DEVELOPMENT OF DIGITAL ORTHODONTIC INDICES ANALYSIS SYSTEM

MUHAMAD NURHADI BIN SALLEH

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UNIVERSITI PENDIDIKAN SULTAN IDRIS

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ABSTRACT

Orthodontics is a specialized field of dentistry that focuses on diagnosing, preventing, and treating dental and facial irregularities. Orthodontic indices are standardized tools used to assess the severity of malocclusions and to plan and evaluate treatment. This study aims to design the orthodontic indices using a digital analysis system, to analyze the orthodontic measurement with Peer Assessment Rating (PAR) Index, Bolton Analysis, and Index of Orthodontic Treatment Need (IOTN), and to compare the orthodontic measurement using a digital analysis system and conventional practice. This cross-sectional descriptive study involves 70 dental casts. The procedure used the orthodontic indices digital analysis system and conventional method. The results are then analyzed using the Statistical Package for the Social Sciences (SPSS) software. The images are taken parallel to the dental cast, which is the perpendicular position (90°) considered the ideal projection. The photograph of the dental cast was saved as two dimensions (2D) in the JPEG file format and uploaded to the National Instrument (NI) LabVIEW software. The analysis began with the Kolmogorov-Smirnov statistical approach, which was used to determine if the data distribution was normal or not. The paired sample T-test will be used for parametric data, whereas, for non-parametric data, the Wilcoxon Signed-rank test will be applied. The results show P-value for Bolton analysis for the anterior ratio obtained from this study is 0.17. Meanwhile, the posterior ratio is 0.49, and the overall ratio is 0.20. The measurement range of P-values for the PAR index ranged from 0.08 to 0.59 for all teeth measured in the two arches, mandibular and maxillary. IOTN, like the PAR index, provides a range of P-values for all teeth measured, ranging from 0.05 to 0.40. The conclusion from this study, there is no significant difference ($p>0.05$) between the digital orthodontic analysis and conventional methods for PAR Index, Bolton Analysis and IOTN Index.

PEMBANGUNAN SISTEM ANALISIS INDEKS ORTODONTIK DIGITAL

ABSTRAK

Ortodontik adalah bidang khusus dalam pergigian yang menumpukan pada mendiagnosis, mencegah, dan merawat ketidakteraturan gigi dan muka. Indeks ortodontik adalah alat piawai yang digunakan untuk menilai tahap keparahan maloklusi dan untuk merancang serta menilai rawatan. Kajian ini bertujuan untuk mereka bentuk indeks ortodontik menggunakan sistem analisis digital, menganalisis pengukuran ortodontik dengan indeks *Peer Assessment Rating* (PAR), Analisis Bolton, dan *Index of Orthodontic Treatment Need* (IOTN), dan membandingkan pengukuran ortodontik menggunakan sistem analisis digital dan kaedah konvensional. Kajian deskriptif keratan rentas ini melibatkan 70 acuan gigi. Prosedur tersebut menggunakan sistem analisis digital indeks ortodontik dan kaedah konvensional. Hasilnya kemudian dianalisis menggunakan perisian *Statistical Package for the Social Sciences* (SPSS). Imej diambil selari dengan acuan gigi, iaitu kedudukan serenjang (90°) dianggap sebagai unjuran yang ideal. Gambar acuan pergigian disimpan sebagai dua dimensi (2D) dalam format fail JPEG dan dimuat naik ke perisian National Instrument (NI) LabVIEW. Analisis dimulakan dengan menggunakan pendekatan statistik Kolmogorov-Smirnov, yang digunakan untuk menentukan sama ada taburan data adalah normal atau tidak normal. Ujian T sampel berpasangan akan digunakan untuk data parametrik, manakala, untuk data bukan parametrik, ujian Wilcoxon Signed-Rank akan digunakan. Keputusan menunjukkan nilai P bagi analisis Bolton bagi nisbah anterior yang diperoleh daripada kajian ini ialah 0.17. Manakala nisbah posterior ialah 0.49, dan nisbah keseluruhan ialah 0.20. Julat pengukuran nilai P untuk indeks PAR adalah antara 0.08 hingga 0.59 untuk semua gigi yang diukur dalam dua lengkung, rahang bawah dan rahang atas. IOTN, seperti indeks PAR, menyediakan julat nilai P untuk semua gigi yang diukur, antara 0.05 hingga 0.40. Kesimpulan daripada kajian ini, tidak terdapat perbezaan yang signifikan ($p>0.05$) antara analisis ortodontik digital dan kaedah konvensional bagi Indeks PAR, Analisis Bolton dan indeks IOTN.

