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ORIGINAL RESEARCH

Comparison of the morphology of the primary first molars and the forms of stainless steel crowns used in clinical practice

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Abstract

This study aimed to assess the difference in the mesiodistal (MD) and buccolingual (BL) dimensions of primary first molars between Taiwanese boys and girls using a three-dimensional (3D) scanner (Microscribe G2 digitizer), record the coordinates in the 3D systems of Graph-R Project and reconstruct 3D images for subsequent analysis. We also determined whether the differences in these parameters between primary first molars and stainless steel crowns (SSC, 3M ESPE, No. 2–7) could be used as a reference for selecting a suitably-sized SSC and performing adjustments during restoration. The results indicated a statistically significant difference in the mesiodistal distance of lower primary first molar crowns between boys (7.75 ± 0.38 mm) and girls (7.41 ± 0.41 mm) ($p < 0.05$) but no differences in the mesiodistal distance of upper primary first molars between the two sexes. The mean mesiodistal distances of the upper and lower primary first molars of boys were close to SSC size 4 and 3, respectively, while those of girls were close to size 3 in both arches. Overall, the buccolingual distance between the first maxillary and mandibular molars of Taiwanese children was greater than the buccolingual distance between the 3M ESPE SSC. Reducing the buccolingual length of the abutment teeth might quickly help achieve a better fit, reduce chair time, and minimize patient discomfort. In addition, trimming the mesial and distal metal margins of SSCs might help reduce microleakage from the crown margins and improve its retention and survival rate. In conclusion, the 3D scanning and analysis method used in this study can serve as a reference for fabricating SSC to achieve better crown adaptation and improve dental procedures.

Keywords

Human; Tooth crown; Crowns; Deciduous tooth; Data analysis; Stainless steel crown

1. Introduction

The preservation of the integrity of primary teeth is crucial for the proper development of young children as they play a vital role in various aspects of oral health [1]. In addition, dentitions are important as they are not only essential to grasp, crush and chew food but also for speech articulation and appealing facial appearance. Further, primary molars are particularly important for the proper development of children's masticatory muscles, jaw bone formation and maintenance of the space necessary for the eruption of permanent teeth [1]. However, these teeth often become affected by dental caries, which remain highly prevalent among young children [2, 3], with early onset of carious lesions frequently observed in the primary first molars [4].

The first choice for restoring a severely decayed primary molar is the use of a stainless steel crown (SSC) [3, 5]. SSCs, also known as chrome steel crowns or preformed metal crowns, were first introduced in 1950 by Engel and subsequently developed by Humphrey. They offer several advantages, including durability, affordability, and full coronal coverage, making them a widely used option for restoring primary molars [3–7]. To ensure optimal results, a suitably-sized SSC should be carefully selected to fit the individual teeth and cemented with a biocompatible luting agent [8]. The retention of SSCs largely depends on their flexible metal crown margin, which can be closely molded to the tooth surface in the undercut areas of the prepared tooth [3, 6, 7]; otherwise, wrong-size fitting and inadequate peripheral crown marginal adaptation might lead to crown loss, gingival inflammation around the edges of crown margins, and occlusal surface changes such as crown wear and perforation [3–5, 8].

Tooth size, especially that of primary first molars, varies based on the patient's race and sex [1, 3, 9–11]. The first primary molar crown has the widest variation in dimension [1, 7, 9], and its distinctive shape (especially the mutable buccal development lobes) indicates the need for special care during restorative and other procedures [1, 7, 9]. Although there has been extensive research on the morphology of permanent teeth [1, 12–14], few have investigated the morphological characteristics of primary dentitions or deciduous molars [1, 7, 9], especially among Taiwanese children [1, 7, 10]. In addition, the influence of the morphological characteristics of individual primary first molars on SSC procedures has not been thoroughly explored. This lack of information makes it challenging for clinicians to choose a suitably-sized crown, trim and adapt an SSC when restoring an unusually-shaped primary first molar. To address this gap, it is crucial for dentists to thoroughly evaluate the morphology of primary first molars and related SSCs during treatment planning to shorten chair time and minimize patient discomfort [7, 9, 11].

