial distal tooth widths in a clinical setting.

El-Zanaty et al[12](2010) stated that dental measurements were obtained from the 3D models are comparable with those from conventional models in the 3 planes of space. This technology has the added benefits of eliminating the need for taking impressions and the time needed for making models.

Fleming et al[13](2011) In a systematic review of digital versus plaster study models assessed the validity of measurements for tooth size and arch length, irregularity index, arch width and crowding. Overall, 283 papers were identified but only 17 studies were reported with sufficient and to be accurate were included in the review. A high degree of validity was found between the two methods.

Akyalcin[2](2011) stated that digital models can only offer a valid alternative to plaster models if they are proved to be accurate. In current evidence, there is no doubt that digital models will take over conventional plaster casts in the near future. Still in facing standardization issues which are related to specific protocols in generating digital dental models. A 3D dental model should be able to be reproduced, viewed, measured and stored regardless of the technique-specific details in a highly consistent manner until a global acceptance is achieved. Practitioners are encouraged to use both the conventional plaster model and digital models until they are able to confirm

repeatedly accurate results related to their practice needs and in treatment planning procedures.

Naidu et al[28](2013)determined the validity, reliability, and reproducibility of tooth-width measurements and Bolton ratios made with the latter system. Thirty subjects had impressions taken of their teeth and rendered as stone casts. In addition, their mouths were scanned with the iOC and the scans were converted into digital models. Tooth widths were measured with a digital caliper from the physical models and with the OrthoCAD software from the virtual models. Bolton ratios were derived using the data from each method. Study concluded that TheiOC/OrthoCAD system has clinically acceptable accuracy in measuring tooth widths and calculating Bolton ratios. The reliability and reproducibility of the digital method is excellent. It appears that theiOC/OrthoCAD system is a clinically acceptable alternative to calipers and stone casts for making tooth-width measurements and calculating Bolton ratios.

Hwang et al[54](2013) The aim of this study is to evaluate the reproducibility of working casts of a digital impression system by comparing them with the original, virtual, and rapid prototyping casts. concluded that Virtual casts made by the iTero intraoral scanner showed excellent reproducibility in general. when comparing original stone casts, virtual casts, RP casts, and casts fabricated by the iTero milling machine, the casts from the iTero milling machine exhibited greater dimensional differences and lower

reproducibility than did the other types of casts The results of the present in vitro study did not come from clinical situations; therefore, there should be in vivo studies verifying the intraoral performance of the scanner system with prepared teeth.

Nalcaci, et al[27](2013) The purpose of the present study was to compare the O3DM system, which uses digital models, with the manual method of measurement with vernier caliper and plaster models with regard to accuracy, reproducibility, efficacy and effectiveness of measurements A total of 20 digital models were produced by the Ortho Three‐dimensional Models (O3DM) Laboratory and their software (O3DM version 2) was used. Identical plaster models were measured with a vernier caliper. In the results the study indicated that accuracy, reproducibility and effectiveness of O3DM are clinically acceptable, making it an alternative to the traditional vernier caliper in orthodontic practice.

Sanches et al,(2013)[37] Thirty plaster casts were scanned and digitized.

with a digital caliper Mesio-distal width measurements of the teeth were performed on both plaster and digital casts using O3d software systemThe sum of the sizes of the lower incisors were used to obtain predictive values of the sizes of the premolars and canines using the regression equation, and these values were compared with the actual sizes of the teeth.

The purpose of this study was to compare dental size measurements, their reproducibility and the application of Tanaka and Johnston regression equation in predicting the size of canines and premolars on plaster and digital dental casts. And concluded that despite an adequate reproducibility of the measurements performed on both casts, most measurements on the digital casts were higher than those on the plaster casts. The predicted space was overestimated in both models and significantly higher in the digital casts.

Kravitzet al[21](2014) reviewed the use of intraoral digital scanners in the orthodontic office, including an in-depth examination of the iTero, True Definition, and Lythos devices. In 2006, Cadent developed the in-office iTero digital impression system, which by 2008 was capable of full-arch intraoral scanning. Advantages of Digital Scanning Alginate and PVS impressions have been associated with problems such as pulls, tears, bubbles, voids, tray-to-tooth contact, separation from the impression tray, temperature sensitivity, limited working time, material shrinkage, inaccurate pouring, model over trimming, and breakage during shipment. The replacement of alginate impressions with these new devices represents a paradigm shift in orthodontics. However, in order to support such a statement, evidence should be provided that accuracy, reliability, time requirement, and patient perception of the several available intraoral scanners are comparable to that of the conventional technique for full-arch impressions.

Shastryetal[43](2014) investigated extent, experience, and trends associated with digital model use, as well as the advantages of using a particular study model type (digital or plaster) concluded that 35% of accredited orthodontic postgraduate programs in the United States and Canada are using digital study models in most cases treated in their programs, and the trend is for increased digital model use in the future.

Robert G. Nedelcu et al[35](2014)evaluated the scanning accuracy and precision of 4 intraoral scanners and to assess the influence of different test materials and coating thicknesses. They concluded that Significant differences exist between coating and non coating scanners. There are specific scanning errors for the system using parallel confocal microscopy for certain test-body materials. Specific areas of sizable deviations for 1 system using laser triangulation technology can be explained by the scanner design and non coating technology. Excessive coating shows no negative effect.

Cecilia Goracci, et al[6](2015) In a systematic review only few studies have evaluated complete-arch scans acquired directly in the patient's mouth. Although verification of accuracy and reliability should be a prerequisite for the clinical application of any new technology, only four studies on intraoral scanners have pursued this objective under intraoral conditions. Moreover, although several intraoral scanners have been commercialized for use in orthodontics, only two of them, Lava COS and iTero, have been tested in the

clinical setting. Therefore, the scientific evidence so far collected on intraoral scanning is neither exhaustive, nor updated. According to the QUADAS tool, no study was adequate with regard to the sampling method.

Helder B Jacob et al[18](2015) compare the reliability and validity of one extraoral scanner (Ortho Insight 3D™) and two intraoral (ITero™and Lythos™) scanners. Fifteen dry human mandibles were scanned twice with each of the scanners, and digital models were generated. Five measurements were made on the dry mandibles and on each of the generated models, including inter-molar width, inter-canine width, posterior arch length, premolar crown diameter, and canine height. This study evaluated the reliability and validity of one extraoral [Ortho Insight 3D™ (Motionview Software, Hixson,TN/USA)] and two intraoral [ITero™ (Align Technologies, San Jose,CA/USA) and Lythos™ (Ormco Corp., Orange, CA/USA)] scanners. Replicate analyses showed statistically significant systematic errors for only one measure (inter-molar width measured from Ortho Insight 3D scans).Measurements taken from all three scanners were highly reliable, with intraclass correlations ranging from .926 to .999. Method errors were all less than 0.25 mm (averaged ≈0.12 mm). Posterior Arch length and canine height were significantly smaller when measured on the Ortho Insight 3D scans than when measured on the dry mandibles and significantly smaller than when measured from the ITero and Lythos models. While all three scanners

produced reliable measures, Ortho Insight 3D systematically underestimated arch length and canine height.

Rhee et al[34](2015) In this study evaluated the appropriate impression technique by analyzing the superimposition of 3D digital model for evaluating accuracy of conventional impression technique and digital impression. Twenty-four patients who had no periodontitis or temporomandibular joint disease were selected for analysis. 3D laser scanner is used for scanning the cast. Each 3 pairs for 25 STL datasets were imported into the inspection software. The results showed that the three-dimensional deviations between intraoral scanner and dual-arch impression was bigger than full-arch and dual arch impression. The two-dimensional deviations between conventional impressions were smaller than intraoral scanner and conventional impressions.

Rossini et al (2016)[36]evaluated the accuracy, validity, and reliability of measurements obtained from virtual dental study models compared with plaster models. He concluded that Digital models are as reliable as traditional plaster models, with high accuracy, reliability, and reproducibility. Landmark identification, rather than the measuring device or the software, appears to be the greatest limitation of the study.

AudeDíaz et al.(2016)[3]assessed variation in the values of Bolton index, by making measurements manually or digitally. 70 pairs of study models were analyzed and measured on two occasions: one using a compass and a millimeter ruler, and the other using an electronic vernier. And

concluded that no statistically significant difference was found between the two measurements. Both ways to perform mesio-distal dental measurements are good choices for Bolton analysis.

Samehet al[40](2017) in this study he evaluate the validity and reliability of three-dimensional (3D) landmark-based palatal superimposition of digital dental models using Ortho Mechanics Sequential Analyzer (OMSA).he compared a sample consisted of pre- and post-treatment digital maxillary dental models of 20 orthodontic cases. scanning was done using Ortho Insight 3D laser scanner (version 5.1, Motion view, Hixson, TN) digital models were also superimposed using 3dMD Vultus software (3dMD, Atlanta, GA) using the best fit surface-based method and he concluded that OMSA offers a valid and reliable tool for 3D landmark based digital dental models superimposition using 3 points marked along the mid-palatal raphe as reference.

TIME REQUIRED FOR DIGITAL IMPRESSION ACQUISITION:

In the study by **Vasudavan et al (2010)[49]** orthodontic assistants required between 16 and 46 minutes (mean 26 minutes) for complete intraoral scanning.

Wiranto et al. (2013)[53] reported that the scanning times following cotton rolls placement and teeth powdering ranged from 14 to 40 minute with an average of 23 minutes.

The studies by **Garinoet al[15](2014)** involved the powder-free scanner iTero. From 328 scans an average of 11 minutes and 58 seconds was calculated, although the scanning times varied between 6 and 18 minutes.

Patzeltet al[30] (2014) conducted a study to compare the time efficiency of three computer-aided impression-making (CAIM) systems;(CEREC Acquisition Center [AC] with Bluecam, Sirona, Bensheim,Germany; iTero, Align Technology, San Jose, Calif.; Lava Chair side OralScanner C.O.S., 3M ESPE, St. Paul, Minn.). To obtain information about the time efficiency of CAI, we used a dentate maxillary and mandibular study model (KaVo, Biberach, Germany) to mimic different clinical scenarios. The total procedure duration for each scenario. Compared with the compiled times required to make conventional impressions, intraoral scanners were up to 23 minutes faster for single abutments, up to 22 minutes faster for single-span FDP preparations and up to13 minutes faster for full-arch preparations (14 abutments) when one considers the total procedure duration for each process. The findings suggest that using CAIM results in a more time-efficient work flow than that possible with conventional impression making; however, there are opportunities to reduce the actual chair time for both approaches by sharing several steps among members of the dental team. Further studies are necessary to determine whether these results are applicable in in vivo settings.

Materials and Method

MATERIALS AND METHODS

The present in-vitro study was carried out in the department of Orthodontics and Dentofacial orthopaedics, Ragas Dental college and hospitals Chennai.

Sample Description:-

A total of 9 patients of different malocclusion with permanent dentition both upper and lower jaws were randomly selected.

Inclusion criteria:

- Patients with permanent teeth from molar to contra-lateral molar in both upper and lower jaw.
- Subjects with no visible lessons or heavily restored teeth.

Exclusion Criteria:

- Subjects who had already undergone orthodontic treatment (Preferably extraction treatment)
- Subjects with missing permanent teeth
- Subjects with severe crowding
- Patients who had teeth with large carious lesions or enamel defect that would effect the morphology of the crown.
- Subjects with chronic or acute infection in the oral cavity.

- Subjects with a restricted mouth opening.

Based on the inclusion criteria all 9 patients were studied using two different methods and measurements were made.

GROUP A (STUDY GROUP)

Group A-(IOS) The patients dentition was scanned with the intraoral (IOS) scanner (iTero/Cadent;in-visalign, carlstad New jersy)(figure 1).

Scanning was done using an intraoral scanner which employs patented optical focus-detection-based on technique to capture the 3D geometry of the dentition and gingivae.[15] Optical digitization by parallel confocal imaging through a combination of laser and optical scanning to capture the dental anatomy and generate a 3- dimensional digital model. The scanning wand (figure 2) which emits multiple light waves of discrete wavelengths and captures returned light from hard and soft tissues in a complementary metaloxide semiconductor imager.[52] Parallel/Confocal is a technique where a light source passes through a small filtering pinhole which focuses the light on the target object. The light then reflects off of the object and only the reflected light that is in focus passes back through the pinhole. Reflected light will be blocked if not in the confocal plane.[21]

Only reflected light that is in focus will return through the filtering mechanism. Better images are produced, as out of focus information is rejected and depth of filed control is enhanced by confocal plane. Better

images are produced.[31] iTero captures 1,00,000 points of laser light in perfect focus at 300 focal depths in a 14x18 mm pattern, producing a 15mm scan depth. An analogue to digital converter in the camera wand, acts to convert the reflected light into digital data in about 1/3 of a second, with an accuracy of 15 microns. The confocal technology is a true optical scan, does not require any powder dusting.[31]

Steps involved- First the lower arch, then the upper followed by right and left checkbites. To register the arches, the camera must be passed over the tooth surfaces in the following manner.[17]

Tip of the wand is placed on the occlusal surface of the terminal molar to start the scanning process.

