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Comparative evaluation of teeth measurements and arch perimeter by digital and conventional methods on dental plaster models

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Abstract

Background: Model analysis is a key factor for space management. The introduction of CAD-CAM techno logy has enabled us to convert conventional manual measurements and designing into digital processes that are independent of operator skill and accuracy. Dental measurements on plaster models using conventional manual methods are time-consuming and prone to error because of anatomical variations, malposition and inclination of teeth. These can be eliminated using handheld 3D scanner and specialized software for measurements.

Aim: To compare the accuracy of measurement of greatest mesiodistal width of teeth and arch perimeter by conventional method and digital method

Methodology: The greatest mesiodistal width of teeth and arch perimeter was measured on 50 sets of perm anent maxillary and mandibular dental plaster models as well as on the corresponding 3D digital models. Each measurement was performed by two qualified operators to avoid inter and intra observer errors. The average value of the two measurements was used for subsequent comparison.

Results: Data were statistically assessed using student paired t test and Pearson's correlation test. There were no statistically significant differences found between the two methods.

Conclusion: Dental metrology in measurement of greatest mesiodistal width of teeth and arch perimeter can benefit from the 3D technology that is clinically acceptable and appropriate. Thus, the laborious procedures of manual measurement can be replaced with a digital method which can be used in future digital mixed dentition analysis.

Keywords: 3D dental metrology, Digital dentistry, 3D dental imaging

Introduction

Model analysis is a key factor for space management. It is the study of dental casts, which helps to study the occlusion & dentition from all three dimensions & analyze the degree & severity of malocclusion & derive the diagnosis & plan for treatment.

In dentistry, plaster models are used to analyze the occlusion and aid in treatment planning. Linear measurements made on plaster models are commonly used for measuring tooth size, arch width analysis.[1]

Dental arch length, width, and perimeter are considered to be important for the diagnosis and treatment of orthodontic cases.[2] Teeth measurements and arch perimeter can be achieved by conventional manual methods. The accuracy of these methods when applied to a different ethnic population is questionable.

The intro duction of Computer-aided design and computer manufacturing (CAD-CAM) technology to create precision tools and parts has enabled us to convert conventional manual measurements and designing into digital processes that are independent of operator skill and accuracy.[3] The dental profession first adopted this technology in 1985**.**

Volumetric things can be turned into three-dimensional digital images using three-dimensional scanners. To put it another way, they examine a physical object and gather information about its appearance and shape before turning it into a three-dimensional digital file. To create 3D scanning devices, various technologies have been created, each with their own restrictions, benefits, and draw backs.

Earlier Three-dimensional scanning and impression was limited to dental restorations including crowns, inlays and onlays, fixed prosthesis bridges etc. Advances in digital workflow have made it possible to test the accuracy of measurement providing benefits to both professionals and patients.

Three - dimensional scanning and impression considered advantageous, since it is objective and the procedures are less time consuming. Plaster models offer a three-dimensional image of occlusion that enables specialists to analyse impressions taken during clinical examinations in greater detail without interference from soft oral tissues, which speeds up the case study process. The electronic handheld digital calliper is currently the gold standard for measuring teeth due to its acceptable accuracy, usefulness, portability, and lower cost. However, there are some drawbacks. For example, the

measurement precision is only 0.01 mm, the plaster models require more space and are difficult to store and retrieve, and the measured models are susceptible to damage, limiting their ability to be used as dental models again.

The dental arch perimeter is one of the most important parameters for determining orthodontic circumstances (or length). The key to developing a more effective treatment strategy is to conduct a thorough assessment of tooth-arch length discrepancy (TALD), which establishes the discrepancy between space needed and space available. A number of methods can be used to deter mine the available area, including direct wire measurement, arcogrammes, 4- or 6-segment arch lengths, clear plastic arch form rulers, and individualised arch form graphing. Several authors have used different approaches to figure out the perimeter of the dental arch. One of these methods comprises extending a brass or steel wire over the required distances, straightening it, and measuring the length to directly measure these characteristics. [2] Dental anomalies include crowding, rotation, and/or displacement of the teeth have an impact on brass wire approach.[2]

A few studies have been done on linear measurements, such as mesiodistal widths of teeth. However, there are no studies done on digital nonlinear measurements such as arch perimeter assessment and also there are no studies available to assess the mixed dentition analysis. Therefore, this method logical study evaluates the accuracy of measurements carried out using digital method.