Existing literature on tooth morphology has shown that dentists primarily used two-dimensional (2D) calipers for measurements [7, 9, 11]. However, since these measurements cannot demonstrate the morphometric characteristics of the variable primary first molars, alternative methods have been suggested [7]. Recently, three-dimensional (3D) scanners were introduced in dentistry and are now widely used to determine preoperative and postoperative changes in orthodontics and oral maxillofacial surgery [7, 15] and assess the morphology of the jaw bone and internal anatomical structures, such as the nerves and veins [11, 15–18]. 3D scanning from a 360-degree side view can provide more detailed morphological information on stereoscopic solids than 2D liner measures. In addition, 3D digitized coordinates can demonstrate the curves and surfaces of the graphics models and machine data for further research. Presently, 3D scanners and 3D modeling are being increasingly used to study tooth morphology and the corresponding preformed crowns to evaluate the necessity of tooth preparation, which has led to improved long-term prognosis [7, 11].

Based on published literature, we hypothesized that: (1) the morphological features, including the shape and the MD and BL dimensions of the mandibular and maxillary primary first molar of Taiwanese children might be equivalent to those of the corresponding SSCs, and (2) no specific tooth preparation technique might be necessary when placing an SSC on a mandibular primary first molar as its shape varies widely among Taiwanese children. Thus, in this study, we aimed to examine the clinically significant morphological characteristics (mesiodistal (MD) and buccolingual (BL) dimensions) of the primary first molars, determine the existence of sexual dimorphism in crown diameters of the primary dentition in Taiwanese children using a 3D method, and apply this knowledge to select suitably-sized SSCs to minimize treatment-related complications.

2. Materials and methods

This cross-sectional study was conducted on 186 children aged 5–7 years who were referred from a university hospital in Taichung, Taiwan. Before performing any measurements, written informed consent was obtained from the patient's parents or legal guardians. Then, alginate impressions of the dentitions were made for all 186 to-be-investigated children (97 girls and 89 boys). The maxillary and mandibular impressions were poured onto a dental stone, and a visual cast examination was conducted by two well-training pediatric dentists. This study mainly focused on the right maxillary and mandibular primary first molars, which were selected based on the following criteria: (1) teeth with intact marginal ridges, intact contours heights, intact cervical gingival lines, and no loss of tooth structure owing to caries, fracture or excessive wear; (2) fully erupted teeth; (3) no restoration of any kind; (4) absence of congenital defect or deformed teeth; and (5) ideal alignment, including that of the opposing teeth. Low-quality casts were excluded from this study. Lastly, of the remaining casts, 63 children (33 girls and 30 boys) were selected for measurements.

The maxillary and mandibular primary first molars on the dental stone casts were marked with 50 reference points (Fig. 1A) using a lead pencil to ensure proper location of the landmarks in the MD direction in the following manner: (1) from the buccal view, 10 reference points were placed along the gingival margins on the cervical line; the first and tenth reference point areas indicated the deepest points of the proximal embrasures, and the lowest point of the cervical line was included in the 10 reference points (Fig. 1A, Points 1–10); (2) from the lingual or palatal view, 10 reference points were placed along the gingival margins; the first and tenth reference point areas indicated the deepest points of the proximal embrasures, and the lowest point of the cervical line was included in the 10 reference points (Fig. 1A, Point 11–20); (3) from the occlusal view, 10 reference points were placed along the line connecting the crest of the marginal ridge to the buccal occlusal table (Fig. 1A, Points 21–30); (4) from the occlusal view, 10 reference points were placed along the lines connecting the crest of the marginal ridge to the lingual occlusal table (Fig. 1A, Points 31–40); and (5) from the buccal view, 10 reference points were placed along the highest point of the buccal contour (Fig. 1A, Points 41–50). Two well-trained pediatric dentists judged the representativeness of the 50 reference points and presented the outline form of each primary first molar tooth. This study also used pretrimmed SSCs (3MTM ESPETM Stainless Steel Crown, primary molar, 3M ESPE Dental Products, St. Paul, MN, USA) for the right primary first molars, varying from size no. 2 (smallest) to no. 7 (largest) for both the upper and lower molars.