Lower arch order of registration:

- Occlusal surfaces
- Anterior surface.
- Lingual surfaces.
- Vestibular surfaces.
- Interproximal lingual surface
- Buccual surface
- Incisal surface.

The cable end of the wand out and maintain **45 degree** angle of wand tip to lingual surface using a twisting motion capturing the interproximal

anatomy of entire lingual surface. And then towards buccal using rocking motion to capture interproximal anatomy of the buccal surface bringing the cable towards the arch will capture the mesial anatomy, taking the cable away from the arch will capture the distal anatomy, moving from posterior to anterior during scan reduced the cheek interference.

Upper arch order of registration:

- Occlusal surfaces
- Vestibular surfaces
- Palatal surfaces
- Interproximal palatal surfaces
- Buccal surfaces
- Incisal surface
- Capturing the palatal started behind centrals and moved posteriorly towards soft palate. Then either side of palate is filled the dentition.

Multiple images of the same tooth were taken from different angles in order to cover the entire surfaces. Areas which are underexposed are highlightened by red demarcation line which needs to be filled completely anytime before the completion of scan. Thus, we can obtain direct registration of intraoral impression.

Using iTero digital models and will be given in STL format. (Figure 4**)** The digital models will be downloaded from the company's website

onto a personal computer.[31]Mesiodistal width of individual tooth were measured for group A(IOS). The measurement is done using Dolphin imaging (Version 11.8) Digital images software, tooth widths is measured using the "Diagnostics" tool.

The measurement is done using Dolphin imaging (version 11.8). Digital images will be opened in the software, tooth widths will be measured using the "Diagnostics" tool. For proper visualization of each tooth, the program's zoom, rotation, and panning features will be fully utilized. Fourteen-inch computer screens with a resolution of 1366*768 pixels and 32-bit colour along with a standard computer mouse will be used to manipulate the models and mark points .Tooth widths will be measured by selecting the maximum mesiodistal diameter of each crown. This is correctly defined as the distance between the anatomic contact areas when the teeth were correctly aligned All recordings will be made up to the nearest 0.1 mm. An anterior Bolton ratio and an overall Bolton ratio will be calculated for each patient from these data.

GROUP B (CONTROL GROUP)

Group B–(plaster cast) maxillary and mandibular impressions were taken using poly vinyl siloxane (PVS) material, cast was poured using orthocal without any dimensional change of the impression. Orthodontic study models were made from PVS impressions.(figure 5).

Each model was marked with long axis of the tooth and centre of the tooth was marked using boons gauge. Mesiodistal width of individual tooth were measured in the models manually with the use of a Digital vernier caliper.

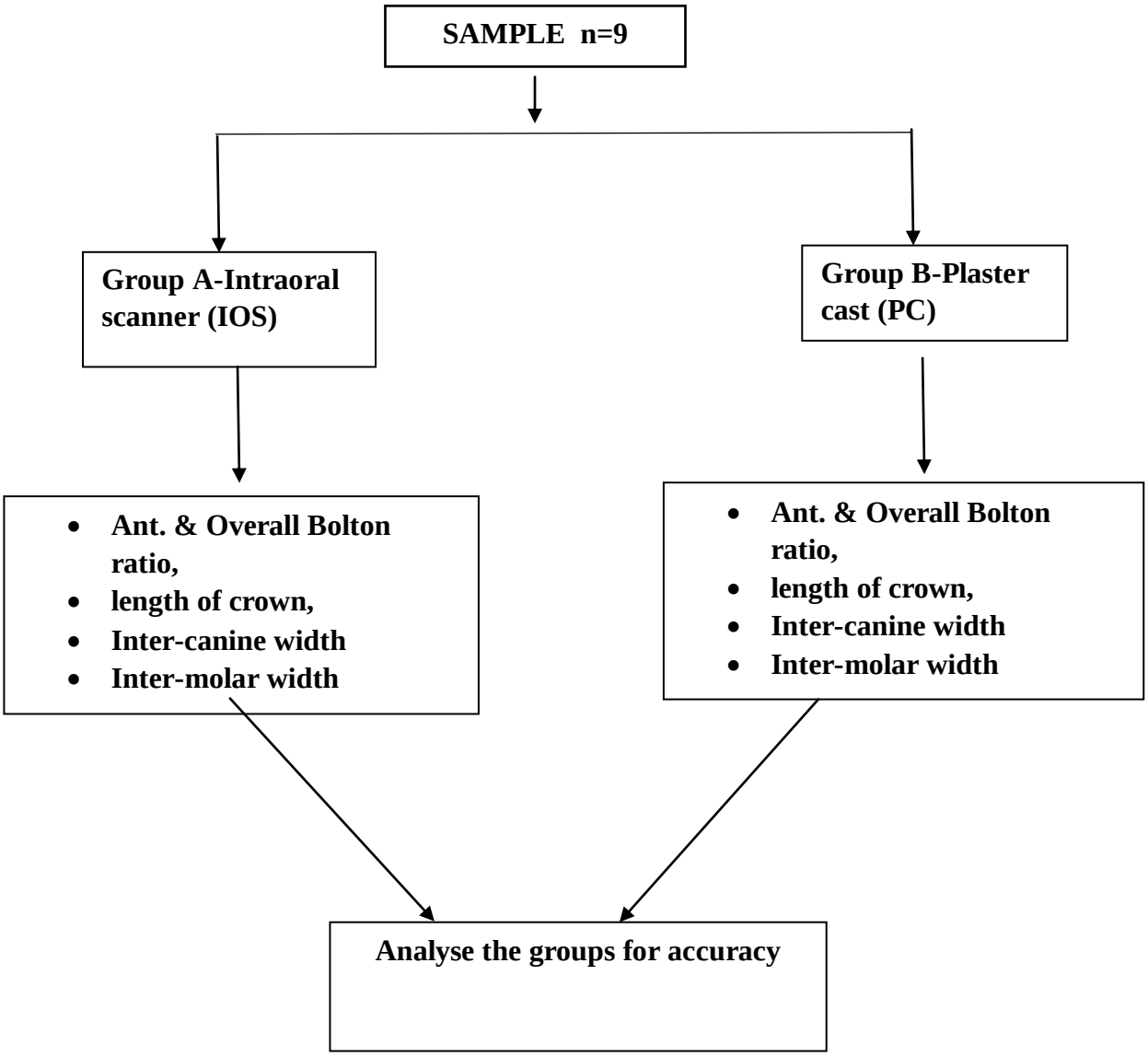
MEASUREMENTS:

Digital vernier caliper was used to measure the mesiodistal width of individual teeth (figure 3).

- Mesiodistal (Greatest) diameter from the anatomic mesial contact point to the anatomic distal contact point in each tooth, parallel to the occlusal surface(figure 7,8,9).
- Length of crown highest point of CEJ to tip of the crown.(figure 6,10,11)
- Inter-canine distance is measured between point connecting long axis of tooth to the gingival margin on palatal / lingual aspect (figure 12).
- Inter-molar distance straight distance between line connecting where palatal/lingual groove connects the gingival margin (figure 13).
- Anterior and overall Bolton ratio.

All measurements made by a single examiner in the study were statistically analysed and the comparison statistical significance of obtained result was done.

FLOW CHART


SAMPLE n=9
Group A-Intraoral scanner (IOS)
Group B-Plaster cast (PC)
Ant. & Overall Bolton ratio,
length of crown,
Inter-canine width
Inter-molar width
Ant. & Overall Bolton ratio,
length of crown,
Inter-canine width
Inter-molar width
Analyse the groups for accuracy

Figures

Figure 1. iTero Intraoral scanner

Figure 2. Intraoral camera (wand)

