RESEARCH PAPER

Accuracy of Korkhaus 3D calliper in adults of Angle's classification of malocclusion: A cross-sectional analytical study

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Abstract

Background: Accurate assessment of maxillary arch dimensions is essential for orthodontic diagnosis and treatment planning. This study evaluated the reliability of the Korkhaus 3D calliper in measuring maxillary arch width and palatal depth in different Angle's malocclusion groups.

Materials and Methods: Inter-canine width, inter-molar width, and palatal depth were measured *In-Vivo* and *In-Vitro* using the Korkhaus 3D calliper. Agreement between both methods was assessed using the Intraclass Correlation Coefficient (ICC).

Results: Excellent reliability was observed between *In-Vivo* and *In-Vitro* measurements. ICC values for inter-canine width, inter-molar width, and palatal depth were 0.972, 0.975, and 0.994 respectively. Variations in maxillary arch dimensions were observed among different malocclusion groups.

Conclusion: The Korkhaus 3D calliper demonstrated high accuracy and reproducibility for measuring maxillary arch dimensions. Direct intraoral measurements showed strong agreement with cast-based measurements, suggesting reduced dependence on alginate impressions.

Keywords: Maxillary arch, Inter-molar arch width, Inter-canine arch width, palatal depth, Angle's classification, Korkhaus 3D calliper, malocclusion.

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Introduction

The korkhaus caliper, also referred to as the Korkhaus tridimensional bow divider, was introduced in the early 20th century by Gustav Korkhaus (1890-1978), a German orthodontist regarded as one of the pioneers of craniofacial measurement in orthodontics.

Korkhaus emphasized the importance of quantitative assessment of dental arch dimensions and developed the bow divider as a simple yet precise instrument for recording transverse widths and palatal depth in both the oral cavity and on dental casts (Proffit *et al*., 2019, Korkhaus, 1926) [1]. The device was designed to provide objective, reproducible, and three-dimensional measurements, overcoming the limitations of purely visual assessment and allowing orthodontists to standardize diagnostic evaluation of maxillary morphology. Its ability to be applied intraorally and on plaster models made it particularly versatile in both

clinical and research contexts.

Over subsequent decades, the Korkhaus caliper became one of the most frequently used manual instruments for assessing arch form and palatal depth, and it continues to be cited as a benchmark tool despite the advent of modern digital scanning and imaging technologies (McNamara, 2000; Proffit *et al.*, 2019) [1, 2].

The morphology of the maxillary arch is a fundamental determinant of dental occlusion, facial esthetics, and functional stability following orthodontic treatment. Variations in arch form, arch width, and palatal depth are closely related to the development of malocclusion and influence the choice of treatment mechanics and long-term stability of outcomes [1].

Dental arch width refers to the transverse distance between corresponding maxillary teeth and is critical for maintaining proper inter-arch relationships. A reduction in inter-canine or interpremolar width has been associated with crowding and constricted arches, while variations in intermolar width often reflect skeletal discrepancies [2, 3].

Similarly, palatal depth—defined as the vertical distance from the palatal vault to the occlusal plane—provides insight into maxillary growth patterns and vertical skeletal relationships. Excessively deep or shallow palates are commonly seen in certain malocclusion types and may complicate orthodontic intervention [4].

Angle's classification of malocclusion, despite being over a century old, remains one of the most widely adopted systems in clinical orthodontics. Distinct differences in maxillary arch dimensions have been documented among Class I, Class II, and Class III malocclusions [5].

For instance, Class II individuals often present with reduced anterior arch widths, while Class III patients tend to exhibit broader intermolar dimensions with shallower palatal vaults [6, 7].

Understanding these variations is crucial for accurate diagnosis, arch coordination, and individualized treatment planning. Traditional two-dimensional measurement techniques on dental casts or radiographs may not capture the three-dimensional complexity of the maxillary arch. To overcome this limitation, devices such as the Korkhaus 3D caliper have been introduced, allowing precise and reproducible assessment of transverse and vertical arch dimensions [8]. The instrument is particularly useful in orthodontic research as it enables standardized evaluation of arch width and palatal depth across malocclusion groups.