After determining the 50 reference points, the stone casts and SSCs underwent 3D scanning using a Microscribe G2 digitizer (Immersion Inc., San Jose, CA, USA). Then, the Microscribe G2 digitizer's probe tip was placed on these 50 reference points to capture the X, Y and Z coordinates of the objects. The primary outcome of this study was the digitized coordinates serving as the basis for the curves and surfaces of the graphics models and machine data. The secondary outcome was obtained by scanning the models from every angle to accurately measure the lengths, angles and volumes through 3D image reconstruction [7]. The models and SSCs in this study had a precision metric of 0.38 mm. For accuracy and reproducibility, it was necessary to mount the casts stably and set the reference plane parallel to the occlusal surface during scanning. Each scan was performed thrice by one examiner, and another examiner calibrated the measurements to obtain the mean values.

The reference points of the primary first molars and SSCs were digitized as coordinates using the Graph-R customized computer program (Graph-R Project, S-NEXT Co., Ltd., Tokyo, Japan) to record coordinates in the 3D systems (Fig. 1B). Graph-R offers a 360° view and illustrates the static 2D projections of the occlusal, MD and BL surfaces. Standardized photographs of the occlusal surfaces of the stone casts were also obtained at 1:1 magnification using a digital camera (Canon EOS 550D, Canon Inc., Tokyo, Japan). For both primary molars and SSCs, the linear measures from the occlusal view were calculated using the coordinate values of the reference points and Keynote (Keynote 2020, Apple Inc., Cupertino, CA, USA), based on which a precision metric of 0.36 mm was obtained (Fig. 2). Then, four diameters were measured. "Mesiodistal (MD)" represented the mesiodistal distance, "buccolingual (BL)" the buccolingual distance, "bucco-occlusal (BO)" the perpendicular distance from the most convex point of the buccal wall to the MD line, and "occlusolingual (OL)" the perpendicular distance from the most convex point of the lingual wall to the MD line (Fig. 3A–B).

After scanning all dental casts, the MD/BL distance ratio was found to dictate the morphological variation of the mandibular primary first molars, which were then classified into three groups (Class A, B, or C) according to the MD/BL features on their occlusal surface for further investigation (Fig. 4). Their distinctive features were as follows: Class A represented the mandibular primary first molars with the intersection of the MD and BL lines near the lingual side, Class B represented the molars with the intersection near the buccal side, and Class C represented the molars with the intersection almost at the center. The sample size was based on an alpha significance level of 0.05 and a beta significance level of 0.10 to achieve a 90% power to detect a difference of 1.0 $\pm$ 0.5 mm between the groups for all the morphological measurements. The calculation indicated that 17 patients were needed in each group.

All data were transferred to Microsoft Excel (Excel 2016, Microsoft Corporation, Redmond, WA, USA) for classification and analysis. Linear measurements (MD, BL, BO, and OL) from the occlusal views were recorded, and statistical comparisons between the males and females were performed using the analysis of variance (ANOVA) (Student's t-test, $p < 0.05$). The chi-squared test was used to analyze the sex ratio in the three groups of mandibular molars (Classes A and B, B and C, and A and C). The MD, BL, BO and OL distances and MD/BL ratio of the first mandibular molars belonging to Classes A, B and C were also analyzed (ANOVA; $p < 0.01$). In addition, the average MD and BL distances of the maxillary and mandibular first molars according to sex were compared with the MD and BL distances of the SSCs (No. 2–No. 7).

3. Results

3.1 Morphological comparison of the mandibular primary first molars between sexes

Table 1 outlines the morphological characteristics of the mandibular primary first molars and corresponding SSCs. The results showed statistically significant differences in the mean MD distance, MD/BL ratio and BO distance between boys and girls. Although no significant difference was observed in BL distance, the BO distance was greater in Taiwanese girls (3.86 $\pm$ 0.54 mm) than in boys (3.52 $\pm$ 0.34 mm; $p < 0.001$).