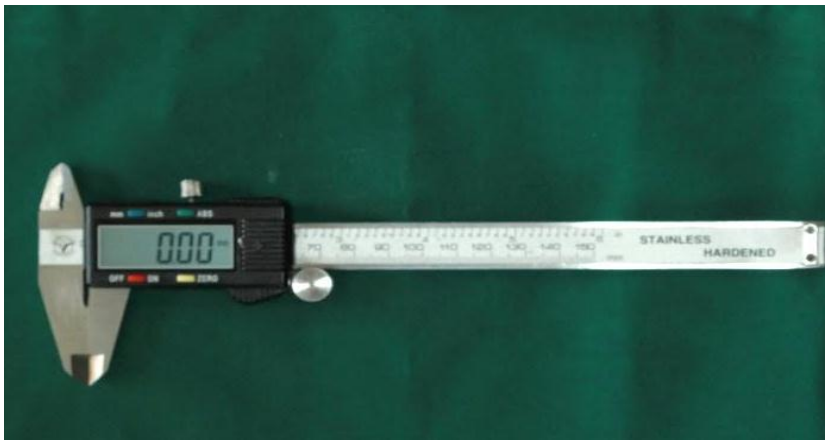


Figure 3. Digital Vernier caliper

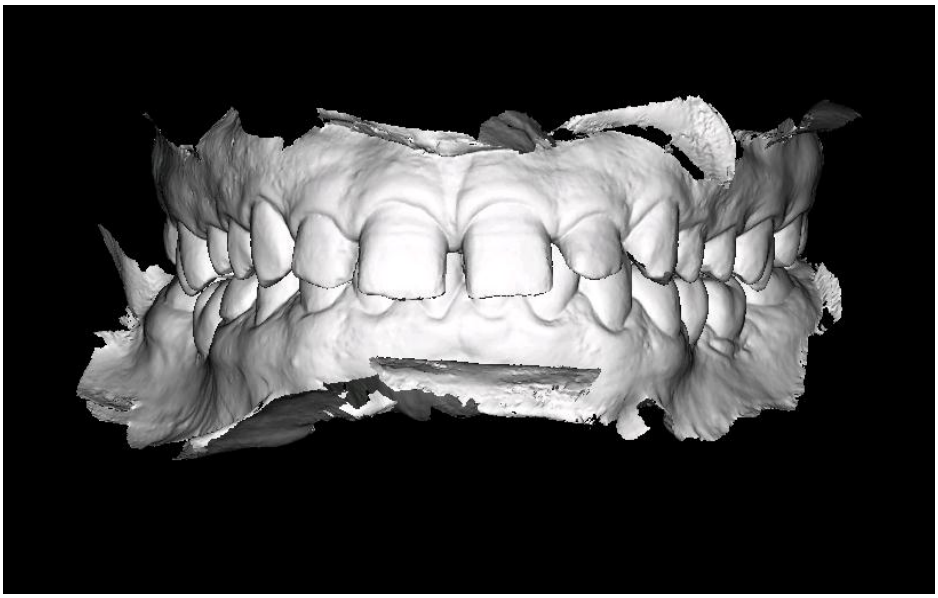


Figure 4. Intraorally scanned model frontal view

Figure 5. Orthodontic stone cast Frontal view

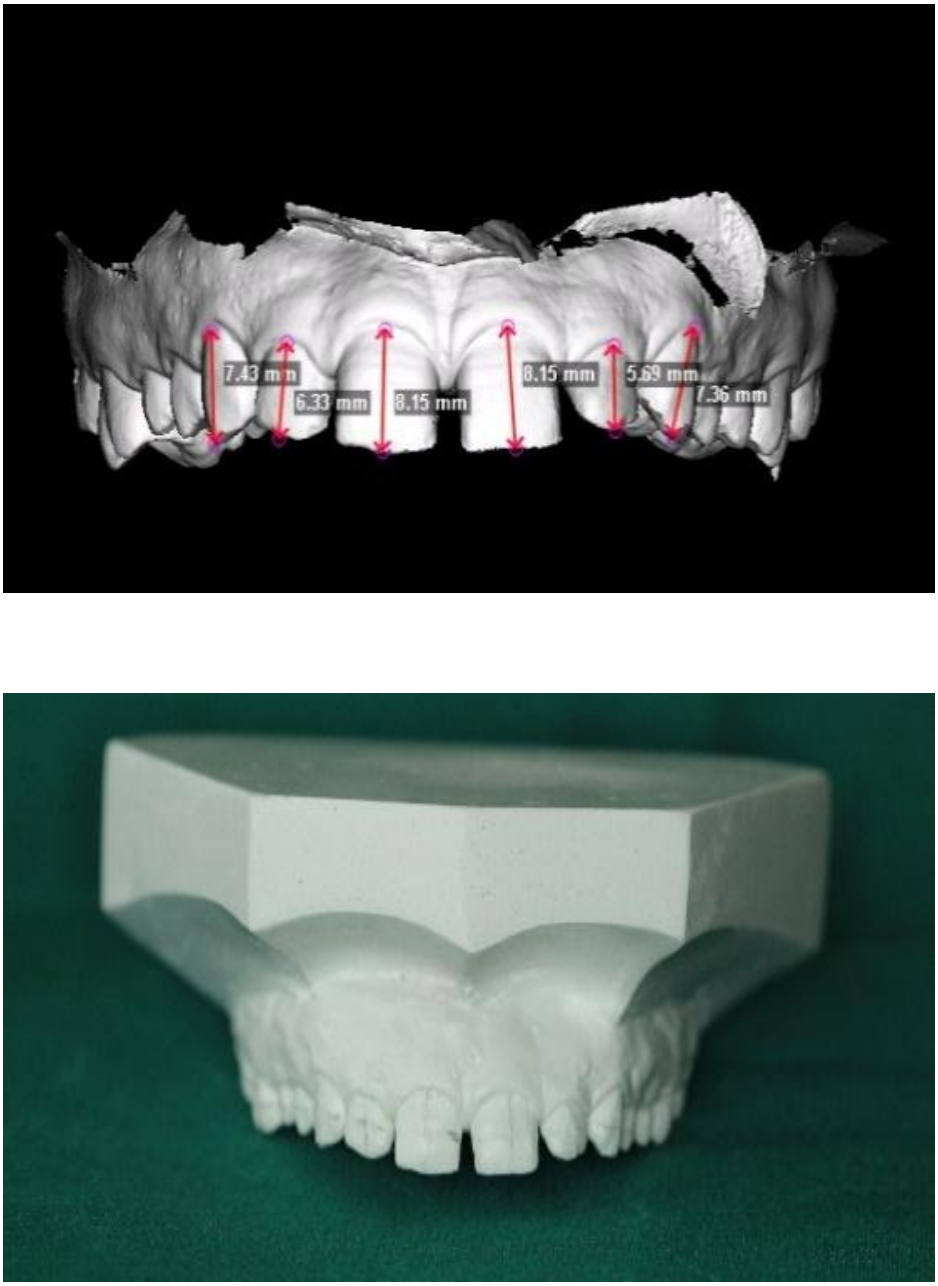


Figure 6. Height of crown measured in frontal view of both intraoral scanned model and plaster cast

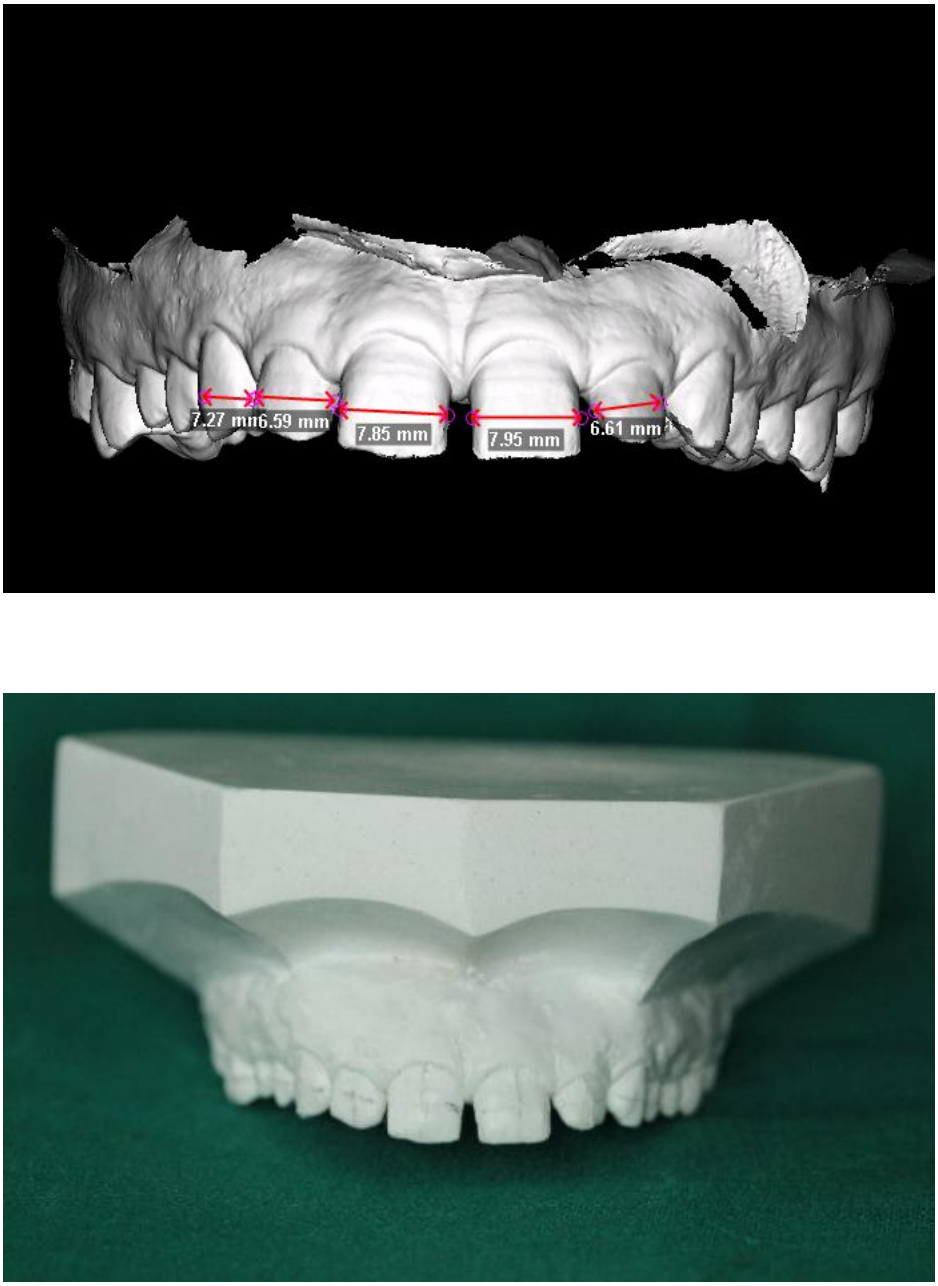


Figure 7. Frontal view of mesiodistal width measured on intraoral scanned model and plaster cast

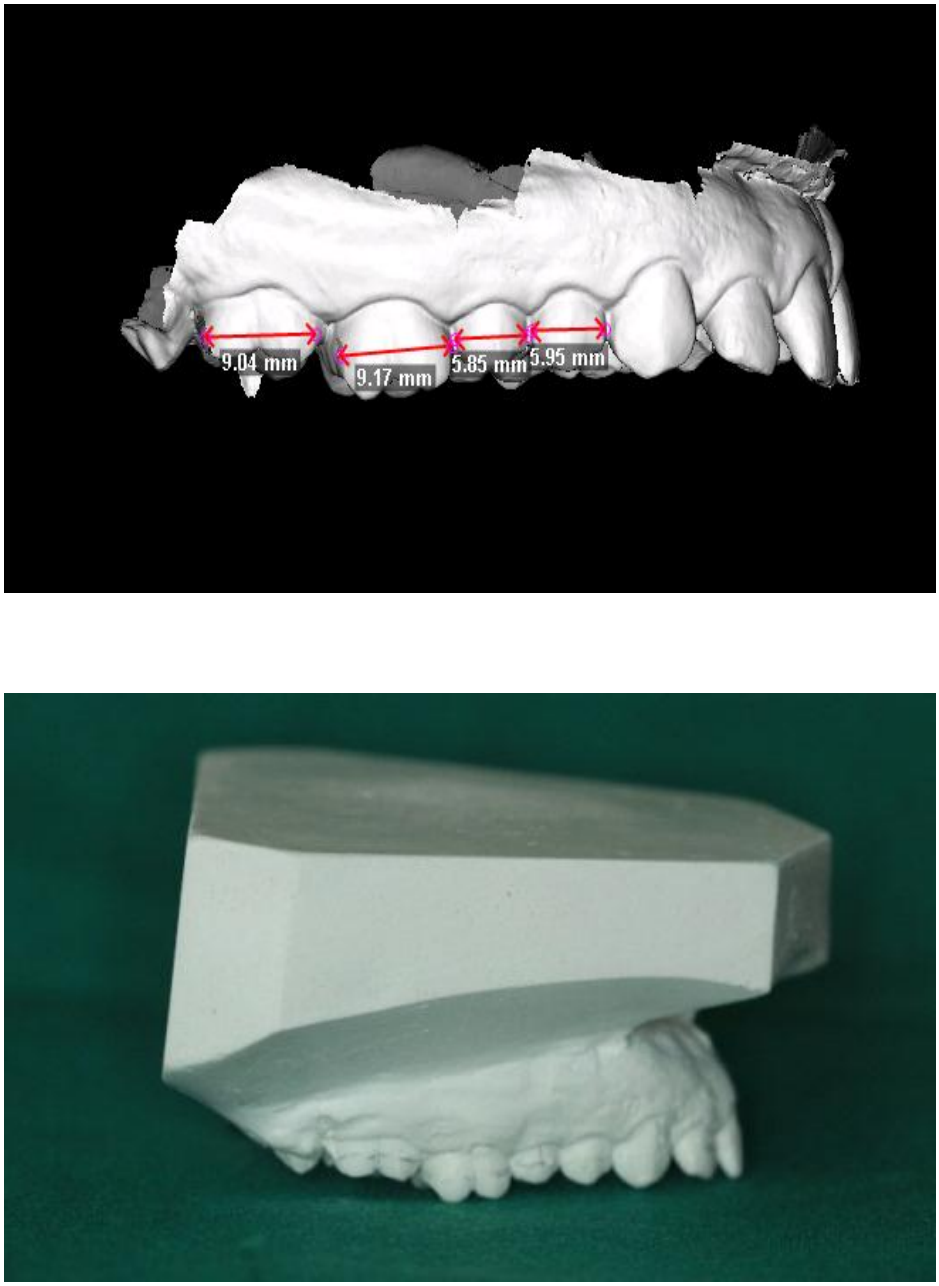


Figure 8. Right lateral view of mesiodistal width measured on intraoral scanned model and plaster cast

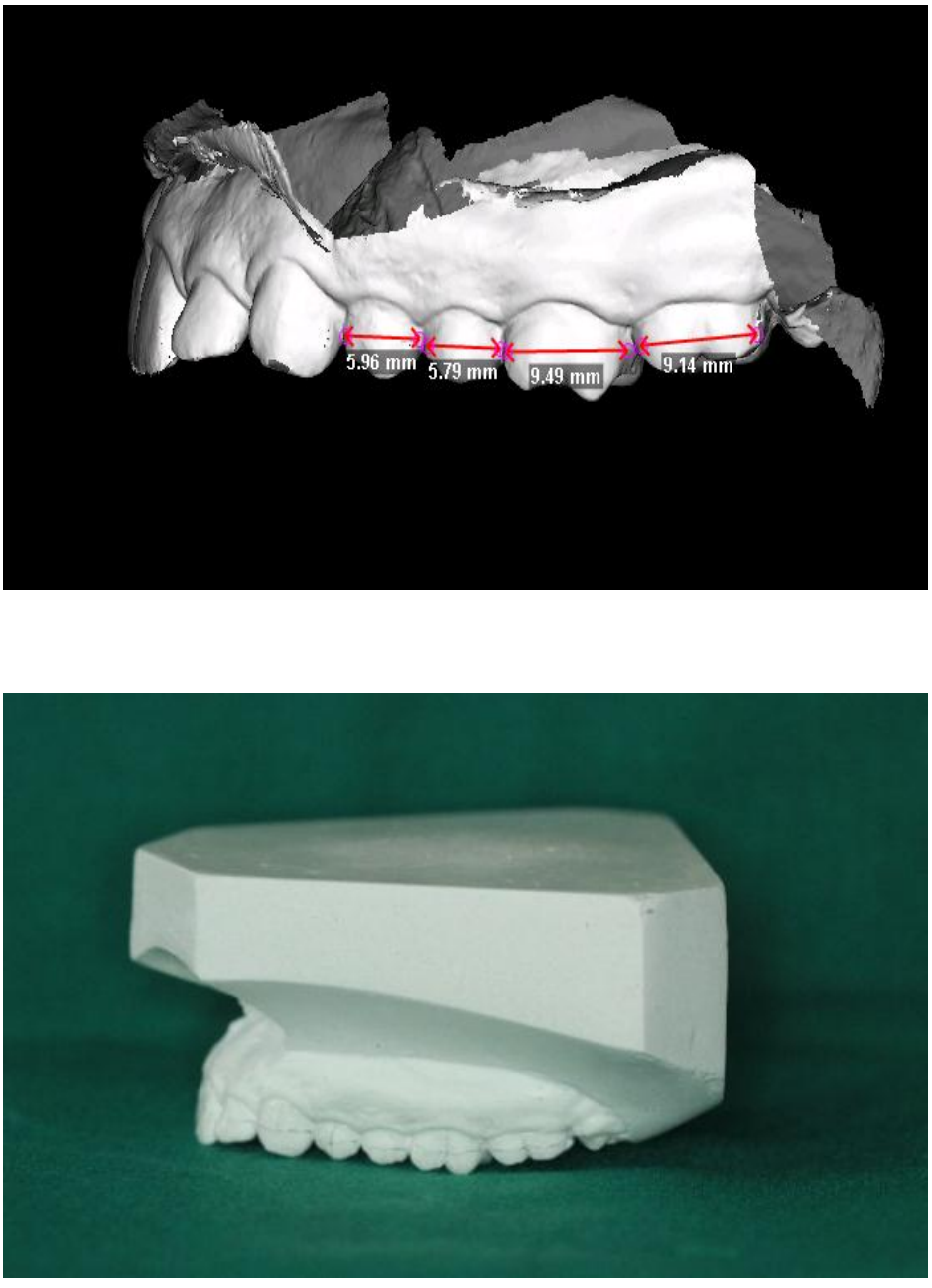


Figure 9. Left lateral view of mesiodistal width measured on intraoral scanned model and plaster cast

