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Dental Cast Measurement Variations in Patients with Maxillary Anterior Crowding: A Comparative Study

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Abstract

Background: Dental crowding, a common orthodontic issue, arises due to a mismatch between tooth size and jaw dimensions, significantly affecting dentofacial aesthetics. This study focused on maxillary anterior crowding (M x AC) to investigate its relationship with the tooth size and jaw dimensions.

Materials and Methods: This retrospective cross-sectional study included 80 participants divided into two groups: 40 with normal occlusion (control) and 40 with M x AC occlusion. Dental casts were prepared using alginate impressions and dental stones, and measurements were taken for mesiodistal dimensions, arch width, arch depth, overbite, overjet, and arch length discrepancy using a modified sliding caliper gauge. Differences between the two groups were compared using an independent t-test. Statistical significance was set at $P < 0.05$.

Results: Significant differences were observed in tooth dimensions and arch measurements between the M × AC and control groups ($P< 0.001$). The M × AC group had larger dental crowns (except for the first molar), smaller overjet, and greater arch length discrepancy. The control group exhibited larger arch widths in the first premolar, second premolar, and first molar positions, but not in the canine position (P=0.420). Additionally, the M x AC group had significantly smaller arch depths at the canine, first, and second premolar positions ($P< 0.001$). However, no significant difference was observed between the groups in dental arch depth at the first molar position (P=0.120).

Conclusion: The study found significant differences in tooth dimensions and dental arch measurements between the M × AC and control groups. The M × AC group had larger dental crowns (except for the first molar), less overjet, and greater arch length discrepancy. Arch widths for the premolars and the first molar were larger in the control group, while the M × AC group had smaller arch depths at the canine and premolar positions. These findings underscore the need for customized orthodontic treatment.

Article Info

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1. INTRODUCTION

Over the past few decades, there has been a growing demand for orthodontic treatment, primarily driven by aesthetic concerns. One of the most common issues observed by orthodontists is dental crowding, which occurs when there is insufficient space in the jaws for proper alignment of the teeth. This condition is typically caused by a mismatch between the size of the teeth and jaws, such as when the jaws are too small to accommodate the teeth. Dental crowding is the most prevalent type of malocclusion in both permanent and mixed dentitions, and can have a significant impact on dentofacial aesthetics [1]. When maxillary canines shift labially, buccally, or labiobuccally and the maxillary lateral incisors become displaced toward the palate, it is typically an indication of maxillary anterior crowding (M x AC). This type of malocclusion is often attributed to a mismatch between the size of the dental arch and the width of the teeth, resulting in insufficient space for proper alignment [2]. Dentofacial structure is primarily influenced by a combination of genetic and environmental factors, including certain habits that can lead to malocclusion during growth and development. Consequently, the etiology of malocclusion is complex. According to Proffit, optimal occlusion not only enhances aesthetics, but also supports efficient oral function and helps prevent diseases. Any deviation from this ideal alignment is termed malocclusion and can affect oral health, speech, chewing, appearance, and other oral functions [3]. Bernabé et al. investigated the intra-arch factors contributing to persistent crowding in a study of 150 dental cast pairs from children aged 12–16 years. They found that while jaw arch length is a significant factor in crowding, other factors, such as mesiodistal tooth size, intermolar arch width, and jaw arch length, all play essential roles. The study categorized casts into three groups: spacing, moderate crowding, and severe crowding [4]. Poosti et al. examined the tooth size and arch dimensions in both crowded and uncrowded Class I malocclusions. They concluded that there were significant differences in transverse arch dimensions and tooth diameters between the two groups. Specifically, crowded groups exhibited a narrower maxillary arch width and a larger total mesiodistal tooth size than non-crowded groups [5]. However, this study aimed to investigate the underlying causes of anterior dental crowding and to explore its relationship with various factors, including tooth size and the dimensions of the jaw, specifically its size, width, and depth.