Given the clinical importance of transverse and vertical arch dimensions, there is a need for further investigation in diverse populations. This study aims to evaluate and compare the maxillary dental arch width and palatal depth among adults with Class I, Class II, and Class III malocclusions using the Korkhaus 3D caliper, *In-Vivo* and *In-Vitro* thereby contributing to a more comprehensive understanding of arch morphology across malocclusion types.

Materials and Methods

Among the instruments frequently employed for assessing maxillary arch morphology, the caliper and the Korkhaus three-dimensional bow divider are most widely reported in the literature. These devices can be utilized either intraorally or on dental casts for precise dimensional evaluation. The caliper, in particular, is a popular choice as it provides objective and reproducible measurements of the hard palate. Its advantages include simplicity, non-invasiveness, pain-free application, and absence of associated risks, making it a reliable tool for both clinical and research purposes [9, 10].

Study design and Setting

This investigation was designed as a cross-sectional analytical study conducted in the Department of Orthodontics, at SMBT IDSR Dhamangaon Nashik. The study protocol was reviewed and approved by the Institutional Ethics Committee (Approval No. - SMBT/IEC/2024/327). Written informed consent was obtained from all participants prior to enrollment, in accordance with the Declaration of Helsinki (World Medical Association, 2013) [11].

Study Population

A total of 125 adult subjects (aged 18-30 years) were recruited for the study. Based on Angle's classification of malocclusion, the sample was divided into three groups:

- **Class I malocclusion:** 55 subjects
- **Class II malocclusion:** 55 subjects
- **Class III malocclusion:** 15 subjects

Inclusion Criteria

- **Age range:** 18-30 years
- Permanent dentition present up to the second molars
- Subjects with Class I, Class II, or Class III molar relationship (according to Angle's classification)
- Absence of craniofacial anomalies or syndromes

Exclusion Criteria

- Previous orthodontic or orthopedic treatment
- Missing teeth (except third molars)
- Extensive dental restorations, caries, or attrition affecting measurement landmarks
- Gross asymmetry of the maxillary arch

Data Collection:

Impression and Cast Preparation

Maxillary impressions were obtained using alginate impression material (Zhermack, Italy) and poured in dental stone (Type III, Kalabhai, India) to prepare study casts. Each cast was labeled with a unique identification code to ensure blinding during measurement.

Measurement Instrument

Arch dimensions were measured using the Korkhaus tridimensional caliper (also known as the Korkhaus bow divider), a validated tool for assessing dental arch width and palatal depth [2, 8]. The instrument allows precise

measurement in three planes and has been widely used in orthodontic research.

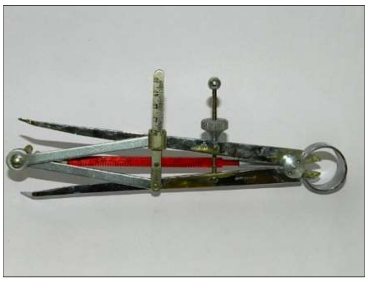

Fig 1: Korkhaus 3D Caliper

Measurement Parameters

- **Inter-canine width:** Distance between cusp tips of right and left maxillary canines
- **Inter-premolar width**: Distance between buccal cusp tips of right and left first premolars
- **Inter-molar width**: Distance between mesiobuccal cusp tips of right and left first molars
- **Palatal depth**" Vertical distance from the deepest point of the palatal vault at the mid-palatal suture to a reference line connecting the mesiopalatal cusp tips of maxillary first molars [4, 7].