Materials and methods

Source of data

The sample of this study was composed of 12 to 14 years old students from multiple schools in Bangalore. 50 children with an average age of 13 years old were selected based on the following inclusion and exclusion criteria.

Inclusion criteria

- The study models with angle's class I malocclusion.
- Fully Erupted permanent Dentition in both the arches.
- Diagnostic Data containing Defect free Casts.

Exclusion Criteria

- Dental casts of patients with syndromes and oral clefts
- Patient's casts with history of ongoing orthodontic treatment
- Teeth with distal slicing
- Abnormally inclined and rotated teeth
- Dental casts with missing teeth
- Mutilation of teeth due to caries, attrition and proximal restoration

Previous preparation

Dental impressions of the participants were made with non - reversible hydrocolloid (alginate) material according to the manufacturer's instructions. Stone plaster models were made using zero expanded super hard gyp sum material on the basis of standard operation. Eventually, 50 sets of maxillary and mandibular dentition plaster models (100 dentitions in total) were completed with smooth surfaces, no bubbles and clear edges.

Dental measurements

Conventional method

The measurements taken were mesiodistal diameter and arch perimeter. Mesiodistal diameter was defined as the maximum distance between the mesial and distal points of each tooth crown (Figure 1). Arch perimeter measured on upper and lower casts using a brass wire touching mesial surface of first molar of one side and passed over buccal cusps of premolars, anteriors and continued to opposite side first molar (Figure 2). Each measurement

was performed by two qualified operators to avoid inter and intra observer errors. The average value of the two measurements was used for subsequent comparison.

Figure 1: Teeth measurement using vernier calliper

Figure 2: Arch perimeter measurement using brass wire

Three-dimensional digital method

3D digital dentition models were obtained by the plaster models scanning through the prime scan. (Figure 3) The scanned data were transferred through connect case Center to the exocad in Connect Software 5 (version 5.2.2.261827). In exocad (version 3.0 Galway Engine build 7754, Ger many) (Figure 4), the greatest mesiodistal measurements of individual teeth were measured by zooming the image and coinciding the guiding sphere drawn from mesiodistal line. The arch peri meter was calculated by adding all the measurements of teeth and the interdental space. All the conventional and digital measurements were repeated by another examiner. The determined greatest mesiodistal width of the teeth and arch perimeter using conventional method and digital method from both the measurements were tabulated in an excel sheet (Micro soft excel 2019). The mean value and the differences were calculated for both teeth measurements and arch perimeter and subjected to statistical analysis.

Figure 3: Scanning of cast on prime scan.

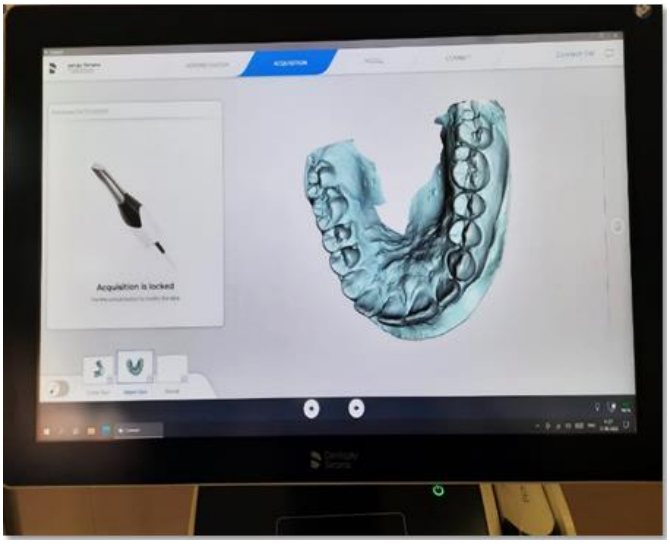
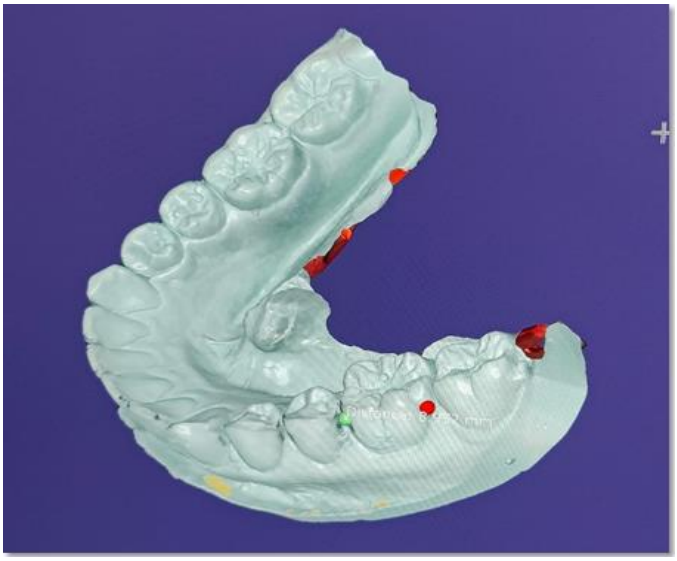


Figure 4: Measurement of teeth using exocad.