3.2 Morphological comparison between the mandibular primary first molars and the SSCs of the mandibular primary first molars

Figs. 5,6 illustrate the mean MD and BL distances of the mandibular primary first molars and corresponding SSCs. We found that the mean MD distance in boys was close to SSC size No. 4 (7.76 mm), while the mean MD distance in girls was close to SSC size No. 3 (7.56 mm). Also, the BL distances in both boys and girls were all shorter than the sizes of all SSCs.

3.3 Occlusal morphology of the mandibular primary first molars

The morphological characteristics of the different classes of mandibular primary first molars are presented in Table 2. In regard to their classification, Class A molars were found in 26.98% of the participants, who had a mean MD/BL ratio of 1.04 and mean MD and BL distances of 7.21 $\pm$ 0.41 mm and 7.14 $\pm$ 0.68 mm, respectively. In addition, Class B molars were present in 31.75% of the subjects, who demonstrated a mean MD/BL ratio of 1.13 and mean MD and BL distances of 7.54 $\pm$ 0.30 mm and 6.67 $\pm$ 0.49 mm, respectively. Lastly, Class C molars were observed in 41.27% of the children, with mean MD and BL distances of 7.84 $\pm$ 0.33 mm and 6.45 $\pm$ 0.41 mm, respectively.

Further assessment based on chi-square tests revealed no significant differences in all classes between both sexes, while all measurements showed statistically significant differences among the three classes.

3.4 Morphological comparison of the maxillary primary first molars between sexes

Table 3 outlines the morphological characteristics of the maxillary primary first molars and their corresponding SSCs. Based on the results of Student's t-tests, no significant differences were observed in occlusal features between boys and girls.

3.5 Morphological comparison between the maxillary primary first molars and SSCs of the maxillary primary first molars

Figs. 7,8 illustrate the MD and BL distances of the maxillary primary first molars and the SSCs of the maxillary primary first molars. In both sexes, the mean MD distances were close to those of SSC size No. 3 (6.83 mm), while the BL distances were between SSC size No. 3 (7.59 mm) and No. 4 (7.96 mm).

4. Discussion

The sexual dimorphism in tooth crown diameter has been less marked in primary teeth than in permanent teeth [1, 10]. In this