2. MATERIAL AND METHODS

2.1. Subjects

This retrospective cross-sectional study involved 80 participants and 80 dental casts divided into two groups: 40 participants with normal occlusion (control group) and 40 participants with maxillary anterior crowding (M x AC group). The study included adult participants over the age of 18 years, no anterior or posterior crossbites, a straight profile without prominent asymmetry, a continuous dental arch without stress on the lips or mentalis muscles, complete eruption of permanent teeth in the maxillary arch from the second molar to the second molar, no systemic diseases or congenital abnormalities, and no history of orthodontic treatment. crowding in the maxillary dental arch (with an arch length discrepancy of < -4.0 mm) and at least one maxillary canine displaced toward the facial direction, indicating that the tip of the canine is positioned outside the dental arch, lying on the facial side of the line drawn between the center of the lateral incisor edge and the buccal cusp tip of the first premolar, as observed from the occlusal plane [6]. Individuals with a history of orthodontic treatment, congenital craniofacial abnormalities (such as cleft lip or palate), or atypical crowns were excluded from the study. The Medical Ethics Committee of the Faculty of Dentistry at Sana'a University granted ethical approval for this study, and written informed consent was obtained from all participants.

2.2. Dental Cast Preparation

Alginate impressions (Chromatic alginate Tropicalgin; Zhermack, Italy) were obtained from the upper and lower arches of all participants. After washing and disinfecting the impressions with a 1:10 sodium hypochlorite solution, they were used to create dental stone casts (Elite Rock, Sandy brown; Zhermack, Italy). The maxillary casts were made of dental stone with bases constructed from Paris plaster. The casts were then documented and measured. As per the standard orthodontic procedures, the bases were trimmed and numbered to correspond to the respective participants.

2.3. Dental Cast Assessment

Dental cast measurements were performed using a modified sliding caliper gauge with an accuracy of 0.02 mm (Figure 1). The landmarks marked on the dental casts included the incisal point, canine cusp tips, premolar cusp tips, mesiobuccal and mesiolingual cusp tips of the first molar, and the distobuccal cusp tips of the second molar. The measurements included the following:

i. Mesiodistal Maxillary Arch Dimensions: Mesiodistal dimensions of the central and lateral incisors, canines, first and second premolars, and first molars (Figure 2).

ii. Maxillary Arch Width (Figure3) The following distances were measured:

- Inter-canine distance: Length measured linearly between points of the canine cusps.
- Inter-first premolar distance: Length of a linear segment connecting the buccal cusp points of the first premolars.

- Inter-second premolar distance: Length measured linearly between the buccal cusp tips of the second premolars.
- Inter-first molar distance: Length measured linearly between the mesiobuccal cusp tips of the first molars.
- Inter-second molar distance: Length measured linearly between the distobuccal cusp tips of the second molars.

iii. Maxillary Arch Depth (Figure 4) Maxillary arch depth was measured at the level of the canines, first and second premolars, and first molars. It is defined as the vertical distance between the midline palatal vault and a point on the palatal width line. The following depths were measured:

- Arch depth between canines: Vertical distance from the inter-canine line to the palatal vault in the midline.
- Arch depth between premolars: Vertical distance from the inter-premolar line to the palatal vault in the midline.
- Arch depth between molars: Vertical distance from the inter-molar line to the palatal vault in the midline.

iv. Relationship of the Central Incisors: Overbite and Overjet. To evaluate the overjet and overbite relationship on dental casts, the following steps were followed:

- Overjet Measurement: Overjet is the horizontal overlap between the mandibular and maxillary incisors. It is measured in millimeters when the teeth are maximally intercuspated.
- Overbite Measurement: Overbite refers to the vertical overlap between the mandibular and maxillary incisors. It is also measured in millimeters when the teeth are maximally intercuspated.

v. Maxillary Arch Length Discrepancy: The following parameters were calculated to determine the relationship between jaw length and tooth size:

- Mesiodistal Width of Teeth: This measurement was taken from the mesial to the distal contact points of each tooth. A total of 12 teeth were measured in each arch, starting with the first permanent molar on the right and moving towards the left.
- Arch Length Required: This refers to the total mesiodistal width of all teeth from the second premolar on one side to the second premolar on the other side measured at the contact points.
- Arch Length Available: This is measured in six segments, starting from the mesial surface of the first molar on the right side to the mesial surface of the first molar on the left. The segments around the upper arch are shown in Figure 5. The tips of the measuring tool were positioned between the teeth on the buccal and labial sides of the arches, below the contact points, and at the highest point of the gingival papillae. Three typical segments were measured on each side:
  - The papilla between the canine and first premolar to the papilla between the canine and second premolar.
  - The papilla between the canine and first premolar to the papilla between the canine and lateral incisor.
  - The papilla between the canine and lateral incisor to the papilla midway between the central incisors.

2.4. Statistical Analysis

Statistical Package for Social Sciences for Windows, Version 28.0, was used to input and analyze the data. The normality of the data distribution was assessed using the Kolmogorov-Smirnov test. Differences between the two groups were compared using an independent t-test. Additionally, we evaluated the intra-examiner reliability of the measurements using the intra-class correlation coefficient (ICC). Statistical significance was set at $P < 0.05$.

3. RESULTS

A comparison of dental cast measurements between the M × AC and control groups is shown in Table 1. In terms of mesiodistal tooth dimensions, all measured dental crowns in the M × AC group were significantly larger than those in the control group ($P < 0.001$). However, there was no significant difference in the mesiodistal dimension of the first molar between the two groups ($P=0.469$). In the comparison of central incisor relationships, the M × AC group had a significantly smaller overjet than the control group ($P < 0.001$). However, the difference in overbite between the two groups was not statistically significant ($P=0.395$). In terms of the tooth size and arch size relationship, the M x AC group exhibited a significantly greater arch length discrepancy than the control group ($P < 0.001$). When assessing dental arch width, the control group had significantly larger arch widths at the first premolar, second premolar, and first molar positions than the M x AC group ($P < 0.001$). However, no significant difference was observed between the two groups in arch width at the canine position ($P=0.420$). There were significant differences in the dental arch depth between the two groups. The dental arch depths at the canine, first premolar, and second premolar positions were significantly lower in the M × AC group than in the control group ($P < 0.001$). However, no significant difference was observed between the groups in dental arch depth at the first molar position ($P=0.120$). Reliability of the measurement was confirmed, with ICC values exceeding 0.95, indicating a strong level of agreement (Table 1).