Flowchart of methodology

Fifty children were selected as per inclusion and exclusion criteria for measurement of teeth and arch perimeter by conventional method and digital method

↓

Alginate impressions and models for maxillary and mandibular arches were made

↓

The greatest mesio-distal width of permanent maxillary and mandibular teeth were marked at the two ends of mesiodsital line over buccal surface and Greatest mesio-distal width were measured using digital vernier callipers which included the incisors, canine, premolars and first molar.

↓

Arch perimeter measured on upper and lower casts using a brass wire touching mesial surface of first molar of one side and passed over buccal cusps of premolars, anteriors and continued on opposite side first molar

↓

For digital measurements, all the models were scanned using a digital scanner

↓

In exocad (version 3.0 Galway Engine build 7754, germany), the greatest mesio-distal measurements of individual teeth were measured by zooming the image and coinciding the guiding sphere drawn from mesio-distal line. The arch perimeter was calculated by adding all the measurements of teeth and the interdental space.

↓

All the measurements were repeated for each of the investigated methods

↓

The determined greatest mesio distal width of the teeth and arch perimeter using conventional method and digital method from both the measurements were tabulated in an excel sheet (Microsoft excel 2019). The mean value and the differences were calculated for both teeth measurements and arch perimeter and subjected to statistical analysis

Results

Table 1: Age & Gender distribution among study samples

Variable	Category	n	%
Age	12 yrs.	11	22%
	13 yrs.	19	38%
	14 yrs.	20	40%
		Mean	SD
	Mean	13.18	0.77
	Range	12 - 14	
Gender	Males	19	38%
	Females	31	62%

Table 2: Comparison of mean overall mesiodistal width (in mm) of teeth in maxillary & mandibular arch between two methods using Student Paired t Test

Parameter	Method	N	Mean	SD	Mean Diff
Mesiodistal width	Manual	50	6.72	0.28	0.01
	Digital	50	6.71	0.24	

Table 3: Comparison of mean overall arch perimeter (in mm) between two methods using Student Paired t Test

Parameter	Method	N	Mean	SD	Mean Diff
Arch Perimeter	Manual	50	74.17	2.97	0.04
	Digital	50	74.13	2.96	

The overall mean mesiodistal width of teeth by manual method was 6.72 ± 0.28, whereas by digital method 6.71 ± 0.24. however, the differences between the two methods were not statistically significant.

The overall Arch Perimeter by manual method was 74.17 ± 2.97, whereas by digital method 74.13 ± 2.96. however, the differences between the two methods were not statistically significant.

Discussion

In this technical progress of computer science, the plaster casts can be turned into Three - Dimensional digital models for ease of patients as well as for the benefits of dentist. The 3D analysis of digital models which is derived from digital approach plays a key role in Pediatric dentistry, orthodontics and prosthodontics.

One of the most important dental arch factors for orthodontic diagnosis and treatment planning is the dental arch perimeter. Brass wire is traditionally used to measure the arch's perimeter. Due to variations in geometric form and arch length, it is not as reliable, especially for establishing the line of occlusion, and it necessitates a great deal of judgement regarding the appropriate arch form. [4,5,6]

The benefits of using a digital method in dentistry include saving space, avoiding breakage risk, easier data storage, simultaneous information sharing with colleagues, and increased productivity.[7]

Despite all these benefits, however, the exclusive use of digital models in normal practice is still uncommon due to various draw backs associated with their use. The draw backs include data loss in the event of electronic storage degradation, reliance on other parties, time-consuming software support, the need to become familiar with the operating system, and high equipment cost.[7]

Considering these new technologies, various authors have evaluated how reliable these new techniques. According to a study, the 3D technique can store and export the 3D digital format which is convenient for fast search, cloud transmission, reutilization and measure ment analysis (including linearity, volume and surface area measure ments), when compared with traditional method.[8]

