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Original Research Article

Orthodontics in 3D: Unveiling the precision of printed models vs plaster traditions

Prince Bedi[1]*, Divya Shetty[1], Bhupender Singh[1], Ayushi Nagar[1], Payal Sharma[1]

[1] *I.T.S- Centre for Dental Studies and Research, Ghaziabad, Uttar Pradesh, India*

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ABSTRACT

Introduction: Orthodontic treatment relies heavily on accurate diagnosis and treatment planning. Traditionally, study casts obtained from plaster models have been an essential component of orthodontic records. However, advancements in three-dimensional imaging and modeling have introduced digital alternatives, offering ease of access, storage, and transfer of patient information.
Aim and Objectives: To compare the accuracy of linear measurements obtained from 3D printed models with those taken from plaster study models and identify the most reliable type of printed model.
Materials and Methods: The study was conducted on ten patients requiring fixed orthodontic treatment. Dental impressions were scanned using laser desktop scanners and intraoral scanning of patients maxillary dentition, and then resulting images were converted to stereolithography (STL) format for 3D printing. Linear measurements, including tooth size and arch width, were taken using a digital caliper on plaster, intraoral, and laser scanned printed models.
Results: Statistical analysis revealed no significant differences in tooth size and arch width measurements between plaster models and both types of 3D printed models (intraoral and laser scanned). The average differences in mesio-distal width measurements were found to be within clinically acceptable ranges.
Conclusion: Three-dimensional imaging and 3D printing technologies have revolutionized orthodontics, providing accurate and reliable digital alternatives to traditional plaster models. The study findings support the use of 3D printed models for orthodontic diagnosis and treatment planning, indicating their potential to replace plaster models in the future.

1. Introduction

In recent years, significant advances in three-dimensional imaging and modeling have paved the way for the development of a virtual orthodontic patient, allowing for the recreation of bone, soft tissue, and teeth in three dimensions. The introduction of cone beam computerized tomography (CBCT) and the refinement of three-dimensional facial imaging have played a crucial role in driving the panacea of complete three-dimensional digital conversion. These technological advancements have enabled the production of dental models in digital format, leading to a trend in orthodontic clinics to replace traditional plaster models with three-dimensional digital models (3D).[1]

Orthodontic treatment success relies on extensive diagnosis and treatment planning. Dental models, photographs, radiographs, and clinical examinations provide crucial information for diagnosis and case presentation. Study casts, particularly plaster models, have long been a standard component of orthodontic records, serving various purposes such as treatment planning, evaluation of treatment progress, and record keeping.[2] However, traditional gypsum-based study models are heavy, bulky, pose storage and retrieval problems, and can

* *Corresponding author*.
E-mail address: orthodoc1997@gmail.com (P. Bedi).

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be challenging and time-consuming to measure.[3] With the evolution of three-dimensional imaging and modeling, digital alternatives, such as 3D printed models, are gaining popularity due to their ease of access, storage, and transfer, along with reported accuracy in image capture techniques.[4]

However, before fully embracing this new approach, it is essential to validate its comparability to plaster models, as the measurement procedure using a digital caliper on plaster models is considered the gold standard in orthodontic research. Additionally, plaster models have the advantages of being easy and inexpensive to produce.[5]

The aim of this present study is to assess the validity, reliability, and reproducibility of 3D printed models obtained from intraoral and extraoral scanning of maxillary dentition for tooth-width measurements, comparing these measurements with those from plaster models (considered the gold standard). This research is conducted to determine the accuracy of measurements from 3D printed models in comparison to traditional plaster models, as well as to identify any potential disadvantages and errors associated with the use of digital models.[6–9]

The results of this study may pave the way for a wider adoption of digital models in orthodontic practices, bringing in greater efficiency, accessibility, and accuracy in orthodontic treatment planning and outcomes.

2. Materials and Methods

2.1. Study design

This study is a prospective comparative study conducted in the Department of Orthodontics and Dentofacial Orthopedics at I.T.S Centre for Dental Studies and Research, Muradnagar, Ghaziabad, Uttar Pradesh, India.