4. DISCUSSION

Spacing and crowding of the teeth are the most prevalent types of malocclusion. When the dentition is crowded, there is insufficient space for the teeth to erupt in the proper location [7]. Subsequently, the teeth may be displaced, rotated, or impacted. A confluence of etiological factors has been identified to attain a more comprehensive understanding of these dental issues. While the literature reports that inheritance, environment, ethnicity, and secular trends are potential causes of crowding and spacing, a pertinent question in this context is the causal significance of the different clinical traits. Several studies have examined the relationship between tooth size and arches, but the results have not always been inconsistent [8, 9, 10, 11]. In our study, all mesiodistal teeth dimensions in the M × AC group were significantly larger than those in the control group, except for the mesiodistal dimension of the first molar, and there was no significant difference between the two groups (P=0.469). Similarly, Mesiodistal diameters of tooth crowns of the M × AC group were significantly larger than those of the control group for all teeth except for the first molar [12]. In terms of central incisor relationships, our study found that the M × AC group had a significantly smaller overjet than the control group. However, the difference in overbite between the two groups was not statistically significant (P=0.395). Our results are similar to those of a study conducted by Ikoma and Arai; the overbite was significantly smaller in the M x AC group than in the control group [12]. In terms of the relationship between tooth size and arch size, our study found that the M x AC group exhibited a significantly greater arch length discrepancy than the control group. McNamara et al.. investigated the relationship between tooth size, dental arch dimensions, and dental crowding. They reported no statistically significant difference in tooth dimensions between the two groups. The size of the dental arches was the main difference between the two groups; the case group showed a somewhat smaller variation than the control group [14]. Another study reported arch length discrepancy and facial-palatal displacement. of the lateral incisors and canines from the dental arch were significantly smaller and greater, respectively, in the M x AC group than in the control group [12]. In 2007, Puri et al. conducted a study to compare three groups: a normal group (without crowding or spacing), crowded group, and spaced group. They examined the relationship between arch length and mesiodistal tooth size in each group and reported that the crowded group had wider mesiodistal teeth than the other two groups [7]. Radnzic investigated the relationship between mesiodistal crown length and dental arch congestion in two racial groups: British and Pakistani. Their findings indicated strong correlations between certain arch dimensions and the degree of crowding in both groups. However, no significant correlation was found between cumulative mesiodistal crown width and dental crowding when examined alone. When combined with other factors, cumulative mesiodistal crown widths play a significant role in the overall regression equation, suggesting a complex interplay among crown widths, arch dimensions, and dental crowding [13]. When assessing dental arch width in our study, the control group had significantly larger arch widths at the first premolar, second premolar, and first molar positions than the M x AC group. However, no significant difference was observed between the two groups in the arch width at the canine position. The results of this study align with the findings of Ikoma et al., in which dental arch widths at the first and second premolars and the first molars and dental arch depths at the canine, first premolar, and second premolar in the M × AC group were significantly smaller than those in the control group [12]. Sayin and Türkkahraman showed that the non-crowding group had more space available for the mandibular permanent incisors, mandibular deciduous inter canine widths, mandibular deciduous intermolar widths, mandibular interalveolar widths, and mandibular permanent intermolar widths than the crowed group. Nevertheless, there was no statistically significant association discovered between crowding and overall arch length [14, 15]. Unlike our subjects, who were selected from a homogeneous Yemeni population, Italian patients with similar malocclusion status and buccally displaced maxillary canines showed significantly wider intercanine widths, whereas no differences were observed in their intermolar widths [16]. In terms of dental arch depth, our study found significant intergroup differences between the two groups. The dental arch depths at the canine, first premolar, and second premolar positions were significantly lower in the M × AC group than in the control group. However, no significant difference was observed in dental arch depth at the first molar position between the groups. A study was conducted on 90 dental casts to compare the mesiodistal dimensions of the upper canines, first molars, and lower incisors of crowded and normal arches. The mesiodistal dimensions of the upper incisors, lower canines, and premolars differed significantly between spaced and normal arches. Further analysis revealed a statistically significant difference in the upper arch perimeter, lower inter-canine widths, lower inter-premolar widths, and arch perimeters between spaced and normal arches compared with crowded arches. Along with these variations, the lower premolars, lower first molars, upper right premolars, and upper lateral incisors have buccolingual dimensions [17]. The study primarily focused on morphological measurements without assessing functional aspects, such as masticatory efficiency, speech, and overall oral health. Integrating functional evaluations may offer a more holistic understanding of the impact of maxillary anterior crowding. Future research should emphasize three-dimensional, longitudinal analyses to track the development of maxillary anterior crowding M ×

AC over time and identify causative factors, which would contribute to a more comprehensive understanding of this condition.

5. CONCLUSION

The study showed significant differences in tooth dimensions and dental arch measurements between the maxillary anterior crowding M × AC and control groups. Most dental crowns were larger in the M × AC group than in the first molar. The M × AC group had less overjet and more pronounced arch length discrepancy. The control group had larger arch widths for the premolars and first molar, but not for the canines. The M × AC group had smaller arch depths for the canine and the first and second premolars. These findings highlight the distinct morphological differences that are crucial for tailored orthodontic treatment.

DECLARATIONS

Ethics approval and consent to participate

The ethical committee of Sana’ a University approved this study for medical research, which was conducted in accordance with the guidelines of the Declaration of Helsinki. Written informed consent was obtained from all the patients in the study.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the study are available from the corresponding author upon reasonable request.

Competing interest

There are no conflicts of interest regarding the submission of this manuscript, which all authors have approved for publication. This manuscript is an original research that has not been published previously and is not under consideration for publication elsewhere, in whole or in part. It does not contain any materials from third parties.