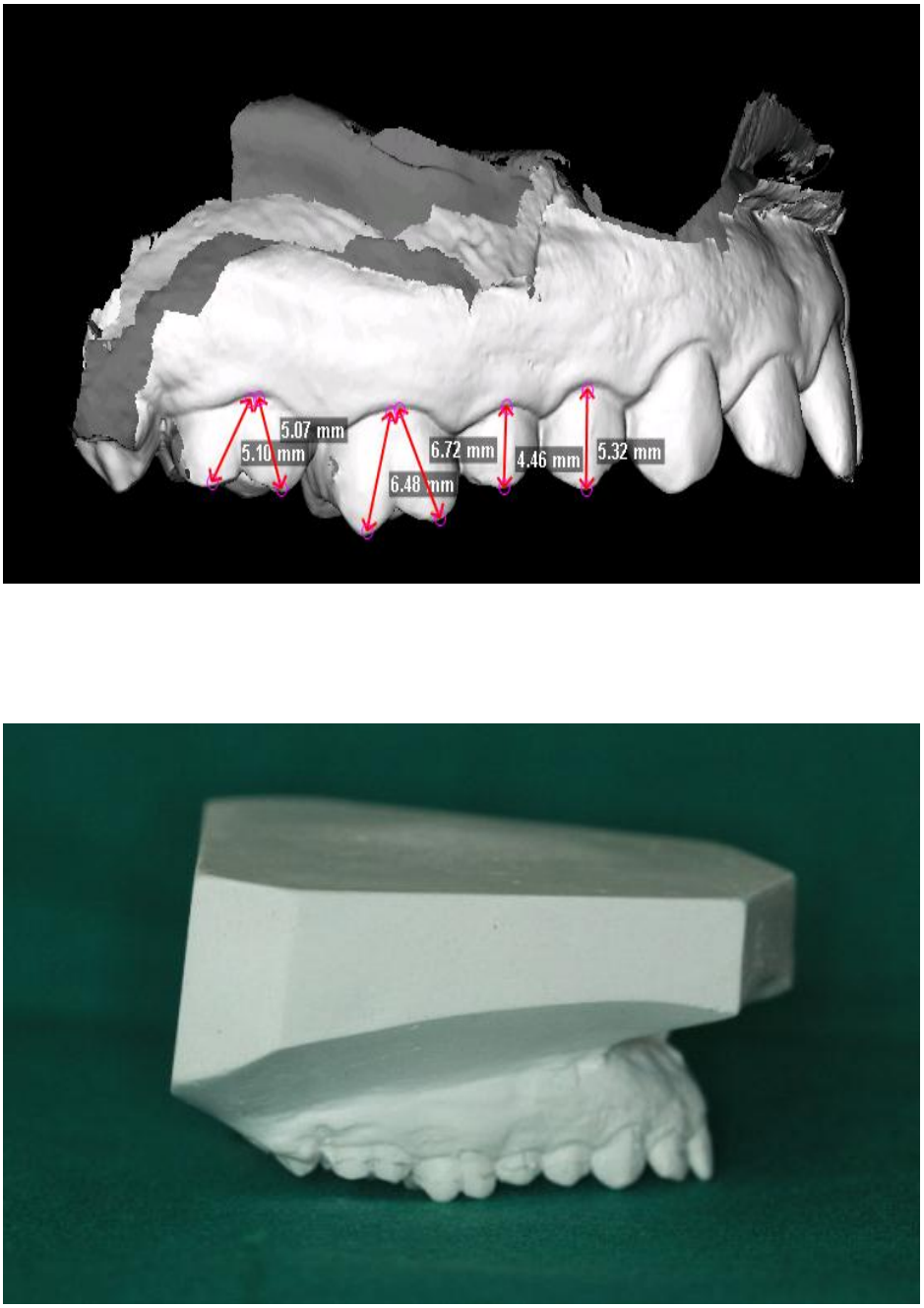


Figure 10. Right lateral view of height of the crown measured on intraoral scanned model and plaster cast

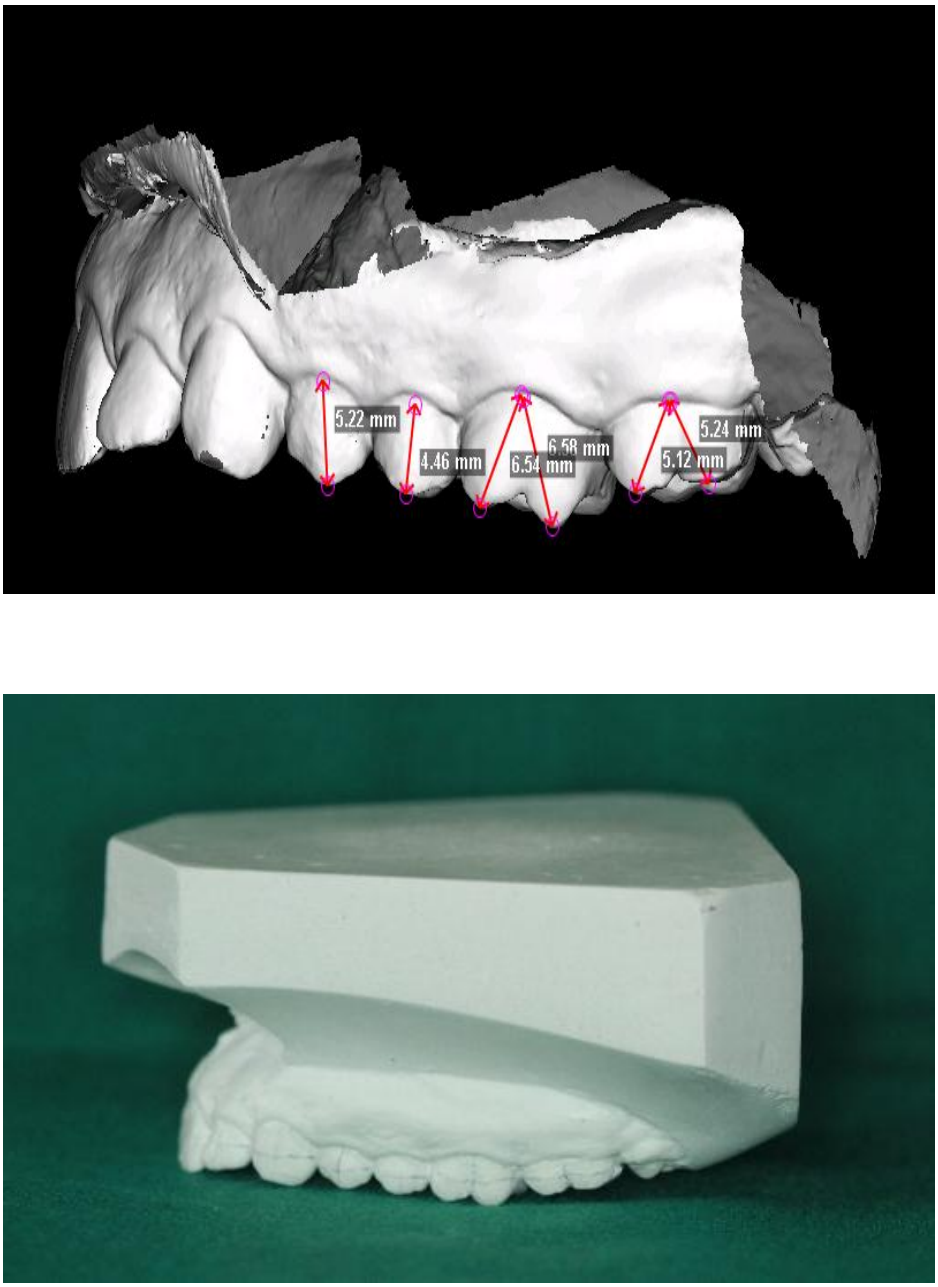


Figure 11. Left lateral view of height of the crown measured on intraoral scanned model and plaster cast

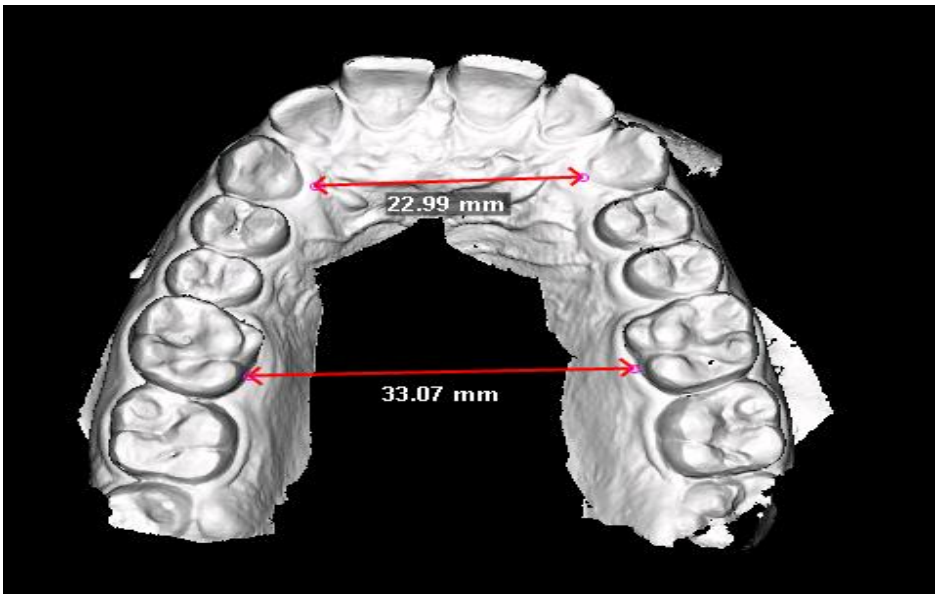


Figure12. Inter-canine and inter-molar width measured on upper occlusal aspect of intraoral scanned model and plaster cast