The aim of this study is to compare the accuracy of linear measurements taken from 3D printed models obtained from intra-oral scanner and a laser desktop scanner with the measurements taken from plaster study models (considered the gold standard) of the maxillary dental arch.[10–12]

2.2. Source of data

Ten patients in the age group of 16-25 years, requiring fixed orthodontic treatment, were selected to participate in this study based on specific inclusion and exclusion criteria.

The inclusion criteria included patients with permanent dentition from the first permanent molar of one side to the other, teeth having normal morphology, absence of anomalies in the number, size, and dental shape, good quality of dental cast, and no severe crowding in the dentition. Exclusion criteria included dental anomalies in size and shape, severe gingival recession, dental crown abrasion, attrition, erosion, history of orthodontic treatment, presence of large occlusal restorations, and presence of prosthesis.

3. Materials and Materials

The materials used for this study included:

IOS intra-oral scanner (Shinning 3D) for intra-oral scanning of the maxillary dentition.

Laser desktop scanner (Ceramill Map400) for extra-oral scanning of the plaster models obtained from alginate impressions.

3D printer (Shinning 3D) with Grey V4 resin for printing the 3D models.

Maxillary plaster casts for comparison with the digital models.

Digital vernier caliper for manual measurements of tooth widths and other linear measurements on the study models.[13]

Table 1: Mesio-distal width comparison

Comparison	Average Difference (mm)	p-value	Conclusion
Plaster vs. Laser Scanners	0.06	0.750	No significant difference found
Plaster vs. Intraoral	-0.01	0.958	No significant difference found
Laser vs. Intraoral	-0.07	0.709	No significant difference found

Table 2: Intercanine and intermolar width comparison

Comparison	Intercanine Difference (mm)	Intermolar Difference (mm)	Conclusion
Plaster vs. Laser Scanners	-0.16	-0.17	No significant difference found
Plaster vs. Intraoral	-0.05	-0.05	No significant difference found
Laser vs. Intraoral	0.11	0.12	No significant difference found

Mesio-Distal Width: No significant differences observed between plaster models, laser desktop scanners, and intraoral scanners.

Intercanine and Intermolar Width: No significant differences observed between the three methods.

Table 3: Evaluation difference in measurement

Comparison	Overall Difference (mm)
Plaster vs. Laser Scanners	0.06
Plaster vs. Intraoral	-0.10
Intercanine Width (ICW)	-0.16
Intermolar Width (IMW)	-0.17

Figure 1: Intraoral scanner (Shinning 3D)

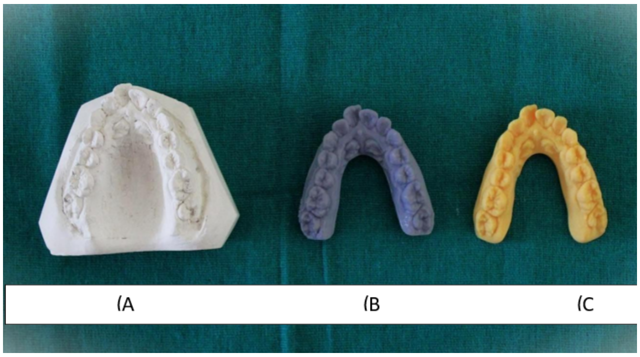

Figure 2: A) Plaster cast, B) Laser scanned printedmodel, C) Intraoral scannedprinted model

Figure 3: Use of digital caliperfor linear measurements

3.1. Methodology

The study involved two different techniques to obtain 3D printed models: intra-oral scanning of the maxillary dentition using the IOS intra-oral scanner and extra-oral scanning of the plaster models using the laser desktop scanner. The resulting digital images from both techniques were converted to the stereolithography (STL) format, which was used for 3D printing of the models.

First, the tooth widths on the plaster models were manually measured using a digital caliper to set the gold standard for the study. Then, the 3D printed models generated from both scanning techniques were also measured with the digital caliper for comparison.