Acknowledgments

Not applicable

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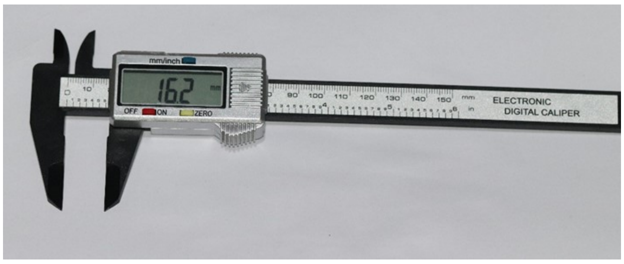

Figure 1. A Digital Vernier Caliper

Figure 2. Mesiodistal teeth dimensions

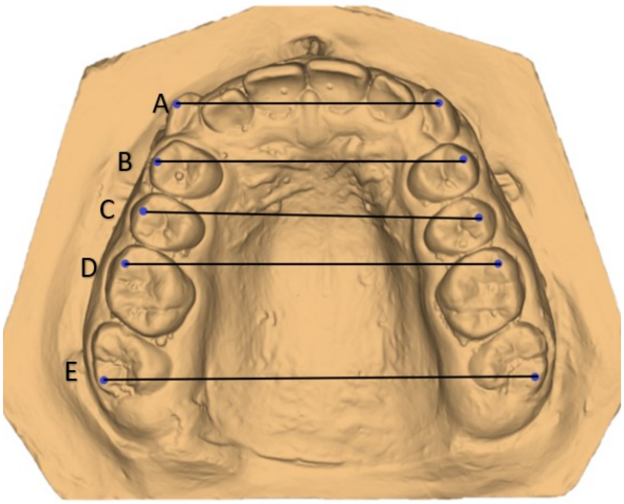

Figure 3. Maxillary arch width; measured the following distances:
A. Inter-canine distance: length measured linearly between points of the canine cusps.
B. Inter-first-first premolar distance: The length of a linear segment connecting the buccal cusp points of the second premolars.
C. Inter–second premolar distance: The length measured linearly between the buccal cusp tips of the second premolars.
D. Inter–first molar distance: The length measured linearly between the mesiobuccal cusp tips of the first molars.
E. Inter–second molar distance: length measured linearly between the distobuccal cusp tips of the second molars.

Table 1. Comparison of dental cast measurements between the M x AC group and control group.

Dental Cast Measurements	M x AC Group Mean ± SD (Min-Max)	Control Group Mean ± SD (Min-Max)	ICC (M x AC)	ICC (Control)	*P*-value
Mesiodistal Tooth Dimension					
Central Incisor	8.6 ± 0.1 (8.4–8.8)	8.5 ± 0.1 (8.2–8.7)	0.988	1.000	< 0.011
Lateral Incisor	7.5 ± 0.2 (6.9–7.8)	7.2 ± 0.1 (7.0–7.4)	0.996	0.952	< 0.001
Canine	8.1 ± 0.1 (8.0–8.3)	7.9 ± 0.1 (7.5–8.0)	0.988	1.000	< 0.001
First Premolar	7.6 ± 0.1 (7.4–7.8)	7.4 ± 0.1 (7.1–7.6)	0.972	0.973	< 0.001
Second Premolar	7.8 ± 0.1 (7.5–8.0)	6.8 ± 0.1 (6.5–7.0)	0.984	0.987	< 0.001
First Molar	10.5 ± 0.2 (10.2–10.9)	10.5 ± 0.2 (10.2–10.8)	0.974	0.998	0.469
Central Incisor Relationship					
Overbite	2.5 ± 0.2 (2.3–2.9)	2.5 ± 0.1 (2.3–2.7)	0.985	1.000	0.395
Overjet	1.6 ± 0.2 (1.3–1.9)	2.2 ± 0.1 (2.0–2.5)	0.992	0.950	< 0.001
Tooth Size-Arch Size Relationship					
Arch Length Discrepancy	-9.8 ± 1.7 (-12.0—0.6)	0.1 ± 0.4 (-0.5–0.5)	0.971	1.000	< 0.001
Dental Arch Width					
Canine	35.5 ± 1.6 (33.4–38.6)	35.7 ± 1.5 (33.2–38.5)	0.992	1.000	0.420
First Premolar	40.7 ± 1.1 (38.7–42.6)	43.2 ± 1.6 (40.4–45.8)	0.986	1.000	< 0.001
Second Premolar	45.6 ± 1.5 (43.3–47.6)	49.1 ± 1.3 (46.7–51.5)	1.000	1.000	< 0.001
First Molar	51.7 ± 1.8 (48.8–54.9)	55.4 ± 1.3 (53.4–57.6)	0.997	1.000	< 0.001
Dental Arch Depth					
Canine	6.7 ± 0.9 (5.3–7.8)	8.2 ± 1.0 (6.4–9.8)	0.956	1.000	< 0.001
First Premolar	14.6 ± 1.1 (12.4–16.5)	16.3 ± 1.3 (13.3–19.6)	1.000	0.995	< 0.001
Second Premolar	20.5 ± 1.2 (18.4–22.8)	22.4 ± 1.2 (20.2–24.6)	0.986	1.000	< 0.001
First Molar	30.2 ± 0.9 (28.5–31.8)	30.6 ± 1.2 (28.5–32.6)	0.997	1.000	0.120