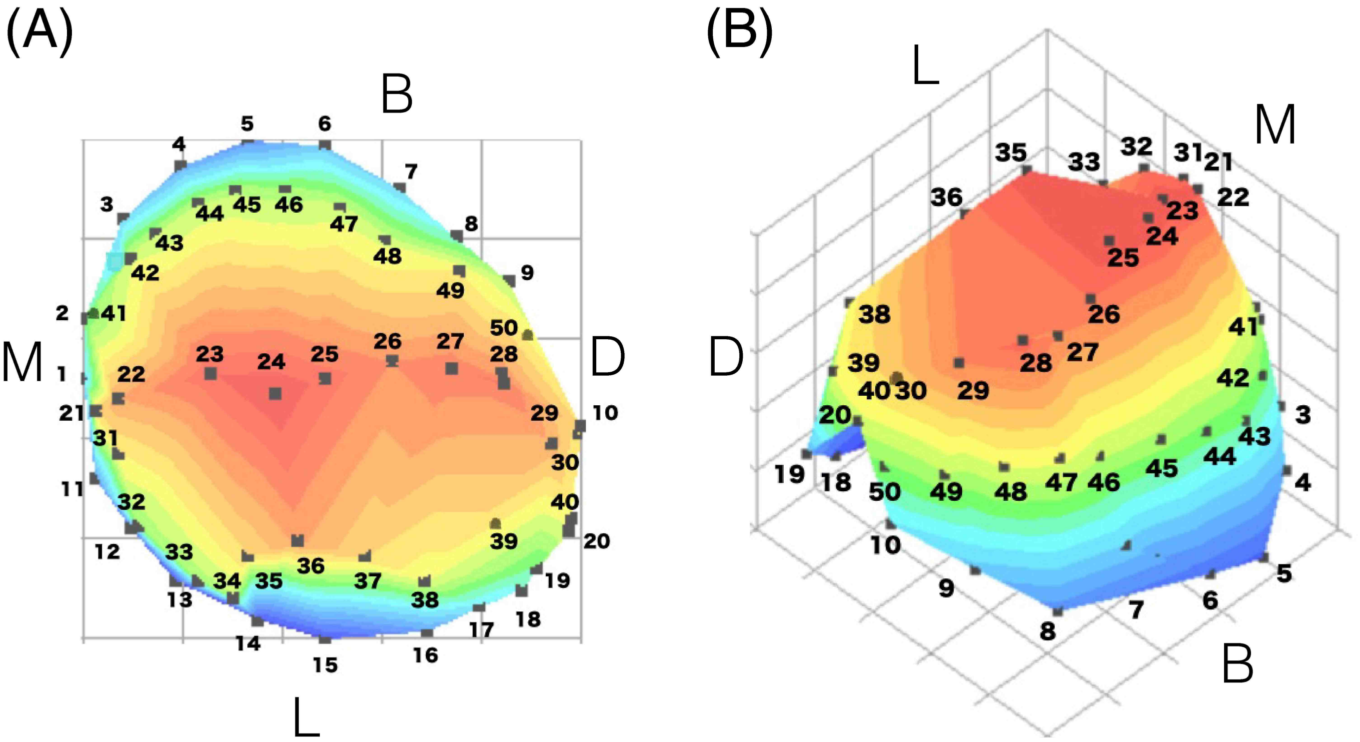

FIGURE 1. The 50 reference points on the primary first molars of a dental stone from different perspectives. (A) The 50 reference points on the primary first molars of a dental stone in the occlusal view (M: mesial side; D: distal side; B: buccal side; L: lingual side). Points 1–10 present the buccal cervical gingival line of the primary first molars; points 11–20 present the lingual cervical gingival line; points 21–30 present the buccal marginal ridge; points 31–40 present the lingual marginal ridge; and points 41–50 present the highest point of the buccal contour. (B) 3D model of a mandibular primary first molar constructed using Graph-R. The black marks on the model are the reference points for the scanning probes during 3D scanning. 3D: three-dimensional.

TABLE 1. Morphological characteristics of the mandibular primary first molars of Taiwanese children and the corresponding stainless steel crowns.

Mandible	MD (mm)	BL (mm)	MD/BL ratio	BO (mm)	OL (mm)
SSC2	7.12	7.04	1.01	4.00	3.75
SSC3	7.56	7.00	1.08	4.00	4.25
SSC4	7.76	7.13	1.09	4.25	3.75
SSC5	7.96	7.83	1.02	4.25	4.25
SSC6	8.38	8.67	0.97	4.86	4.86
SSC7	8.65	8.85	0.98	5.43	4.29
Girl					
Mean	7.41	6.86	1.10	3.86	3.23
SD	0.41	0.66	0.16	0.54	0.32
Boy					
Mean	7.75	6.61	1.18	3.52	3.22
SD	0.38	0.45	0.10	0.34	0.44
t-test	***	NS	*	**	NS

*BL: buccolingual distance; BO: the perpendicular distance between the highest point of the buccal contour perpendicular to the MD line; MD: mesiodistal distance; NS: not significant; OL: the perpendicular distance between the highest point of the lingual contour perpendicular to the MD line; SD: standard deviation; SSC: stainless steel crown. ***$p < 0.001$, **$p < 0.010$, and *$p < 0.050$.*