Fig 2: Inter-canine width

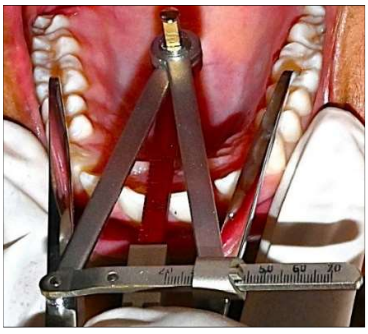

Fig 3: Inter-molar width and palatal depth

Each measurement was taken twice by the same calibrated examiner at two different sittings, and the mean value was used for analysis. Intra-examiner reliability was assessed using the Intraclass Correlation Coefficient (ICC).

Results

Intra-Class Correlation Coefficient (ICC) between *In Vivo* and *In Vitro* Measurements. The accuracy and reliability of the Korkhaus 3D caliper in measuring inter-canine width, inter-molar width, and palatal depth were assessed among adults with Angle's Class I, II, and III malocclusions. ICC values demonstrated good to excellent reliability (ICC > 0.90 for most parameters), confirming high reproducibility of the instrument.

Class I Malocclusion (n = 55)

In Class I subjects, minimal differences were observed between *In-Vivo* and *In-Vitro* measurements for inter-canine width, inter-molar width, and palatal depth ($p > 0.05$). ICC values ranged from 0.972 to 0.994, indicating excellent reliability and

consistency of the Korkhaus 3D caliper. These findings establish the consistency of the Korkhaus caliper across direct and indirect measurements in Class I subjects (Staley *et al*., 1985; McNamara, 2000) [2, 7].

Class II Malocclusion (n = 55)
Class II subjects showed minimal differences between *In-Vivo* and *In-Vitro* measurements for all parameters ($p > 0.05$). ICC values ranged from 0.895 to 0.994, demonstrating good to excellent reliability of the Korkhaus 3D caliper.

Class III Malocclusion (n = 15)
Class III subjects demonstrated negligible differences between *In-Vivo* and *In-Vitro* measurements ($p > 0.05$). ICC values ranged from 0.986 to 0.994, indicating excellent reliability and precision of the Korkhaus 3D caliper. Measurements were repeated twice by the same calibrated examiner at different sittings to ensure consistency.

Comparative Analysis Across Malocclusion Groups:
Across all malocclusion groups, differences between *In-Vivo* and *In-Vitro* measurements were minimal (<0.3 mm) and statistically non-significant ($p > 0.05$). ICC values showed excellent agreement for most parameters, confirming the accuracy and reliability of the Korkhaus 3D caliper in both clinical and cast-based measurements.

Table 1: Intra Class Correlation Coefficient between *In Vitro* & *In Vivo* measurement of Inter Canine width, Inter Molar Width & Palatal Depth by Korkhaus 3D Caliper among adults with angle's class I Malocclusion.

Measurements	*In-Vivo*	*In-Vitro*	Mean Difference	Intra Class Correlation Coefficient	Signiifcance 'P' Value	Inference
N=55	Mean±SD	Mean±SD				
Inter Canine width	35.60±2.4	35.31±2.3	0.29	0.972	0.001(HS)	Excellent Reliability
Inter Molar Width	46.49±1.9	46.33±1.7	0.16	0.975	0.001(HS)	Excellent Reliability
Palatal Depth	25.55±3.4	25.42±3.2	0.13	0.994	0.001(HS)	Excellent Reliability

Table 2: Intra Class Correlation Coefficient between *In Vitro* & *In Vivo* measurement of Inter Canine width, Inter Molar Width & Palatal Depth by Korkhaus 3D Caliper among adults with angle's class II Malocclusion

Measurements	*In-Vivo*	*In-Vitro*	Mean Difference	Intra Class Correlation Coefficient	Signiifcance 'P' Value	Inference
N=55	Mean±SD	Mean±SD				
Inter Canine width	34.18±2.2	34.31±2.2	0.13	0.895	0.001(HS)	Good Reliability
Inter Molar Width	44.67±2.8	44.40±2.7	0.27	0.994	0.001(HS)	Excellent Reliability
Palatal Depth	24.04±2.1	23.82±1.9	0.22	0.985	0.001(HS)	Excellent Reliability

Table 3: Intra Class Correlation Coefficient between *In Vitro* & *In Vivo* measurement of Inter Canine width, Inter Molar Width & Palatal Depth by Korkhaus 3D Caliper among adults with angle's class II Malocclusion.