Few authors assessed the accuracy of mesio distal measure ment of teeth and arch perimeter by comparing linear dental measurements obtained from the three-dimensional digital model by 3D software and the plaster model by electronic digital caliper. Currently, the acquisition of the 3D model adopting structured light 3D scanning technology is widely used due to its speed, high precision, good security, fewer blind scanning, and better multiangle scanning.[8]

A Research was conducted to evaluate the accuracy of measurements made on digital models acquired using a 3Shape D250 scanner. The measurements that were taken directly on the plaster models vs the computer models did not show any statistically significant differences, according to the authors. Therefore, they came to the conclusion that computerized models may be used in orthodontic practise. [9,10] Similarly, the present study did not show any statistically significant differences.

In comparison to digital models scanned with a 3Shape R-700TM Scanner, a study compared the accuracy and reproducibility of tooth size and interdental measurements collected on plaster models. For the manual measurements, a digital calliper was used, but for the digital measurements, O3d (Widia labs) software was employed. The calliper and the O3d software both performed similarly in terms of enabling measurements and analyses, according to the results. There were no

statistically significant differences in measurements, showing that the software and digital models are more accurate than the traditional measurement approach.[7] The above study concluded that there was no statistically significant difference between plaster and digital models when determining the arch perimeter using traditional (vernier) and digital (Ortho Analyzer software) techniques. [11] This result is in accordance with the current study result.

In the current study, there was no statistically significant differences between the maxillary and mandibular arches of male and female Bangalore children were identified, nor was there any sexual dimorphism of the teeth's greatest mesiodistal width or the arch perimeter.[12]

In the present study, distribution of the dental arch form was mostly ovoid shape, followed by the V-shape and the U-shape and also tooth size ratio was not affected by types of arch form either in maxillary or mandibular arch.[13]

Studies were carried out to compare permanent mesiodistal (MD) and buccolingual crown dimensions between different ethnic groups, the coefficients of variation for teeth within each class were compared, it was discovered that the later-forming teeth had more variation in MD size than the earlier-forming teeth.[14] There was no such variation found in the current study.

Another similar study showed that the different patterns of tooth size observed between the study samples were thought to reflect differences in the relative contributions of genetic and environmental influences to dental development between the four populations.[15] However the present study did not include different ethnic groups hence there was no variation in tooth size observed.

According to the results of the previous study, measurement using the segmental distance method on plaster models is simpler and faster than using the arch form length since the reproducibility is thought to be low when using curved arch length.[16] The arch perimeter in this study was also determined using the segmental distance method in digital models.

A study suggests that discrepancy in tooth size and arch dimensions contribute to proclination of dental arches and malocclusion. In the present study malocclusion models were excluded, however a study including malocclusion can be done to develop a digital mixed dentition analysis.[17]

In a review it was pointed out that the major source of random error in this type of study is the difficulty in identifying a position to use as a reference point for the measuring instruments, which leads to a problem in reproducibility when using computer analysis.[18] In the present study the greatest mesiodistal width of permanent maxillary and mandibular teeth were marked at the two ends of mesiodistal line over buccal surface to use as a reference point before the measurements were taken.

In the current study similar type of plastic impression trays, same brand alginate and dental stone were used to make the models to reduce any discrepancy; the greatest mesiodistal width of teeth in the cast models were marked to ensure reproducibility of measurements.[9]

A study was conducted to assess changes in the length of the maxillary and mandibular arches over a 45-year period. The Iowa facial growth study included 15 males and 15 girls who underwent evaluations at ages 3, 5, 8, 13, 26, and 45. The first two years of life saw the biggest incremental improvements. Arch length continued to increase until 13 years in the maxillary arch, and until 8 in the mandibular. Then significant and consistent decrease in both arches mesial to the permanent first molars occur.[19] Hence, in the present study, average age group of 13 years were included.

Conclusion

Within the limitations of this study, the following conclusions were drawn:

- The values for Tooth Size-Arch length discrepancy found by digital calliper and brass wire versus digital methods did not differ.
- The measurement of greatest mesiodistal width of teeth by digital method was comparable to conventional method.
- The measurement of arch perimeter by digital method was comparable to conventional method.
- Using 3D technology in dental metrology to measure greatest mesiodistal width and arch perimeter is advantageous because it is a rapid, reliable alternative method to conventional teeth measurement that is clinically acceptable. Thus, the laborious procedures of manual measurement can be eliminated using digital method.

It is recommended to conduct further studies with larger sample size and various malocclusion for future application.

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