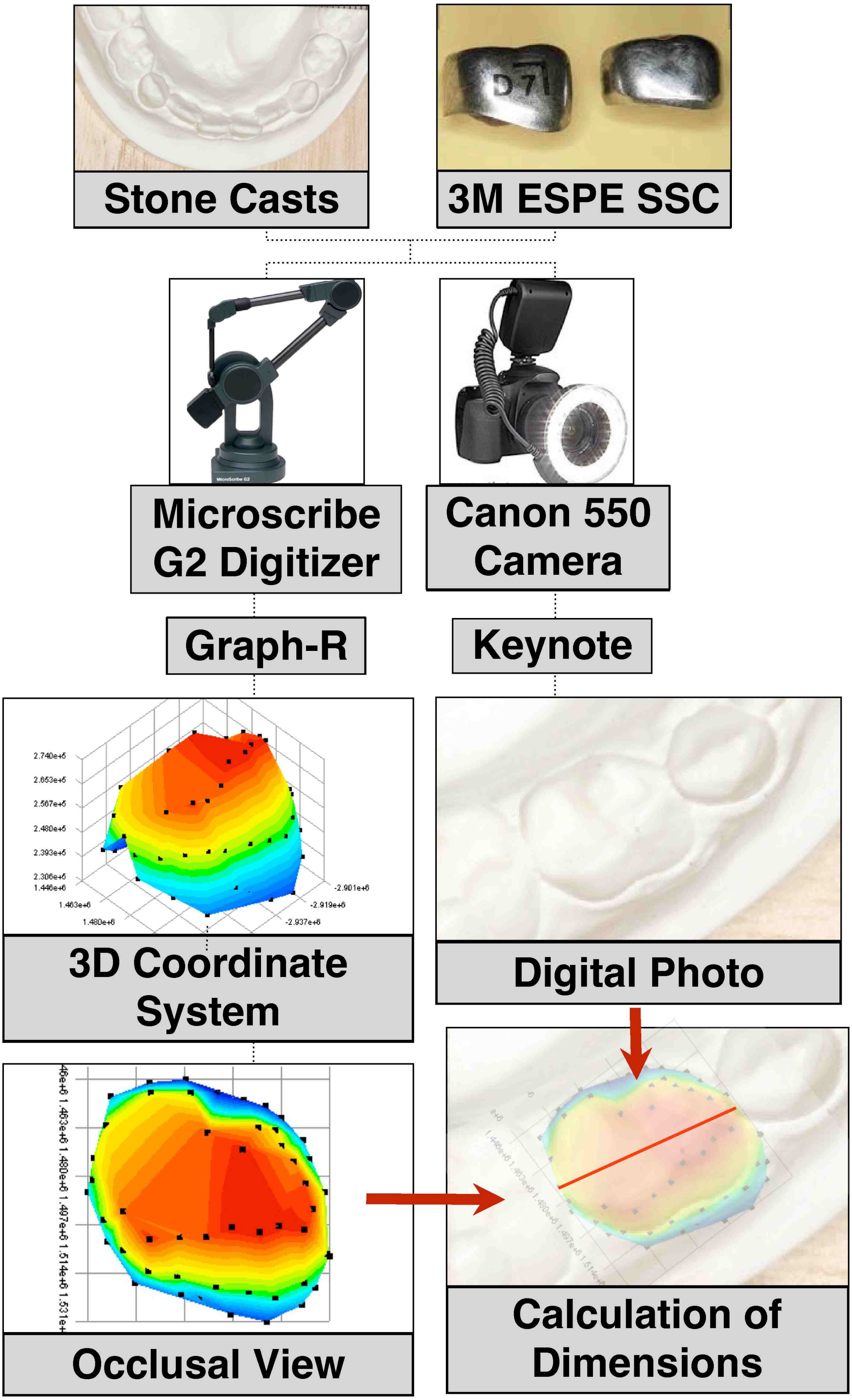

FIGURE 2. The schematic diagram of the three-dimensional (3D) scanning, 3D coordination, and calculation. SSC: stainless steel crowns.