Various linear measurements were made on the models, including tooth widths (maximum mesiodistal distance between anatomic contact points), inter-molar width (from the mesio-buccal cusp tip of the first molar to the same point on the contralateral first molar), and inter-canine width (from the cusp tip of the cuspid to the same point on the contralateral cuspid).

3.2. Statistical analysis

The collected data was tabulated and analyzed using statistical software SPSS 16.0. The independent t-test was used to compare measurements between plaster models and printed models. The normality of data was tested using the Shapiro-Wilk test, and a significance level of 0.05 was considered for all analyses.

The sample size was calculated using the confidence interval of 95% and power of 80%, resulting in a total sample size of 18 (10 patients each in the two groups).

By comparing the measurements from the different scanners and plaster models, the validity, reliability, and reproducibility of 3D printed models will be evaluated, providing valuable insights into their accuracy and potential applications in orthodontics.

4. Results

The results of this study provide valuable insights into the accuracy and comparability of measurements obtained from 3D printed models, scanned using intraoral and extraoral methods, with traditional plaster study models. The study focused on linear measurements, including tooth widths, intercanine width (ICW), and intermolar width (IMW) of the maxillary dental arch.

For the comparison between plaster models and 3D printed models obtained from the laser desktop scanner, the average differences in mesiodistal width measurements for individual teeth were minimal, ranging from 0.04 mm to 0.10 mm. These differences were not statistically significant, indicating that measurements from the laser-scanned printed models were highly accurate and comparable to the plaster models.

Similarly, when comparing plaster models with 3D printed models obtained from the intraoral scanner, the average differences in mesiodistal width measurements ranged from -0.01 mm to 0.10 mm, with no statistically significant differences. This suggests that the intraoral scanned printed models also exhibited high accuracy and comparability to the plaster models.

Regarding the comparison between the two types of printed models, i.e., laser desktop scanner and intraoral scanner, the average differences in mesiodistal width measurements were minimal, ranging from -0.07 mm to 0.11 mm, with no statistically significant differences. This implies that both types of printed models yielded highly accurate and comparable measurements.

Additionally, the study examined intercanine and intermolar widths. The differences in measurements for both variables between plaster models and printed models were negligible, ranging from -0.17 mm to -0.05 mm, and again, no statistically significant differences were found. This indicates that 3D printed models, regardless of the scanning method used, were reliable for assessing intercanine and intermolar widths.

Overall, the results provide strong evidence that 3D printed models obtained from both intraoral and extraoral scanning methods are accurate and comparable to traditional plaster models. These findings support the notion that 3D printed models can be effective replacements for plaster models in orthodontic diagnosis and treatment planning.

5. Discussion

The study under consideration explores the integration of 3D printing technology into the field of dentistry, with a particular focus on orthodontics. The primary aim is to evaluate the accuracy of measurements obtained from 3D printed models, generated through both intraoral and laser desktop scanners, in comparison to traditional plaster study models—a longstanding gold standard in dentistry. The research addresses critical aspects of reliability, validity, and practical considerations associated with each type of study model.

Orthodontics depends significantly on precise measurements for diagnostic purposes, capturing various dimensions and relationships within the dental arch. Traditionally, plaster study models have been essential, providing physical representations of patients' dental anatomy. However, advancements in technology, particularly 3D printing, have introduced new opportunities for creating orthodontic appliances such as clear aligners and bonding trays. These digital alternatives offer potential enhancements in workflow and clinical efficiency, necessitating an evaluation of their accuracy and reliability.

This present study differed from previous studies as it used intra-oral scanners to create 3D printed models which were subsequently measured for comparison against plaster and printed study models. Abizadeh et al. used an extra-oral scanner, R250 Scanner by 3Shape® to scan plaster study models that were then digitised to create printed study models. 12 These were compared to plaster study models. Jiang et al. used CBCT to scan dental impressions that were subsequently converted to printed study models. Reuschl et al. used the D800 extra-oral scanner by 3Shape® to scan plaster study models to create printed study models. 20 Czarnota et al. used the D700 extra-oral scanner by 3Shape® to digitise their plaster study models. 21

In the context of measurement tools, the study emphasizes the importance of reliability, validity, and practical considerations. Reliability refers to the consistency of measurements under constant conditions, while validity assesses the extent to which a measurement represents the intended parameter. The choice of measurement tools, in this case, electronic digital calipers, introduces an operator-dependent element, contributing to potential variability in the results.