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LIST OF ABBREVIATIONS

AC	Aesthetic Component
CO	Central Occlusion
DAI	Dental Aesthetic Index
DHC	Dental Health Component
DPH	Dental Public Health
HLD	Handicapping Labio-lingual Deviation Index
ICON	Index of Complexity, Outcome & Need
IOTC	Index of Orthodontic Treatment Complexity
IOTN	Index of Orthodontic Treatment Needs
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
LII	Little's Irregularity Index
OPG	Orthopantomography
PAR	Peer Assessment Rating
POP	Plaster of Paris
SPSS	Statistical Package for the Social Sciences
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides an overview of the background study that was conducted on the orthodontic indices digital analysis system. After that, the problem statement explains why orthodontic indices are so important in determining whether or not the teeth are misaligned or in an incorrect position between them. The following phase is to provide a description of the objectives, which is then followed by the research questions and hypotheses. At long last, the explanation of the significance of the study as well as its limitations followed.

1.2 Research Background

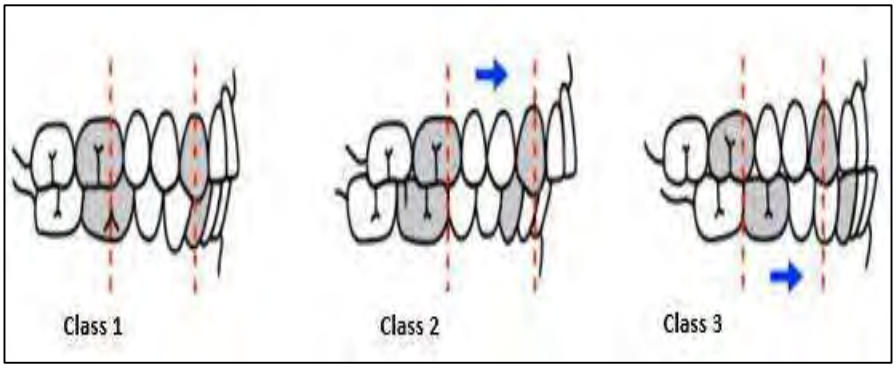
Orthodontics is a branch of dentistry that deals with diagnosing, treating, and preventing malocclusion, which is the misalignment of teeth in an arch. Malocclusion is a condition in which the teeth are incorrectly positioned when closed mouth. This condition results in an improper bite, poor facial, and tooth appearance. Since malocclusion is not an acute disorder, treatment of malocclusion has been associated with a high degree of subjectivity and distorted perceptions of the need for treatment.

Approximately 80% of children and teenagers show some degree of malocclusion (Balogh, 2006). The most common problem is crowding, where thumb sucking tends to push the maxillary incisors to the labial side and the mandibular incisors to the lingual side (Oyamada et al., 2016). Generally, children suck a finger with the nail facing downwards. Thus, the ball of the finger may strongly force the maxilla forward, and protrusion occurs.

Malocclusion is divided into three major groups (Proffit, 2000). Class I, known as neutroclusion, is characterized by an ideal mesiodistal relationship between jaws and dental arches. The mesiobuccal cusp of the first molar maxillary occludes with the first molar mesiobuccal groove. Class II, known as distoclusion in the permanent dentition, is characterized by the mesiobuccal cusp of the maxillary first molar occluding mesial to the mesiobuccal groove the mandibular first molar. Class III, known as mesiooclusion, is the mesiobuccal cusp of the maxillary first molar occludes by more than the width of a premolar distal to the mesiobuccal groove of the mandibular first molar. Figure 1.1 shows the angle classification of the malocclusion.

Figure 1.1

Angle Classification of Malocclusion (Balogh, 2006)



An index is a tool used to provide numerical values describing the status of a case on a graded scale. It is essential in orthodontics for diagnosing and assessing treatment needs, severity, complexity, and outcomes. Orthodontic indices are used in clinical and epidemiological studies of malocclusion, as they allow comparison with other populations classified by the same criteria and methods. However, none of these indices are ideal for all purposes, as none are accurate, valid, or reliable. An ideal index should be finite, equal, sensitive, correspond closely to the clinical importance of the disease stage, be reproducible, simple, accurate, and adaptable for data collection. (Gusain et al., 2021)

The Peer Assessment Rating (PAR) Index, the Bolton Analysis, and the Index of Orthodontic Treatment Needs (IOTN) are three standard valid and reliable assessments of orthodontic treatment. The PAR Index summarizes all occlusal anomalies and their variations from malocclusion to normal occlusion. The difference in scores between pre-and post-treatment instances represents the degree of change and, as a result, the success of orthodontic interventions. The PAR Index included 11 components. Occlusal features recorded include spacing, crowding, and impacted teeth.