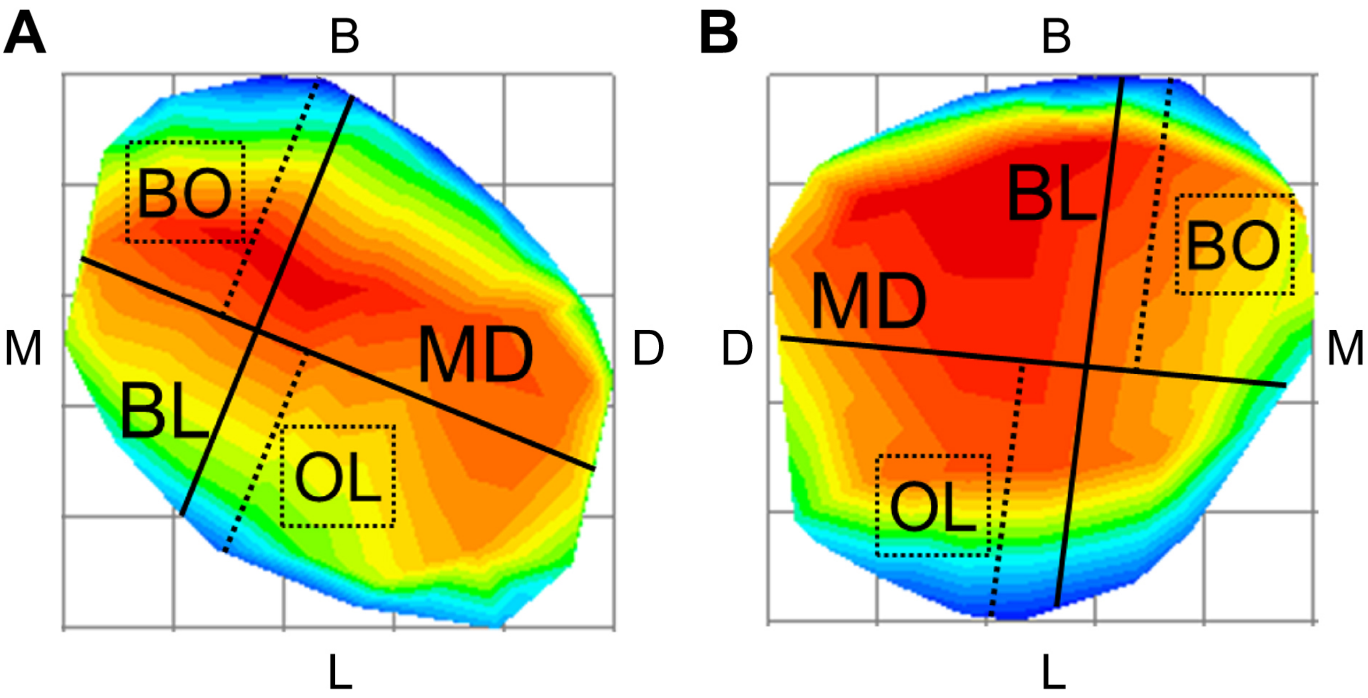

FIGURE 3. Graphical representations of primary first molars from different perspectives (M: mesial side; D: distal side; B: buccal side; L: lingual side). (A) The coordinate plane of the mandibular primary first molar viewed from the occlusal surface. (B) Coordinate plane of the maxillary primary fist molar viewed from the occlusal surface. BL: buccolingual distance; BO: distance between the highest point of the buccal contour perpendicular to the MD line; MD: mesiodistal distance; OL: distance between the highest point of the lingual contour perpendicular to the MD line.