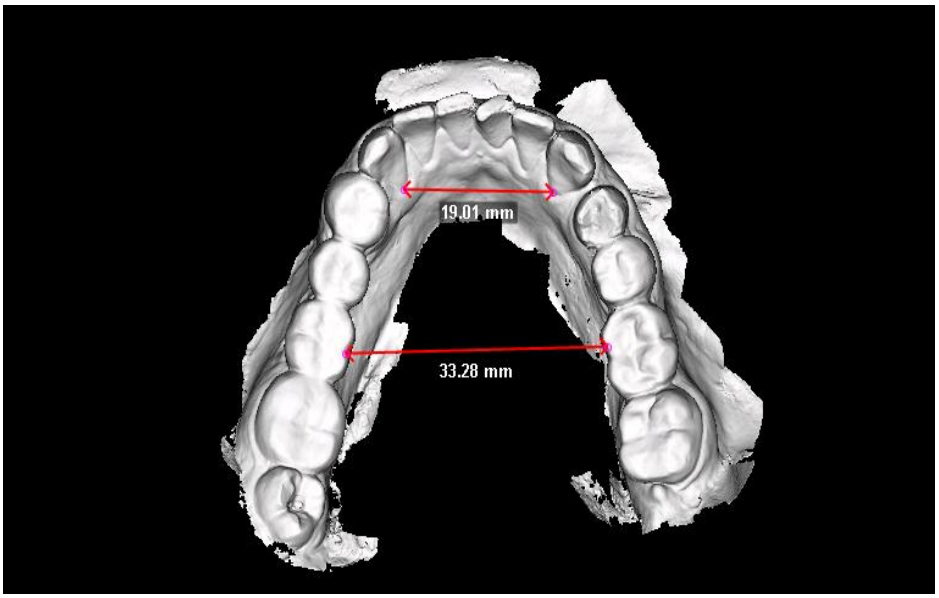
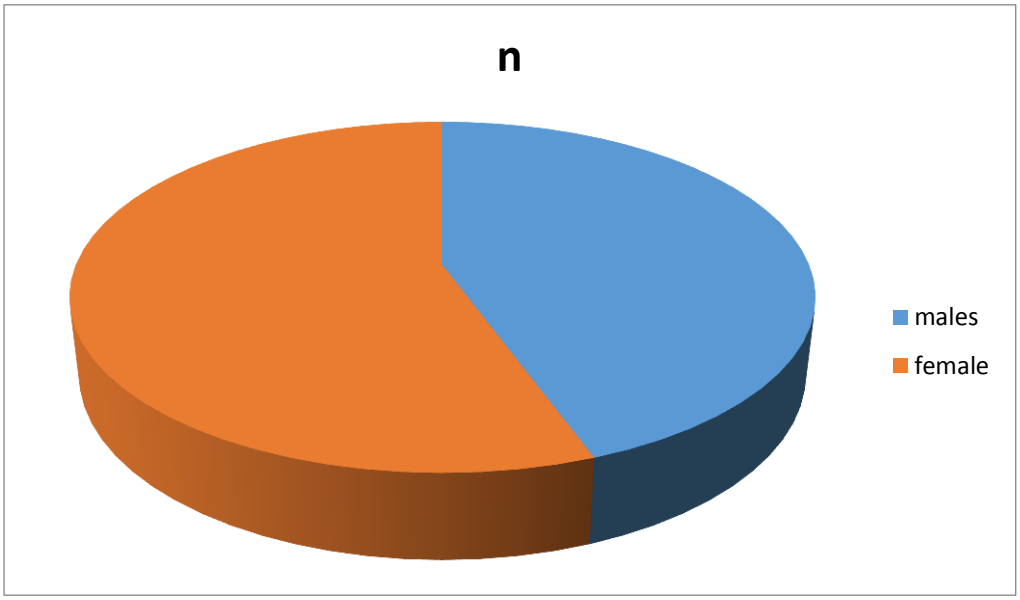


Figure 13. Inter-canine and inter-molar width measured on lower occlusal aspect of intraoral scanned model and plaster cast

Results

RESULTS

A total of 9 patients were selected using simple random sampling based on the inclusion criteria in which total of 4males and 5 females, within the age group of 15-30.



Total number of patients n=9 in which 5 females and 4 males

The measurements were made from 2 groups and the following parameters were measured and following statistical data, were derived.

1. The mesiodistal width of individual tooth in maxillary and mandibular arch.
2. The height of the crown of individual tooth in maxillary and mandibular arch.
3. The inter-canine and inter-molar width of maxillary and mandibular arch.
4. Anterior and Overall Bolton ratio.

Statistical analysis were performed using statistical package for social sciences software (SPSS version 22.0) and data comparison was done by applying specific statistical test to find out the statistical significance of obtained result

MESIODISTAL WIDTH

The mesiodistal width of each tooth measured with the 2 different groups by single examiner and were compiled systematically in Microsoft excel sheet for descriptive statistics. The mean mesiodistal width for each group (PLASTER and IOS) was calculated for each tooth with the above data(Table 1). There was no statistically significant difference in mesiodistal width of each tooth.

Normality of the entered data set was checked statistically using Shapiro-wilk test and the data was found to be normally distributed ($p < 0.05$).Independent sample t test was used to compare mesiodistal width, between both the groups**(**Figure 14,15).Depending on the nature of data statistical test was chosen with p value of ≤ 0.05 was considered to be significant.

There is no statistically significant difference in both the groups.

LENGTH OF CROWN

The length of the crown was measured for both the group separately by a single examiner and were compiled systemically in Microsoft excel sheet for descriptive statistics.

The mean length of crown for each group (PLASTER and IOS) was Calculated for each tooth with the above data. There was no statistically significant difference in length of each Tooth (Table 2), Independent sample t test was used to compare, length between both the groups**(**Figure 16,17).

There was no statistically significant difference in both the groups.

ANTERIOR BOLTON RATIO

The anterior Bolton ratio was measured separately for both the groups (PLASTER and IOS) and statistical mean was taken. Mean Anterior Bolton ratio were calculated for both the groups (Table 3&Figure 18).

There was no statistically significant difference in both the groups.

p(0.856).

OVERALL BOLTON RATIO

The overall Bolton ratio was measured separately for both the groups (PLASTER and IOS) and statistical mean was taken for both the groups(Table 4 &Figure 19). Comparison of overall Bolton ratio for both groups was done with and it was found that.

There was no statistically significant difference between both the groups

p(0.958).

INTER-CANINE WIDTH

The inter-canine width was measured separately for both upper and lower arch separately in both (PLASTER and IOS).And mean for both the group was calculated separately (Table 5).

Results showed that no statistically significant difference between both the groups.

with the following p value (Table 5&Figure 20).

Inter-canine upper (p=0.699).

Inter-canine lower (p= 0.692).

INTER-MOLAR WIDTH

The inter-molar width was measured for both the upper and lower arch Separately in (PLASTER and IOS).And mean value for both the group was calculated separately (Table 6 & Figure 21).

Results showed that there was no statistically significant difference in both the groups.

with the following p value (Table 6).

Inter-molar upper (p=0.936).

Inter-molar lower (p=0.938).

Tables and Graphs

Table 1 – Measurement of Mesiodistal width (mean value & SD) in the 2 groups.

MEAN AND STANDARD DEVIATION N=18			
TOOTH NUMBER	**IOS**	**SC**	**p-value**
11	8.32± 0.56	8.36 ±0.53	0.860
12	6.65± 0.78	6.82 ±0.65	0.623
13	7.57± 0.49	7.69 ± 0.42	0.581
14	6.89 ± 0.45	6.81 ± 0.46	0.718
15	6.28 ± 0.59	6.02 ± 0.44	0.319
16	9.70± 0.54	9.71 ± 0.55	0.983
17	9.20± 0.28	9.48 ± 0.31	0.060
21	8.09± 0.79	8.34 ± 0.47	0.426
22	6.55± 0.75	6.92 ± 0.71	0.295
23	7.48± 0.56	7.53 ± 0.56	0.841
24	6.90± 0.56	6.69 ± 0.30	0.324
25	6.15 ± 0.72	5.95 ± 0.51	0.505
26	9.37 ± 0.72	9.16 ± 0.57	0.502
27	9.25 ± 0.36	9.44 ± 0.45	0.333
31	4.96± 0.13	5.04 ± 0.20	0.350
32	5.42± 0.44	5.41 ± 0.29	0.990
33	6.38 ± 0.29	6.45 ± 0.42	0.675
34	6.72 ± 0.66	6.76 ± 0.64	0.899
35	6.72 ± 0.43	6.78 ± 0.30	0.748
36	10.60± 0.89	10.53 ± 1.02	0.866
37	10.06 ± 0.57	9.95 ± 0.61	0.700
41	4.97 ± 0.38	5.11 ± 0.40	0.463
42	5.37 ± 0.53	5.53 ± 0.51	0.532
43	6.45 0.42	6.45 ± 0.43	0.970
44	6.50 ± 0.45	6.73 ± 0.45	0.286
45	6.60 ± 0.71	6.42 ± 0.42	0.524
46	10.61 ± 0.77	10.42 ± 0.88	0.629
47	9.99 ± 0.47	10.05± 0.55	0.830

Table 2– Measurement of length of crown (mean value & SD) in the 2 groups.

MEAN AND STANDARD DEVIATION N=18			
TOOTH NUMBER	**IOS**	**SC**	**P-VALUE**
11	9.23 ± 1.19	9.47 ±1.26	0.675
12	7.52 ±1.02	7.53 ±1.01	0.987
13	8.37 ±1.65	8.53 ±1.61	0.840
14	7.28 ± 0.99	7.23 ± 0.94	0.918
15	6.34 ± 1.00	6.35 ± 0.93	0.989
16	6.88 ± 0.63	7.05 ± 0.70	0.610
17	6.08 ± 0.75	6.24 ± 0.61	0.638
21	8.82 ±1.68	9.19 ±1.29	0.611
22	7.41 ± 1.25	7.42 ±1.12	0.984
23	8.54 ± 1.61	8.57 ±1.52	0.964
24	7.10 ± 0.95	7.07 ± 0.85	0.947
25	6.03 ±1.13	6.03 ± 0.80	0.996
26	6.68 ± 0.58	6.83 ± 0.62	0.597
27	6.20 ±1.09	6.33 ±1.08	0.800
31	7.48 ±1.40	7.54 ±1.36	0.927
32	7.45 ± 0.96	7.58 ±1.03	0.788
33	8.82 ± 1.13	8.89 ±1.19	0.902
34	7.52 ±0.74	7.66 ± 0.83	0.715
35	6.94 ± 0.74	6.79 ± 0.71	0.688
36	6.98± 0.72	7.09 ± 0.78	0.751
37	6.46± 0.97	6.45 ± 0.90	0.982
41	7.18 ±1.22	7.22 ±1.30	0.946
42	7.06 ±1.33	7.04 ±1.50	0.973
43	8.32 ±1.32	8.55 ±1.44	0.731
44	7.43 ± 0.58	7.48 ± 0.55	0.875
45	6.77 ± 0.36	6.62 ± 0.35	0.397
46	6.87 ± 0.59	6.92 ± 0.65	0.880
47	6.38 ±.0.94	6.63 ± 0. 82	0.564

Table 3- Comparision of Anterior Bolton Ratio for 2 groups

Groups	Mean	SD	P-value	Ovreall P-value
IOS	74.74	2.57	0.856	0.856
PC	74.52	2.44		

Table 4- Comparision of Overall Bolton Ratio for 2 groups

Groups	Mean	SD	P-value	Ovreall P-value
IOS	90.53	3.39	0.958	0.958
PC	90.43	4.33		

Table 5- Comparision of Inter-canine value for 2 groups (mean value & SD) in the 2 groups

GROUPS	INTERCANINE		P-Value	
	UPPER	LOWER	UPPER	LOWER
IOS	24.36 ± 2.69	19.11 ± 1.92	0.699	0.692
PC	23.85 ± 2.85	18.74 ±1.89		

Table 6- Comparision of Inter-molar value for 2 groups (mean value & SD) in the 2 groups.

GROUPS	INTERCANINE		P-Value	
	UPPER	LOWER	UPPER	LOWER
IOS	35.15± 5.42	34.22 ± 5.22	0.936	0.938
PC	34.94 ± 5.41	34.03 ± 5.15		

Tables and Graphs

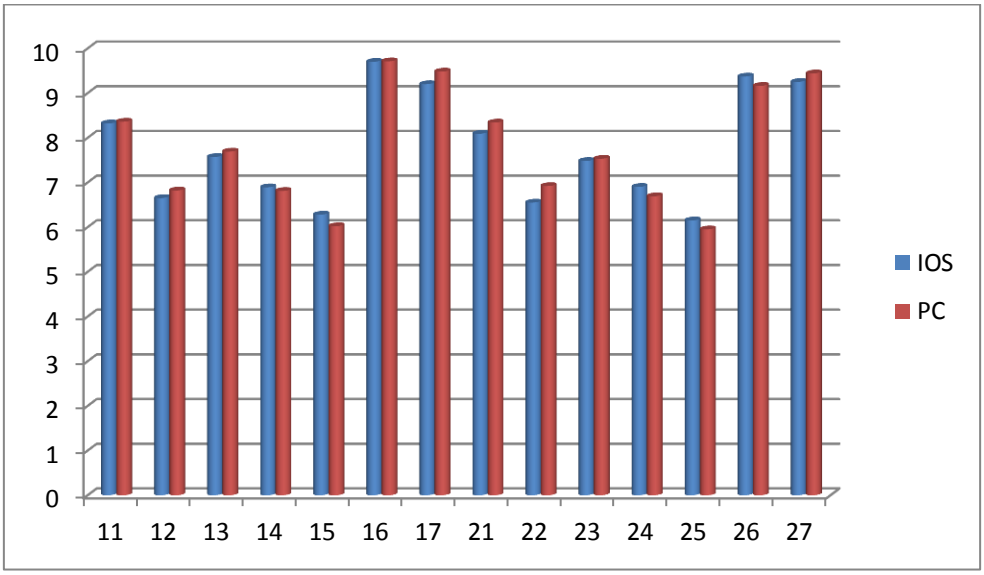


Figure 14. Comparison of mesiodistal width of individual tooth in maxillary arch under 2 groups.