A Bolton Analysis is a tooth size analysis that detects any discrepancies in tooth size. Teeth must be proportional for proper occlusion (Proffit, 2000). A good mediodistal proportion between maxillary and mandibular teeth is essential for ensuring good overbite, overjet, and maxillary and mandibular teeth interdigitations after orthodontic treatment. One of its benefits is that it allows the orthodontist to forecast the expected outcomes of the treatment and the necessity for tooth reduction or addition ahead of time and without a diagnostic setup.

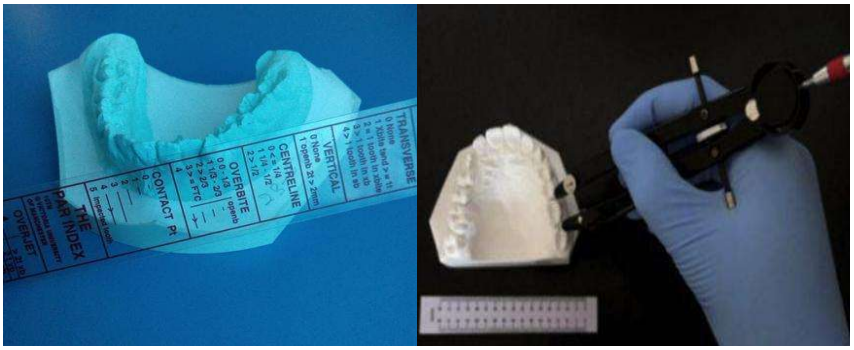
The Index of Orthodontic Treatment Need (IOTN) was developed in 1989 in the United Kingdom by British orthodontists Peter Brook and William Shaw (Borzabadi-Farahani, 2011). The IOTN is split into two sections, the Dental Health Component (DHC) and the Aesthetic Component (AC). DHC offers five treatment levels, ranging from Grade 1 to Grade 5. Displacement, overjet, crossbite, openbite, occlusion, hypodontia, cleft lip and palate deformities, overjet, inhibited eruption, supernumerary teeth, retained deciduous teeth, and other pathologic reasons are some of the features. The Aesthetic Component consists of 10-grade standard reference images representing a variety of subjects.

Among all indices, PAR index, Bolton Analysis, and IOTN are widely used in orthodontics. It assists in orthodontic assessment also analysis for pre and post orthodontic treatment, unfortunately, until this year, they are still being measure conventionally. Traditional tools like PAR and IOTN ruler that are readily available in a form of small sized paper-thin and flexible plastic ruler. Nonetheless, stationaries, caliper, thread, metal ruler and scoring sheet are the important item that required for the

procedure. Analog or digital caliper can be used to measure. Analog caliper and PAR ruler shown in Figure 1.2.

Figure 1.2

PAR Ruler, Vernier Caliper and Measurement Ruler



Dental cast is a model made from Yellowstone or Plaster of Paris (POP). It acts as study model to the operators or working model to the technologist as it copies all the anatomical structures captured by the impressions with exact dimension. The cast can be dental cast, eye, ear, nose, or any other desired anatomical structure. An impression of required area taken by using alginate, silicone, compo, or any other suitable impression materials. A negative imprint from the impression will then be poured with Yellowstone or gypsum to produce a positive impression.

Yellowstone is a type of hemihydrate plaster. It is also known as model plaster with the chemical name β-calcium sulphate hemihydrate, α-calcium sulphate hemihydrate or hydrocal also known dental stone. These plasters are an ideal choice to produce study or working model as it adequately hard and low setting expansion, compared to impression plaster or Plaster of Paris. Hence, it is recommended choice for laboratory work.

Every orthodontic case required study and working model for analysis and treatment planning. On the day of visit, patient will be examined extraoral and intraorally. The orthodontist will do the clinical screening, and dental charting. An impression will then be taken using impressions material with appropriate impression tray. The negative impression will then be sent to the laboratory for reproduction of positive impression. Those positive impression will be used for study and working model for that patient. Every patient will have their own models for laboratory and orthodontist reference.