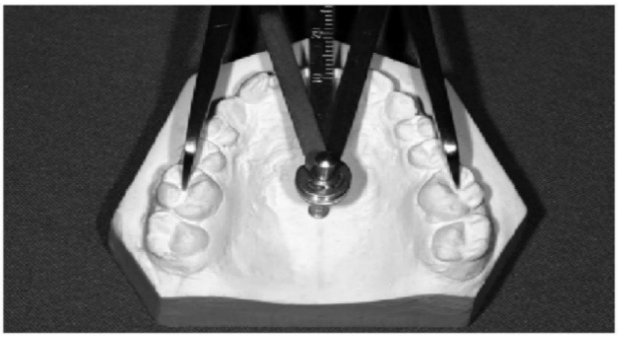

Figure 4. Maxillary arch depth at the level of the canines, first and second premolars, and first molars. It is defined as the vertical distance between a midline palatal vault and a point on the palatal width line. The authors have measured the following depths:

- Arch depth between canines: vertical distance from the intercanine line to the palatal vault in the midline.
- Arch depth between the premolars: vertical distance from the interpremolar line to the palatal vault in the midline.
- Arch depth between molars: vertical distance from the intermolar line to the palatal vault in the midline.

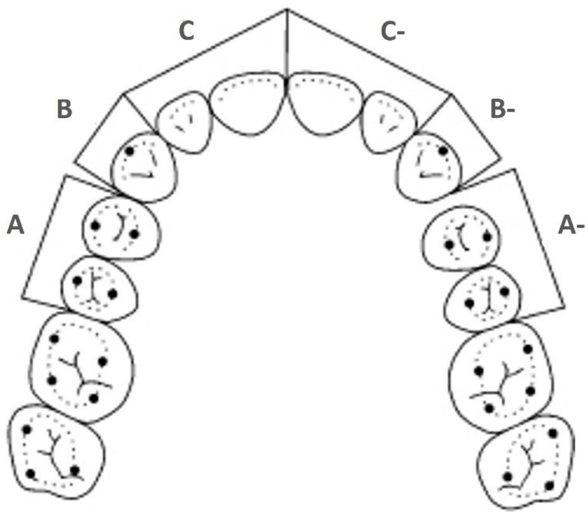

Figure 5. Arch length available: It is measured in six segments, starting from the mesial surface of the first molar on the right side and ending at the mesial surface of the first molar on the left. On each side, three typical segments are measured:

(A , A-): From the papilla between the canine and first premolar to the papilla between the canine and second premolar.

(B , B-): From the papilla between the canine and first premolar to the papilla between the canine and the lateral incisor.

(C , C-): From the papilla between the canine and lateral incisor to the papilla midway between the central incisors.

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