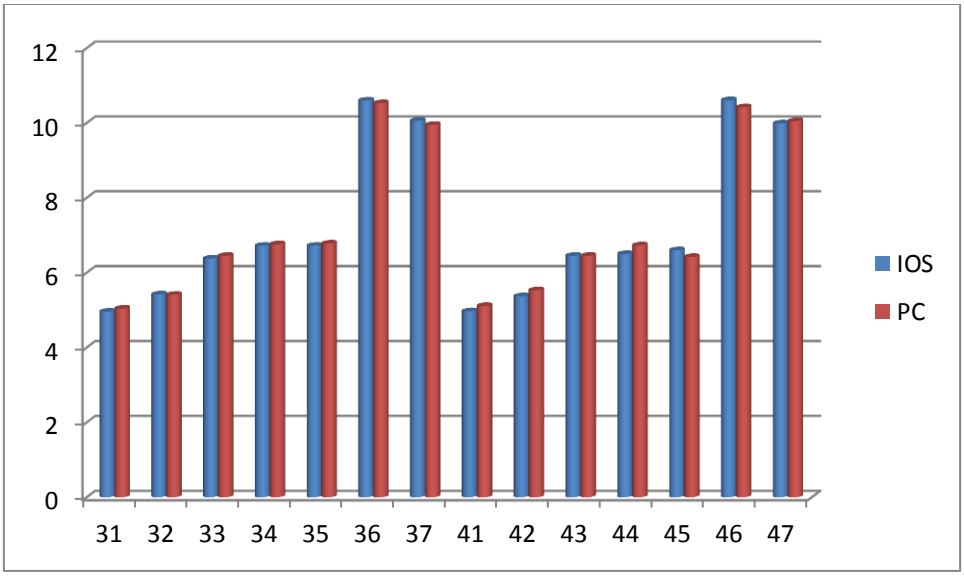


Figure 15. Comparison of mesiodistal width of individual tooth in mandibular arch under 2 groups.

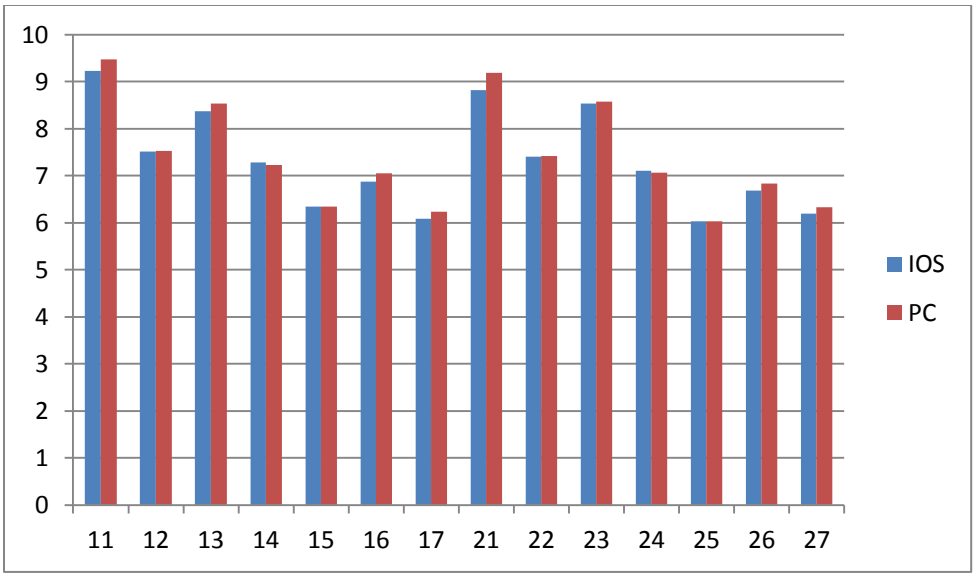


Figure 16. Comparison of length of crown of individual tooth in maxillary arch under 2 groups.

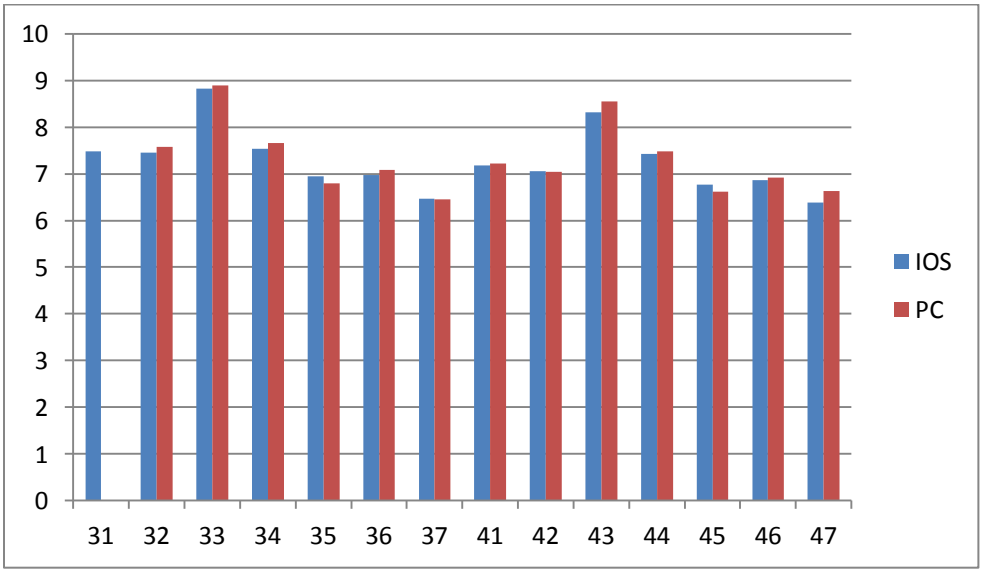


Figure 17. Comparison of length of crown of individual tooth in mandibular arch under 2 groups.

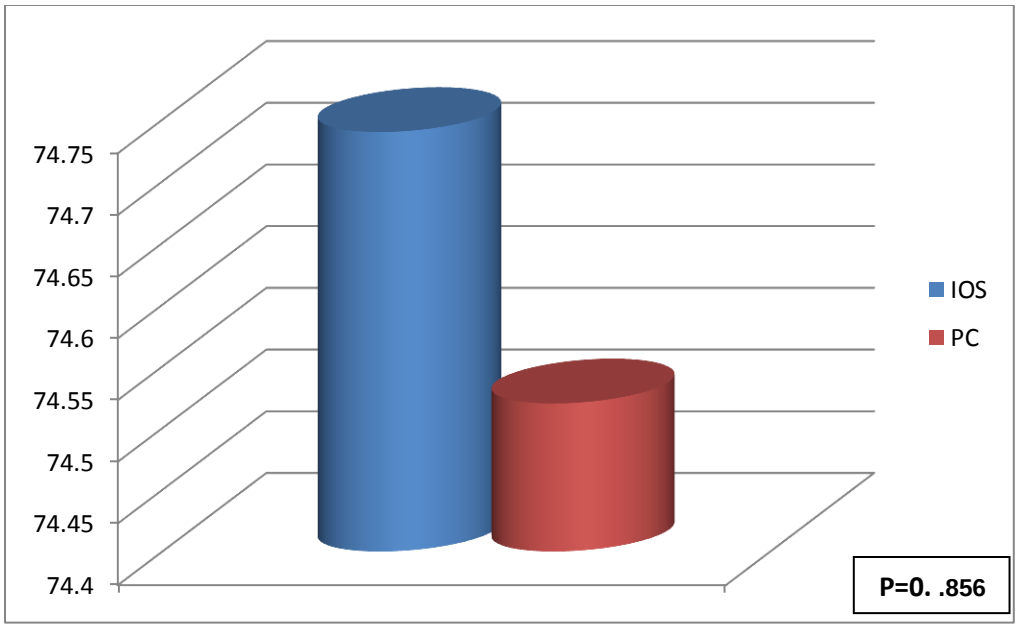


Figure 18. Comparison of anterior bolton's ratio between 2 groups.

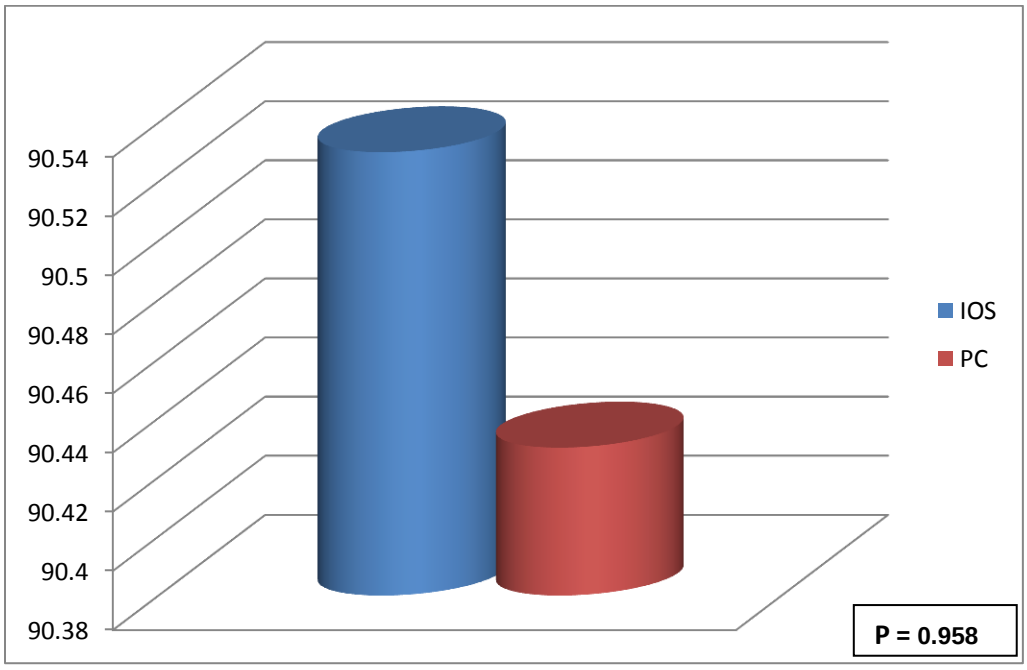


Figure 19. Comparison of overall bolton's ratio between 2 groups.

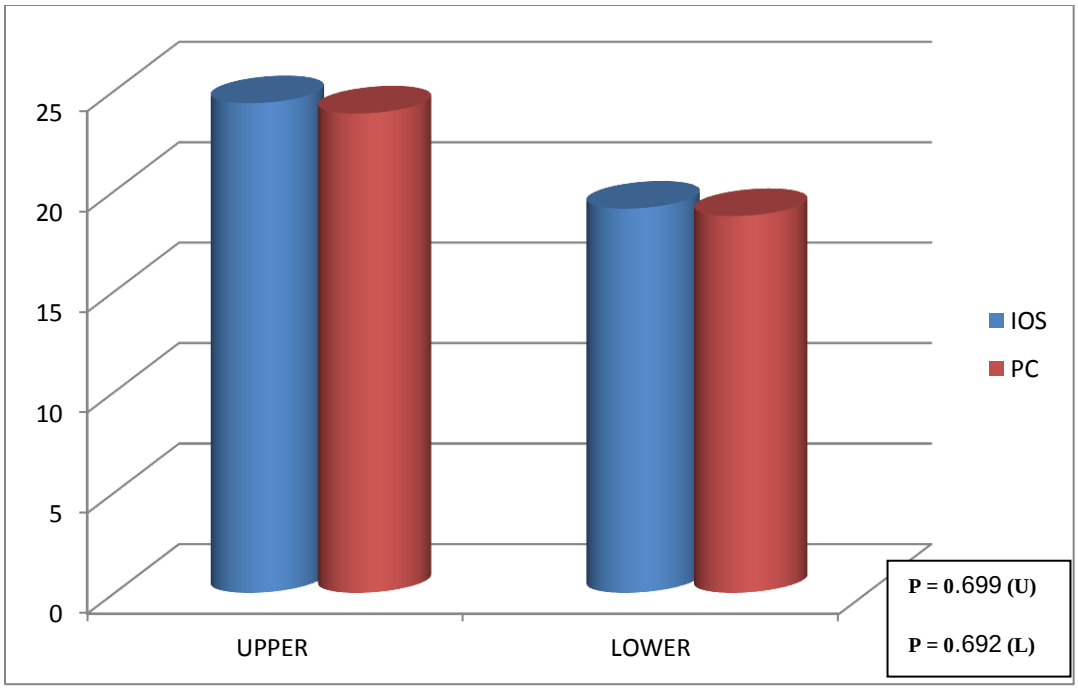


Figure 20. Comparison of inter-canine values between 2 groups.