Study model will be used for treatment planning and being used to compare before orthodontic treatment initiated and after treatment completed. The same principle of study model on other dentistry branch, for instance, in the process of fabrication of eye or dental prosthesis. In a case of scoring PAR, pre-treatment model will be compared with post-treatment model, same goes to Bolton Analysis, study model is vital to measure the tooth width and arch length to plan for treatment for each patient. IOTN may also grade by using study model.

From the mentioned above purposes, study model is a very important requirement for every patient, and it is a valid clinical record. Those analysis and needed measurements are a tedious to perform. Eventhough Yellowstone have a durable property, it still could break into pieces if it dropped from table or certain height. If it happens, the original clinical record will be lost or deteriorated. Moreover, the conventional method was no guarantee reduction of model breakage risk.

By keeping the model in image form may propose safety of study models. To do the analysis via image, an image processing step will take place. An image processing will do the work by detection of points or any necessary parameters. This step will produce precise results with utilization of digital image processing via machine vision systems. The detection is done with the aid of two parameters: shape and texture, besides aspect ratio, perimeter ratio, circularity, compactness, elongation, and other form attributes, as well as texture-based properties such as contrast, energy entropy, and correlation (Raveendra et al., 2019).

Horriat et al. in 2022 state that the idea that photographs serve as a valid method for assessing orthodontic outcomes using the PAR index. The decision to opt for the PAR index is influenced by factors such as the ease of calibration and the overall simplicity of the method. This recognition underscores the versatility of photograph-based assessments in orthodontics, allowing practitioners to choose an approach that best aligns with the goals and priorities of their specific evaluation while acknowledging the inherent strengths and considerations associated with each method

The storage and representation of images can be categorized into two main types: two-dimensional (2D) and three-dimensional (3D). In a 2D representation, an image possesses length and width but lacks height, essentially existing on a flat plane. This is the conventional type of image that we encounter in everyday scenarios, such as photographs or graphics on a computer screen. On the contrary, a 3D representation implies a visual portrayal of an object or scene that has length, width, and height, creating a sense of depth and volume.

Storing and manipulating these image types come with significant differences. 3D images, due to their additional dimension, demand a larger storage capacity compared to their 2D counterparts. The complexity of 3D images requires high-end hardware devices or specialized scanners to capture the intricate details of the three-dimensional space. Additionally, the processing and rendering of 3D images involve intricate software modules, adding to the computational demands. This makes 3D imaging more resource-intensive in terms of both storage and processing requirements.

Conversely, 2D images are simpler to handle and require less storage capacity. These images are commonly captured using cameras, scanners, or other imaging devices that can record the length and width dimensions. While 2D images are more straightforward, they still necessitate sufficient storage space, especially when dealing with high-resolution images. The accessibility and ease of use of 2D images make them widely applicable in various fields, such as photography, graphic design, and medical imaging.

1.3 Problem Statement

Since 1956 up to the present day, orthodontists have continued to rely on traditional methods for measuring and analyzing indices in their practice (Gusain et al., 2021). However, these methods are susceptible to errors, particularly due to the intricate nature of dental anatomy. The small scale of the working area, the use of outdated tools, and a limited set of parameters contribute to the tedious and time-consuming nature of the work. Additionally, the reliance on physical scoring sheets for each patient further adds

to the workload. One major drawback of the traditional approach is the potential for human error, given the multitude of tiny measurements involved. The dental anatomy being inherently small and detailed exacerbates the risk of mistakes. Moreover, the readings obtained in this manner are highly dependent on the individual performing the measurements. Different operators may have varying perspectives, leading to inconsistencies in the recorded data. This issue is further compounded by the fact that premeasured PAR (Peer Assessment Rating) and IOTN (Index of Orthodontic Treatment Need) rulers do not show a noticeable increase in length during the measurement process.

The reliance on human observation in the conventional method introduces a significant source of error, necessitating the need for repeated checks and measurements (Horriat et al., 2022). Digital measurements, in contrast, offer a superior alternative in terms of accuracy. By employing digital technology, orthodontists can mitigate the shortcomings associated with human-dependent observations, ensuring more precise and reliable results. The transition from traditional to digital methods not only enhances accuracy but significantly streamlines the workflow, reducing the time and effort required for comprehensive orthodontic analysis (Luqmani et al., 2020).