Measurements	*In-Vivo*	*In-Vitro*	Mean Difference	Intra Class Correlation Coefficient	Signiifcance 'P' Value	Inference
N=15	Mean±SD	Mean±SD				
Inter Canine width	35.67±1.4	35.53±1.5	0.14	0.986	0.001(HS)	Excellent Reliability
Inter Molar Width	44.87±2.5	44.87±2.3	0.00	0.994	0.001(HS)	Excellent Reliability
Palatal Depth	24.0±2.8	23.93±2.5	0.07	0.993	0.001(HS)	Excellent Reliability

Table 4: Comparative evaluation of *In Vitro* & *In Vivo* measurement of Inter Canine width, Inter Molar Width & Palatal Depth by Korkhaus 3D Caliper among adults with angle's class I Malocclusion.

Measurements	*In-Vivo*	*In-Vitro*	Mean Difference	Student 't' Test Value	Signiifcance 'P' Value
N=55	Mean±SD	Mean±SD			
Inter Canine width	35.60±2.4	35.31±2.3	0.29	0.644	0.521(NS)
Inter Molar Width	46.49±1.9	46.33±1.7	0.16	0.468	0.641(NS)
Palatal Depth	25.55±3.4	25.42±3.2	0.13	0.198	0.843(NS)

Table 5: Comparative evaluation of *In Vitro* & *In Vivo* measurement of Inter Canine width, Inter Molar Width & Palatal Depth by Korkhaus 3D Caliper among adults with angle's class II Malocclusion.

Measurements	*In-Vivo*	*In-Vitro*	Mean Difference	Student 't' Test Value	Signiifcance 'P' Value
N=55	Mean±SD	Mean±SD			
Inter Canine width	34.18±2.2	34.31±2.2	0.13	0.296	0.768(NS)
Inter Molar Width	44.67±2.8	44.40±2.7	0.27	0.509	0.612(NS)
Palatal Depth	24.04±2.1	23.82±1.9	0.22	0.559	0.577(NS)

Table 6: Comparative evaluation of *In Vitro* & *In Vivo* measurement of Inter Canine width, Inter Molar Width & Palatal Depth by Korkhaus 3D Caliper among adults with angle's class III Malocclusion.

Measurements	*In-Vivo*	*In-Vitro*	Mean Difference	Student 't' Test Value	Signiifcance 'P' Value
N=15	Mean±SD	Mean±SD			
Inter Canine width	35.67±1.4	35.53±1.5	0.14	0.243	0.810(NS)
Inter Molar Width	44.87±2.5	44.87±2.3	0.00	0.000	1.000(NS)
Palatal Depth	24.0±2.8	23.93±2.5	0.07	0.068	0.946(NS)

Discussion

The present cross-sectional analytical study evaluated the accuracy and reliability of the Korkhaus 3D caliper in measuring maxillary inter-canine width, inter-molar width, and palatal depth among adults with Angle's Class I, II, and III malocclusions. Minimal differences between *In-Vivo* and *In-Vitro* measurements (<0.30 mm) and high ICC values (≥0.895) demonstrated good to excellent reproducibility of the instrument [12].

The findings suggest that the Korkhaus 3D caliper is a reliable chairside tool for orthodontic diagnosis, treatment planning, and monitoring treatment changes such as maxillary expansion and arch coordination. Its cost-effectiveness, radiation-free nature, and ease of use make it particularly useful in resource-limited clinical settings where advanced digital imaging systems may not be readily available [12, 13].

Conclusion

The Korkhaus 3D caliper showed excellent accuracy and reliability across all malocclusion groups, with negligible differences between *In-Vivo* and *In-Vitro* measurements. High ICC values confirmed good to excellent reproducibility. The device is a cost-effective, radiation-free, and clinically reliable tool for orthodontic assessment.

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