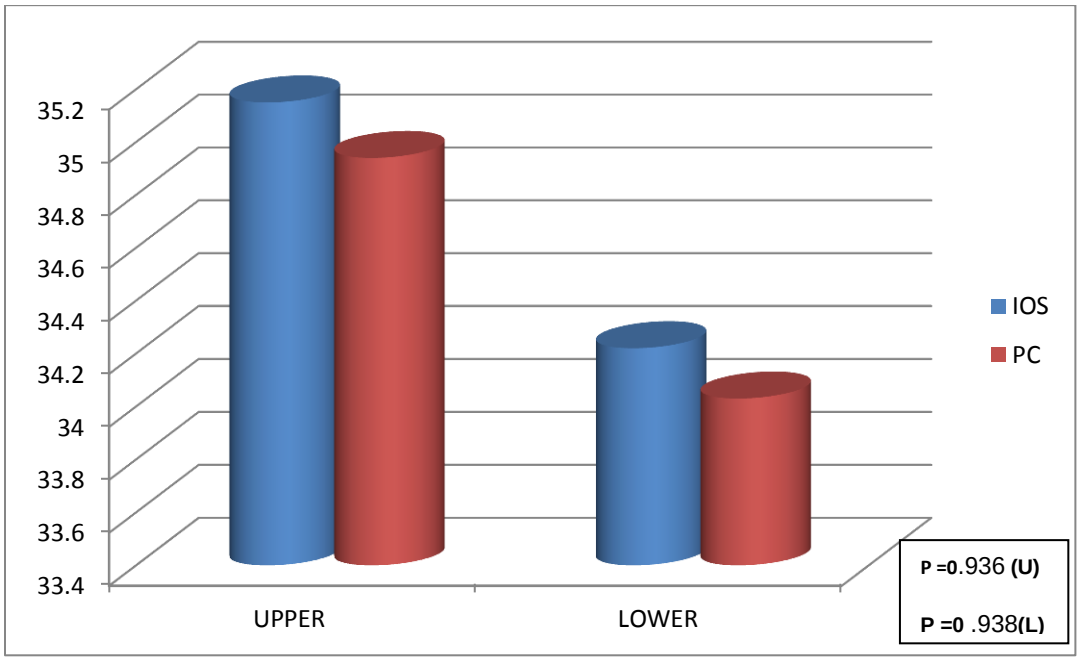


Figure 21. Comparison of inter-molar values between 2 groups.

Discussion

DISCUSSION

Digital technology is evolving each day in the field of dentistry. The progression to paperless office has promoted the use of digital records, including consent form and financial agreement. Orthodontic study models are a cornerstone in diagnosis and treatment planning. Clinical examination along with study models, photographs, and radiographs, gives us the complete information which is required to diagnose the malocclusion and also helps to develop an comprehensive treatment plan.[48,43]

By definition, "orthodontic study models are an accurate plaster reproductions of teeth and their surrounding soft tissues that are essential diagnostic aid that make it possible to study the arrangement of teeth and occlusion from all directions"

Study models provide a three-dimensional view of a patient's occlusion, which helps the clinician to evaluate the severity of the malocclusion. The downside of conventional plaster models are mainly the long term storage of study models, chipping of the anatomic details leading to loss of information and breakage of study models are the frequent problems encountered but the same information can be obtained from study models which are stored electronically.[52]

Digital impression systems eliminate several dental office procedure such as selection of trays, preparation and mixing materials, disinfecting the impressions and sending impressions to lab. Moreover, lab time is reduced by not having to pour the plaster models.[21] Additionally, they enhance patient comfort and improve patient acceptance and understanding of the care.[31]

Since, the introduction of **CAD/CAM in 1980** it had three phases which are **digitization, computer aided design, and computer aided manufacturing**. With the continuous advancement of the digital era, Cadent in 1995, was early developed by Technomatrix. The first commercial product was released in 2001 and was termed as OrthoCAD; it was the device which allowed scanning of the conventional Plaster model. It can be used to do a virtual setup as well as customized fabrication of orthodontic bracket placement, **Cadent in 2006 launched iTero** digital Impression enabling quadrant scan along with crown restoration, and fabrication of inlay/onlays. In **2007,** it included ¾ crowns, implant abutment, veneers and an measurement tool and a quad processor was added along with it for enhancing the speed of the capture. In the year **2008,** full arch scanning was added and upgraded with following indications such as bridges, cantilever and bonded bridges and also added a feature of video view. In **2010,** it was upgraded to **100% digital production workflow without cadent milled model.** In **2011** cadent along with implant companies developed feature of implant scanning and the

current iTero v4.05 has released with full arch scan capability which is expanded to the current invisalign.[31]

To overcome the demerits of conventional plaster model, digital impression was chosen as an alternative.

There are two different digital scanning technologies that are available in dental scanning industry**; parallel/confocal and triangulation sampling**.

The operative principle used in the CEREC or E4D scanner is called **triangulation.**

Powder coating is applied to one angled cone of light and it captures a single image at 15,000 microns a total of 3 beams of light intersect to locate a particular point in space. Most common problems with this technology is the various Surfaces light disperses differently and it may affect the accuracy and the thin and uniform coating of titanium dioxide/ zirconium oxide may affect the accuracy of scan. To replace the demerits of powdered scanner, non-powdered iTero scanner came into exsistance.[31]

The operative principle used in the iTero scanner is called "parallel confocal".

A laser light source passes through a small filtering pinhole. The sensor which is placed in the confocal plane (in focus) when the light is focused on the target object. The light is then reflected off of the object and a

small aperture which is present in front of the sensor blocks light which is not in focus. Only the reflected light that is in focus passes back through the pinhole. Only reflected light that is in focus will return through the filtering mechanism. Better images are obtained.

iTero captures 1,00,000 points of laser light at perfect focus at 300 focus depth in a 14x18 mm pattern, and produces a 15mm scan depth. camera wand, converts the reflected light into digital data in 1/3 of a second, with an accuracy of 15 microns. The confocal technology is a true optical scan, does not require powder dusting.[21,31]

Cameras capture the **data** and the technology stitches the images together in real time and Captures 20 3-D **data points** per second. These are created to represent the surface of the tooth and partly the supporting soft tissue. All the data points are then sent via internet to the dentist's office and are viewed in proprietary company- supplied software, which resides on the practitioner's computer. The software allows total visualization of the models in three dimensions so that the orthodontist can evaluate several parameters of the patient's dentition such as the occlusion, mesiodistal width, Bolton's Ratio, length of crown, inclination of tooth, arch length, arch width, overjet, and overbite and also treatment simulation can be done using the software. Every company has a own program to produce these and other measurements.[21]

Digital technology has now spread into the entire field of orthodontics, and Intra oral cameras are now easily available enabling practitioners to capture digital impressions. Digital three-dimensional(3D) orthodontic models has become a vital alternative to traditional models for few diagnostic measurements, like Bolton ratio, tooth size, arch width, overjet, overbite and arch length. According to Profit, computer analysis requires less time with an additional benefits of easier storage.

According to Bolton, the correct maxillary and mandibular mesiodistal tooth size relationship is the most important factor in achieving the proper occlusal interdigitation in the finishing stages of orthodontic treatment. He computed particular ratios of the mesiodistal width that should exist between maxillary and mandibular teeth from both canine-canine and first molar-first molar so as to obtain proper optimum occlusion. The precision of the plaster models are mostly influenced significantly by the processing aspects and impression technique.[4]

It is, therefore, important to evaluate the tooth size- arch length discrepancy for all orthodontic cases.

Virtual casts can be kept clean and are easy to archive. Storage is no longer a problem. Digital casts can also be uploaded to patients, who simply open the file and view using 3D visualization software. Apart from storage other features of digital technology include.

Clincheck –iTero software accelerates clincheck treatment plan, along with in office simulation. Which greatly improves patient acceptance and communication. 3D printing in case of need for physical model. Fabrication of aligners, appliances and indirect bonding set up trays.[31]

Hence, the aim of the present study is to evaluate the accuracy of non powdered digital impression (iTero) by comparing mesiodistal width measurements and Bolton ratio, height of tooth and inter-canine and inter-molar width obtained through intraoral digital impression and compare it with conventional models.

The selection criteria of the patients included:

- Teeth which showed no visible attrition
- Teeth with no Caries or restorations which can affect the mesiodistal or buccal-lingual diameter/ measurement of the crown.

To evaluate the tooth size-arch length discrepancy by Sheridan (2000), determining the index with traditional measuring methods is laborious, so it is not undertaken in more than half of the cases in clinical practice. **Digital procedure included the iTero Digital Impression System presented in this study makes measurements and calculations much faster and precise after the casts are digitized using clincheck simulation feature of iTero**.[46]

Mesiodistal width of the tooth measured in plaster model is conventionally done by using a boley gauge or needle point divider for bolton's analysis. The Operator variation plays an important role when the measurements are done on 3D computer images. The operator has to use a mouse to click on the relevant points. Since the distance between the points are calculated by the computer, there is no need for the operator to read in a measuring scale therefore, reducing the **intra operator variability.**[5]

Champagne, in 1992 studied another technique **by photocopying plaster model** and measured the mesiodistal width in those images and concluded that this method did not show accurate and reliable measurement compared to manual measurements done in plaster model.[7]

Mullen et al 2007, said that it is necessary to remove certain teeth in a crowded dentition, followed by an accurate space analysis which is a very important step before a treatment plan is fabricated. Steps in diagnosis involves computation of the space which is available in that arch to the overall mesiodistal (MD) widths of all the teeth to be accommodated. And to achieve functional occlusion with proper overbite and overjet, the mandibular and maxillary dentition must be well proportioned in size .[25]

Redlich et al, 2008 states that regular measurments like arch length and tooth width is needed for space analysis. Which is often required on deciding on the appropriate treatment plan. Today 3D technology gives new

alternative for the clinician to replace manual measurements and avoid measuring errors. The technology includes 3d images of scanned object along with measuring software.[33]

Several companies now offer computer based three-dimensional models. Generally, impressions of the patient's occlusion, are taken at the practitioner's office, and forwarded to the company.

The CEREC system (powdered intraoral scanning) was developed as visit in-office scanning and milling system to produce ceramic restorations from prefabricated ceramic "blocks". **The much different Cadent (iTero) system developed an in–office intraoral optical scanning unit which uses digital data sent via the internet to a centralized milling center, or specific dental laboratory.** The current iTero v 4.05 software was released with full arch scan capability expanded to Invisalign previous software which didn't had full arch scan capability.[31]

The iTero device consists of a mobile cart and it is mounted on caster wheels to facilitate moving the unit between operatories. There is a hand held scanner wand attached to the cart via a cord to carry scan data to the unit.

The Align iTero technology does not require any powder dusting or accent frosting, regardless of the type of scan or restoration desired. The full arch scanning and detailed coronal reproduction required for Invisalign

submission mandate the use of high-quality scan with interproximal detail and accuracy.

ClinCheck treatment plans or in-office treatment simulation which greatly improves patient acceptance and communication.[31]

DICOM and iTero STL files offer virtual "waxup" and planning to create precise tissue and tooth supported surgical guides.[31]

Some of the software's that help orthodontist in diagnosis and treatment planning:

eModels (GeoDigm), Suresmile (Orametrix), Anatomodel (Anatomage), Orthocad, Digiceph, and vistadent.

There are many types of digital dental casts available for the clinician today; The question arises regarding the accuracy and reliability of these digital casts when used for measurements and analyses. To achieve a proper diagnosis and better treatment planning, it is necessary that digital casts accurately replicate the patient's intraoral condition and it is important that the clinician selects a method that is accurate, reproducible.

Hence, the present study has chosen to measure the accuracy of (iTero) digital model to overcome the operator error failures and demerits of conventional plaster model. To check the accuracy, dolphin

11.8 version, most familiar and easily available software to an orthodontist is used.

The current iTero v 4.05 software which has several features like fabricate all types of restorations from single unit to multiple units, fabrication of any indirect restoration from provisionals, all metal (gold), porcelain fused to metal, porcelain full, partial veneer coverage to inlays/onlays of any type material or in virtual "wax-up as an surgical guides. **Our study** aim to use an alternative software **(dolphin 11.8)**which is as accurate as that of current iTero v 4.05.[31]

iTero software features direct export of STL files. Which were used in the present study which is considered to be most accurate and standardized.

Though several studies have published reports on accuracy of other Intra-oral scanners like CEREC AC BLUECAM and iOC intraoral scanner, not many studies have reported on the accuracy of linear measurements done with intraoral scanner obtained through digital impressions.

Accuracy of measurements

Study models are more amenable to routine measurements than intraoral measurements and routine essential step in the analysis of a patient's malocclusion .Till date several methods have been used to measure and analyze plaster casts. Dividers, calipers, and Boley gauges have provided the standard of measurement against which newer methods have been evaluated.