In 2015, Westerlund and his team delved into the realm of orthodontic digital software. Their focus extended beyond mere measurements to evaluating the overall performance of four different software systems which are Cadent, OthoLab, OrthoProof, and 3Shape. The assessment encompassed three crucial aspects which are service, functionality, and usability. It was observed that all four systems exhibited the

capability to perform measurements independently, showcasing their proficiency in the quantitative aspect of orthodontic analysis.

However, a notable point emerged from their study, none of the evaluated software systems seemed to integrate the comprehensive range of indices, specifically the PAR (Peer Assessment Rating), Bolton Analysis, and index IOTN (Index of Orthodontic Treatment Need), within a singular software platform. This implied a gap in the availability of a unified solution that could encompass these diverse orthodontic measurements, potentially highlighting an area for further development or integration in orthodontic digital software.

1.4 Research Objectives

The aims of this study are:

1) To develop the orthodontic indices using a digital analysis system.
2) To analyze the orthodontic measurement with Peer Assessment Rating (PAR) Index, Bolton Analysis, and Index of Orthodontic Treatment Needs (IOTN) using a digital analysis system.
3) To compare the orthodontic measurement using a digital analysis system and conventional method.

1.5 Research Hypothesis

H_{01}: There is no significant difference for orthodontic measurement with Peer Assessment Rating (PAR) Index between the conventional orthodontic index measurement method and the digital measurement method.

H_{02}: There is no significant difference for orthodontic measurement with Bolton analysis between the conventional orthodontic index measurement method and the digital measurement method.

H_{03}: There is no significant difference for orthodontic measurement with Index of Orthodontic Treatment Needs (IOTN) between the conventional orthodontic index measurement method and the digital measurement method.

1.6 Research Question

1) What is the significant difference for orthodontic measurement with Peer Assessment Rating (PAR) Index between the conventional orthodontic index measurement method and the digital measurement method?

2) What is the significant difference for orthodontic measurement with Bolton analysis between the conventional orthodontic index measurement method and the digital measurement method?

3) What is the significant difference for orthodontic measurement with Index of Orthodontic Treatment Needs (IOTN) between the conventional orthodontic index measurement method and the digital measurement method?

1.7 Significance of the Study

The introduction of this digital method represents a significant advancement in the realm of orthodontic assessments, offering a streamlined approach for orthodontists and doctors. The proposed system serves as a comprehensive solution by consolidating multiple conventional tools into a single digital platform, simplifying the often complex procedure of assessing the orthodontic measurement index. By harnessing the capabilities of computer software and image processing, all measurements are executed with precision, reducing the likelihood of systematic errors that could arise from faulty equipment during the measurement of dental casts. This ensures a higher level of accuracy and reliability in the assessment process.

One key feature of this digital system is its capacity to eliminate or greatly reduce paper usage in orthodontic measurement workflow. Traditionally, physical records of dental cast measurements were stored on paper, leading to potential inefficiencies, environmental impact, and financial costs associated with paper usage. However, with proposed digital system, all dental cast records are stored electronically in a centralized database (Verma et al., 2019). This transition to a paperless approach not only aligns with environmental sustainability efforts but also results in substantial cost savings by eliminating the need to purchase and manage physical paper documents.

The benefits of the paperless concept extend beyond cost savings. Storing dental cast records digitally in a database ensures efficient organization, easy retrieval, and long-term archival of patient data. The digital database system facilitates quick access to historical records, contributing to a more efficient and effective patient care process. Moreover, the secure and centralized storage of digital records enhances data integrity and reduces the risk of information loss or damage.

In summary, the adoption of this digital method in orthodontic assessments not only simplifies the assessment procedure through the integration of various tools but also brings about efficiency, accuracy, and sustainability by minimizing systematic errors, eliminating paper usage, and ensuring organized digital storage of dental cast records.

1.8 Limitation of the Study

This study focuses specifically on measuring tooth displacement for orthodontic indices, narrowing its scope to this particular aspect of orthodontic evaluation. As a result, individuals who wear braces and those with abutments, along with those experiencing mouth diseases, are intentionally excluded from the experiment. This limitation allows for a more focused investigation into tooth displacement, minimizing confounding variables that could arise from the presence of braces, abutments, or oral diseases, and ensuring that the research outcomes primarily reflect the impact on tooth movement.