The study's first objective is to compare the accuracy of measurements obtained from 3D printed models with those from traditional plaster study models. Plaster models are conventionally regarded as highly accurate representations of dental anatomy. The results of the study, however, suggest that measurements from 3D printed models, regardless of the scanning method used (intraoral or laser desktop), do not exhibit statistically significant differences from those obtained from plaster models. This finding implies that 3D printed models can serve as reliable substitutes for traditional plaster study models, supporting the argument for their integration into orthodontic practices.

The second objective seeks to determine which type of study model—digital or printed—demonstrates superior accuracy compared to plaster study models. Surprisingly, both digital and printed study models exhibit statistically similar accuracy, challenging the notion that one may be inherently more precise than the other. This result reinforces the idea that, from a statistical standpoint, measurements taken from digital and printed study models are on par with those from traditional plaster study models.

The third and final objective involves identifying potential disadvantages associated with each type of study model. Plaster models are criticized for their laborious and time-consuming fabrication processes, involving pouring and finishing. Digital models, particularly the process of measuring digital study models with Ceramill map400 software, present a learning curve for practitioners. This adjustment period and the time-consuming nature of the initial stages are noted as potential drawbacks. Printed study models, on the other hand, entail a time-consuming printing process, requiring approximately 30-35 minutes for each model. Additional steps, including the removal of supporting structures, brushing with solvent, post-processing curing, and finishing, contribute to the overall time investment. The study also acknowledges that the supporting structures, made from the same material as the study models, result in material wastage. Practitioners are urged to familiarize themselves with the printer software to optimize the design of supporting structures and minimize unnecessary material usage. Storage of both plaster and printed study models is identified as a logistical challenge.

Despite these disadvantages, the study emphasizes that they are minimal compared to the challenges associated with traditional plaster study models. Additionally, it recognizes potential errors in 3D printing, such as distortion during data conversion and model shrinkage during fabrication and post-curing processes. However, the study argues that the observed range of error falls within clinically acceptable limits, with a range of 0.20 to 0.50 mm considered suitable for diagnostic and treatment planning purposes.

6. Limitations

It is important to acknowledge the limitations of the study. The sample size was relatively small, which may restrict the generalizability of the findings to a larger population. Additionally, the study focused on a specific age group (16-25 years) and specific inclusion criteria, potentially limiting the applicability of the results to other age groups or dental characteristics.

Despite these limitations, the results are promising and suggest that the use of 3D printed models in orthodontics could have significant advantages, such as ease of access, storage, and transfer of patient information. As 3D imaging and printing technologies continue to evolve and become more affordable, they have the potential to revolutionize the traditional orthodontic workflow and enhance treatment outcomes. Further research with larger and more diverse samples is warranted to validate and expand upon these findings.

7. Conclusion

In conclusion, this study demonstrates the accuracy and reliability of 3D printed models obtained from intraoral and extraoral scanning, showcasing their potential as viable alternatives to traditional plaster models in orthodontics.

The measurements taken from the printed models were comparable to those from plaster models, supporting their use for initial diagnosis and treatment planning in clinical orthodontics.

While there are limitations to consider, such as sample size and specific age group, the promising results indicate that 3D imaging and printing technologies hold great potential for enhancing orthodontic practices in the future.

Further research with larger and diverse samples will provide valuable insights into their broader applicability.

8. Source of Funding

None.

8.1. Conflict of Interest

None.

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Author's biography

Prince Bedi, Professor and Head

Divya Shetty, Professor

Bhupender Singh, Senior Lecturer

Ayushi Nagar, Senior Lecturer

Payal Sharma, Professor and Head

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