Vernier caliper, method relies on the operator placing the tips of the caliper on definite landmarks and the distance must be read from the ruler on the caliper**. Using a measuring caliper is for that reason subject to inter-and intra operator variation** (**Bell et al, 2003**), stated that a slight differences in the positioning of measuring calipers manually and even when the points to be measured are visibly marked, **there will always be some variations in manual measurements.**[5]

Operator variation also plays a role when the measurements are done on 3D computer images. The operator has to use a mouse to click on the relevant points. **Since the computer calculates the distance between points, there is no need for the operator to read a measuring scale (Bell et al, 2003).**[5]

An operator error of 0.5 was chosen to be acceptable as in accordance with **Akyalcin (2011)**study which states that measurements up to a small range up to 0.5 mm may be included as operator error and therefore, it is considered as clinically acceptable.[1]

Watanebe-Kanno et al (2009) stated that interproximal contact, there can be possibility for the differences and difficulty in locating points. Which is also affected by the operator's familiarity in using a digital model. The disadvantage of digital models according to the author, order to mark or locate the points necessary to obtain a measurement, the models need to be

stationary. The digital models in computer screen can be enlarged, so it gives a significant benefit in locating landmarks because a 3- dimensional structure is viewed as a 2-dimensional image.[52]

Shellhart et al in 1995 found that compared with needle pointer **the vernier caliper is more reliable.** It is said to be reliable because the operator does not have to read it from the ruler and the measurement and intra-observer variation errors are avoided.[45]

In our study, digital vernier caliper and standardized dolphin version 11.8 is used, which is believed to be most accurate measuring tool than boley guage or needle point divider to avoid any intra-observer error.

In the **present study**, Normality of the entered data set was checked **statistically** using Shapiro-wilk test and the data was found to be normally distributed ($p < 0.05$).Independent sample t test was used to compare mesiodistal width, between both the groups.

MESIODISTAL WIDTH AND BOLTONS RATIO

In the present study, Comparison of both (IOS and PLASTER) results Showed there is **no statistically significant** difference in the two groups and in anterior Bolton ratio with p(0.856), for overall bolton ratio with p(0.958).

For locating exact mesiodistal width, boons gauge was used and width of the crown was located and marked in all the plaster cast were measured in reference to the line drawn in maximum mesiodistal width.

Naidu et al found there was large difference in tooth width and Bolton measurement with IOC and digital caliper with mean value of p(0.0083)for tooth width and bolton ratio p(0.0354) and the discrepancy was deemed to be significant statistically. **Not in accordance** with the values of our study, possible reason might be because of using OrthoCADsoftware.[28]

Santoro et al reported OrthoCAD digital tooth width measurements were smaller (statistically significant) compared to traditional orthodontic stone model. In comparison, the present study values where also smaller but statistically not significant.[41]

Horton et al (2010) found that digital model measurements tended to show slightly higher values than actual plaster cast measurements, **not in agreement with** the results of our study.[19] **Tomassetti et al** 2001, found a more significant difference of 1.02 – 1.2 mm between direct measurement on plaster model and digital measurement using OrthoCad. **Not in accordance** with the present study.[47]

Quimby et al (2004) study found that no significant differences between measurements made on the plaster models and those made on the

computer based models. The difference were generally small and **agree** the trend of the results in the present study**.**[32]

For the **accuracy of digital models Mullen et al (2007)**[25] measured Mesiodistal tooth widths ; found that digitally measured values appeared to be slightly smaller statistically than the plaster models.[18]But there was no significant difference between the Bolton ratios calculated with the two methods. Our study **concur** with the results of above.

Watanebe-Kanno et al (2009)[53]concluded that measurements in digital models were lower than the plaster models, differences were considered as clinically insignificant **in accordance with our study.**

Height of the crown

The present study, is the first to evaluate the mean height of the crown which was measured from highest point of CEJ to tip of the crown, in posterior region an occlusal table was drawn and mean value of the cusps were taken to interpret exact length of the crown**.** Which showed mean digital values to be lower as compared with that of plaster model and the result showed that there is no statistically significant difference between the two groups.

TRANSVERSE DIMENSION

In present study, Independent sample t test is used to compare transverse dimension (inter-canine width, inter-molar width) between both the groups. Comparison of both (IOS and PLASTER) results, where ios group showed a slightly higher value. There is **no statistically significant** difference between the two groups in transverse dimension with; Inter-canine upper (p=0.699),Inter-canine lower (p= 0.692), Inter-molar upper (p=0.936), Inter-molar lower(p=0.938).

MAXILLARY INTER-CANINE WIDTH

In **the present study,** the mean maxillary inter canine width for the plaster measurement are slightly less than that recorded for the digital with the difference between digital and plaster being 0.48mm for upper arch respectively.

Quimby et al (2004)[32] calculated a **mean** difference between **maxillary inter canine width to be 0.22** with digital having slightly higher value in transverse dimension, **agree** with our study**.**

Watanebe-Kanno et al (2009)[52] stated that the comparable differences being 0.4mm and 0.16mm respectively, and their plaster measurements are higher. **Not in line** with the result of the present study.

MAXILLARY INTER-MOLAR WIDTH

The mean maxillary inter-molar widths of the plaster measurements are slightly less as compared with digital measurements. The differences between the means for plaster and digital models were 0.21mm for upper arch in **the present study**.

Watanebe-Kanno et al **(2009)** and **Keating et al(2008)**[52,20], concluded that the mean difference between plaster and 3D models were 0.12mm and 0.14mm and found that plaster measurement to be slightly higher. Our study **not in concordance** with the results of above study.

Quimby et al (2004)[32],where digital measurement of mean maxillary inter-molar width to be higher by 0.4mm than of plaster cast, **in agreement** with the result of our study.

MANDIBULAR INTER-CANINE WIDTH

The mandibular inter-canine width for the plaster measurement is slightly lower than that of digital and the differences in the means between plaster and digital were 0.37mm for lower arch **in the present study.**

For lower inter-canine width study by **Watanebe-Kanno et al (2009)** and **Keating et al (2008)[52,20]** found that plaster measurement to be slightly lower, with mean difference of 0.21mm.**Supports** the results of the present study.

Quimby et al (2004)[32], found that mandibular inter-canine width to be higher by a mean of 0.34mm for plaster measurements. **Not in accordance** with the present study.

MANDIBULAR INTER-MOLAR WIDTH

The mandibular inter-molar width for plaster is slightly lower than that of digital and the differences in the mean between digital and plaster model were 0.19 mm in lower arch respectively **in the present study.**

Quimby et al (2004)[32]found the mandibular inter-molar width is almost similar for plaster and digital measurements, with the digital measurement being slightly higher by 0.04mm. **Concur** with the results of our study.

Watanebe-Kanno et al (2009)[52] found the plaster measurement for the Mandibular inter-molar width to be slightly lesser by0.19mm.**In agreement** with the results of our study**.**

Observation of the study states that the Intraoral scanned models (iTero) have more of dimensional variation in transverse dimension**.**

SOFTWARE USED

In the present study, standardized software dolphin 11.8 the STL files were loaded which did not show any dimensional change in trans-proximal contact areas during enlarging of the image.

Santoro et al, 2003[41], compared the **accuracy of OrthoCAD** system on digital model with that of plaster model because of their 3-dimensional visual pointing of interproximal contacts. The clinician gets an enlarged image and digital tools to calculate diameters and distances along certain points and planes measuring on a computer screen can be more or less accurate than the traditional gauge-on-cast method depending on the training, abilities, and preferences of the clinician. And stated more time is needed to measure plaster models. A long learning curve involved in the use of OrthoCAD. It strongly depends on familiarity with the system and newer methods to improve the measurement accuracy.

Schirmer and Wiltshire (1997)[42] found the digitized dimensions are smaller than the manual dimensions. This complexity was of measuring a 3D model in 2 dimensions, because of the curve of Spee, convex structure of the teeth and inclination differences of the teeth.

Garino F and Garino BG et al (2014)[15]Concluded that mean duration of complete scan was 11 min 58 seconds and for one tooth was 16 seconds, scanning time was higher in females and increases with age. And he also recommends that additional scan in the region of second molar, crowding, missing tooth, deep bite, was needed to get more accuracy.

The **irregularity index** was measured by **Goonewardene et al, 2008**, concluded an identical mean values of irregularity were calculated with both

techniques using OrthoCad digital models.[16] Using emodels, **Stevens et al 2006**, reported a significant discrepancy with the digital software underestimating irregularity by 3.7mm.[44]

The agreement between manual and digital measurements was high with respect to both **PAR** (**vig et al 2005, flores-mir et al 2006**)[23,44] and **ICON (kuijpers-jatman et al 2009**)[50]. In relation to **ABO** score **Okunami et al 2007**, and **Costalos et al 2005**, reported a significant discrepancy with respect to occlusal contact and buccolingual inclination scores. These discrepancies were attributed to limitations pertaining to one software program (OrthoCad).[27,7]

Likewise, in this study using dolphin version 11.8 software the results showed clinically insignificant difference in Bolton ratio. Similarly **Naidu et al** found the accuracy of the IOC/OrthoCAD system in measuring tooth widths and performing Bolton ratio is clinically acceptable.[28] In **contrary**, the study of **Santoro et al** reported OrthoCAD digital tooth width measurements were always smaller compared to traditional orthodontic plaster model measurements.[41]

Both **randomized trials** and the **nonrandomized trials** observed differences between digital and plaster cast in reproducibility and reliability in the normal range of accepted errors. **DeWaard et al 2014**, observed relevant differences in reliability between measurements. More precisely the models

from CBCT are not sufficiently reliable in reconstructing the occlusal surfaces when producing 3D casts. [11]

Taking into account all the observations made in our study, we have **rejected the null hypothesis**.

From our study, we can conclude that intra-orally scanned iTero digital models with using dolphin version 11.8 software is a viable option for diagnostic purpose instead of traditional orthodontic models.

Digital models are as reliable as traditional plaster models, with high accuracy, reliability and reproducibility. With the potential advantages like possibility of performing 3D measurements and mapping, superimposition of tooth movements, evaluation of tooth inclination, in terms of cost, time and space required, digital models can be considered as the **new gold standard** in current practice.

Limitations

Differences in impression procedures and **digital model** reconstruction process may have contributed to inconsistent reports. The **most recurrent** sources of **error** for measurements on digital models were landmark identification and low accuracy of inter-proximal surfaces. The main limitation of **this study** is, the smaller sample size, validity and reliability

needs to be checked for more accurate results. **Further research** should be done on 3D mapping of models, accuracy regarding ABO objective grading system measurements of digital models and dimensional variation of 3D printed models needs to be evaluated.

Summary and Conclusion

SUMMARY AND CONCLUSION

Digital technology is invading all the fields of dentistry. It has a major role in orthodontics. Digital model is an alternative to plaster model and it is accurate, efficient and easy to use. Many clinical Orthodontists prefer to have plaster model available at chair side when treating patients. They use this as reference to arch form, inter-canine width, inter-molar width, etc. To save space after treating patients, these models can then be digitized after treatment.

Digital models promote advanced practice in field of orthodontics. The new era of faster digital technology for scanning teeth as become a replacement for conventional plaster model. The accuracy of these digital models replicating actual intraoral measurements has not been sufficiently documented.

Hence, the **present study** was designed to evaluate accuracy of digital model obtained by non-powdered (iTero) scanner and compare it with conventional plaster model. Based on the inclusion criteria 9 patients were selected. Intraoral digital models were measured using dolphin version (11.8) and the outcome was compared with convention plaster model for accuracy.

The conclusion made from the present study are:

- Calculated **Mesiodistal** width of digital models showed minor differences with lesser values which was statistically insignificant.

- Measured **height of the crown** in digital model showed lesser value when compared with plaster models and the results were statistically insignificant.
- In **transverse dimension,** digital model showed variation with higher value as compared with plaster model which was clinically insignificant. Indicating that the digital models can be an alternative to traditional plaster models for orthodontic diagnosis and treatment planning.

Based on the outcome of this study, we conclude that iTero (invisalign) models are capable of capturing exact tooth size accurately along with dolphin version (11.8) as compared with manual measurement on conventional plaster model with decreased clinical time makes it a valuable tool in practice. Which leads to further research of assessing the reliability and validity of 3D prototype model generated from digital scanning devices.

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Annexures

Annexure – I

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The dissertation topic titled **"EVALUATION OF DIAGNOSTIC ACCURACY OF DIGITAL MODELS."** submitted by **Dr. RISHI RAGHU.,** has been approved by the Institutional Review Board of Ragas Dental College and Hospital.

Dr. N.S. Azhagarasan M.D.S,
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Annexure – II

URKUND

Urkund Analysis Result

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