To maintain consistency and accuracy in image acquisition, a specific protocol is set for the use of the camera. The camera must be positioned parallel to the dental cast, and separate views of the maxillary and mandibular occlusions are required. This meticulous approach aims to standardize the imaging process, reducing potential distortions that may occur with varying camera angles. By adhering to these specific guidelines, the study ensures a uniform and reliable collection of data, enhancing the validity of the measurements related to tooth displacement.

However, like any research endeavor, this study faces certain limitations. The researchers acknowledge constraints in terms of both time and cost during the conduct of the research. The limited duration implies that the study may not be able to capture long-term effects or changes over an extended period. Additionally, budget constraints may restrict the scope of the research, potentially affecting the size of the sample or the range of variables that can be investigated. Despite these limitations, the researchers aim to maximize the efficiency and effectiveness of the study within the given resources.

In summary, this study deliberately confines its focus to tooth displacement for orthodontic indices, excluding specific groups of individuals to enhance the clarity of results. Strict imaging protocols are established to ensure consistency, but the study acknowledges practical limitations such as time constraints and budget considerations, demonstrating a transparent approach to the challenges faced during study.

1.9 Operational definition

1. Orthodontic

   Orthodontics is specialized with facial growth, development of the dentition and occlusion, diagnosis, interception, and treatment of occlusion anomalies (Mitchell, 2007).

2. Malocclusion

   Malocclusion is related to the lack of ideal dentition form, while in centric occlusion, an estimated 80% of children and teenagers have some degree of malocclusion. (Balogh, 2006).

3. Orthodontic Indices

   Orthodontic indices are numerical values used in malocclusion clinical and epidemiological research that indicate a population's relative condition on a graded scale with particular upper and lower limits. (Gupta & Shrestha, 2015).

4. Peer Assessment Rating (PAR) Index

   The peer assessment rating (PAR) index is an occlusal index designed and validated as an instrument to measure how much a patient deviates from normal alignment and occlusion (Firestone et al., 2002).

5. Bolton Analysis

   Bolton analysis determine the ratio of the mesiodistal widths of the maxillary teeth to the mandibular teeth (Balogh, 2006).

6. Index of Orthodontic Need (IOTN)

   Index of Orthodontic Need (IOTN) is the measurement index to assess the probable impact a malocclusion may have on an individual's dental health and psychosocial wellbeing (Mitchell, 2007).

1.10 Summary

Orthodontics is a branch of dentistry that diagnoses, treats, and prevents malocclusion, a misalignment of teeth in an arch. Approximately 80% of children and teenagers show some degree of malocclusion, with crowding being the most common problem. Malocclusion is divided into three major groups: neutroclusion, distoclusion in the permanent dentition, and mesiooclusion. Three standard assessments of orthodontic treatment are the Peer Assessment Rating (PAR) Index, Bolton Analysis, and the Index of Orthodontic Treatment Needs (IOTN).

The PAR index, Bolton Analysis, and IOTN are widely used in orthodontics for assessment and analysis before and after treatment. Traditional tools like PAR and IOTN rulers are still used, but stationaries, calipers, thread, metal rulers, and scoring sheets are essential for the procedure. Dental casts, made from Yellowstone or Plaster of Paris, act as study and working models for analysis and treatment planning. Study models are crucial for patient reference and are used for pre-treatment, post-treatment, and IOTN grades. Image processing can help maintain the safety of study models, with 2D images being more user-friendly and requiring less storage space.

Traditional methods for measuring and analyzing dental indices have been used since 1956, but they are vulnerable to errors due to human error and the need for physical scoring sheets. Digital measurements offer superior accuracy and reliability compared to traditional methods. A 2014 study by Cabral Correia, found that digital measurements are as accurate as plastic models and highly reliable. A 2015 study by Westurlund, compared four orthodontic digital software and found that all could perform measurements individually, with no software combining IOTN, Bolton Analysis, and PAR index in one.

This study aims to develop orthodontic indices using digital analysis system, analyze measurement using PAR Index, Bolton Analysis, and IOTN, and compare it with conventional methods. The research hypothesis states that there are no significant differences in orthodontic measurement between conventional and digital methods, including Peer Assessment Rating, Bolton analysis, and Index of Orthodontic Treatment Needs.

The study presents a digital method for simplifying orthodontic measurement index assessment, combining conventional tools with computer software and image processing. This reduces systematic errors and replaces paper usage by saving dental cast records in a database, saving money on paper and ensuring long-term document storage. The study measures tooth displacement for orthodontic indices, excludes braces and abutment wearers and mouth disease patients, requires parallel camera use, and faces limitations in duration and cost.