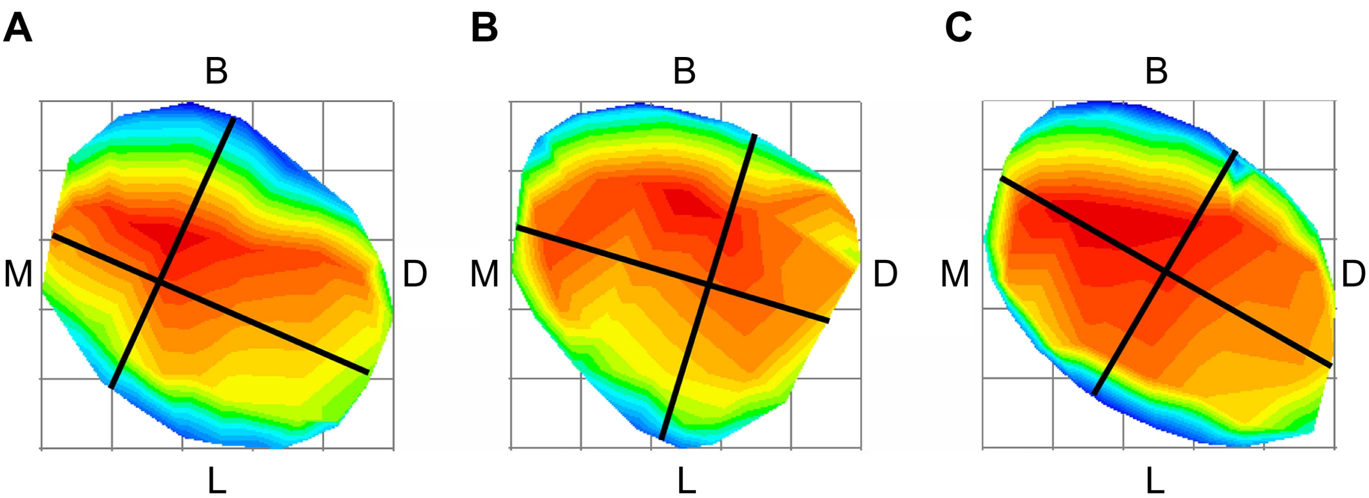

FIGURE 4. Classifications of mandibular primary first molars according to their occlusal morphological features. Class A refers to mandibular primary first molars, wherein the mesiodistal (MD) and buccolingual (BL) lines intersect near the lingual side; Class B represents the molars in which the intersection is near the buccal side, and Class C represents the molars in which the intersection is almost at the center.

present study on the mandibular primary first molars of Taiwanese children, we found that boys had a significantly larger MD distance than girls, which was in agreement with previous studies on the dental morphology of Taiwanese [10], African American [19], Caucasian [20], Jordanian [21], Aboriginal Australian [22], Indian [23], and Hong Kongese children [9, 24]. Compared to children from Beijing, Hong Kong and Iceland, as well as American Caucasian and Aboriginal Australian children, the MD distance of the mandibular primary first molars is shorter in Taiwanese children regardless of sex, while those from Sweden and Iran are even shorter [9, 24]. The stone casts used in our study were previously investigated and described, thus could be considered representative of the typical primary dentition among Taiwanese children [1, 10].

The MD distance of the abutment tooth often serves as the basis for determining SSC size [3, 9, 25, 26] due to the influence of MD distance on the length of dental arch and its impact on the arrangement of crowns. We selected 3M

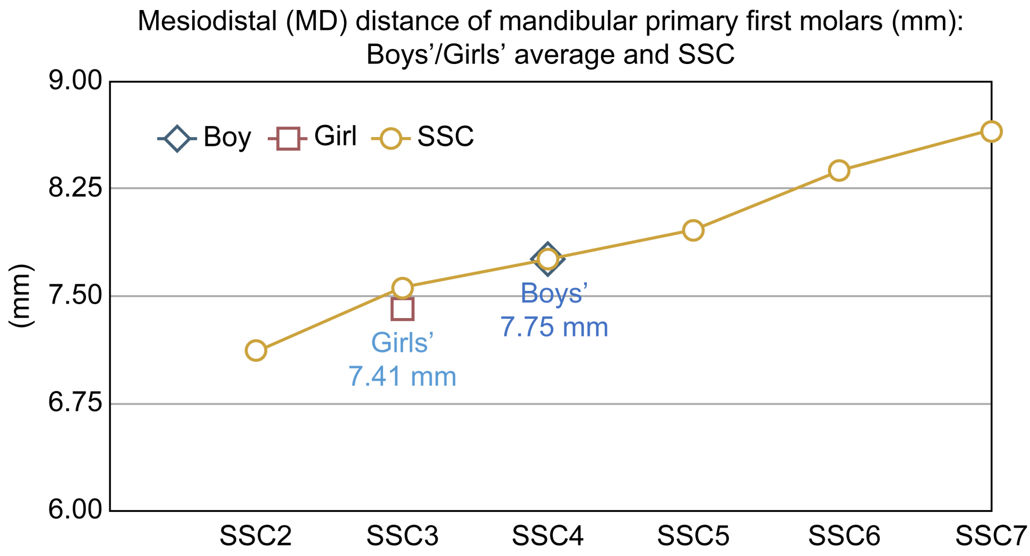

FIGURE 5. Comparison between the mesiodistal (MD) distances of mandibular primary first molars in Taiwanese children and stainless steel crowns (SSCs) size 2–7. The average MD distance in boys could be covered by SSCs size 4 and that of girls by SSCs size 3. SSC: stainless steel crowns.

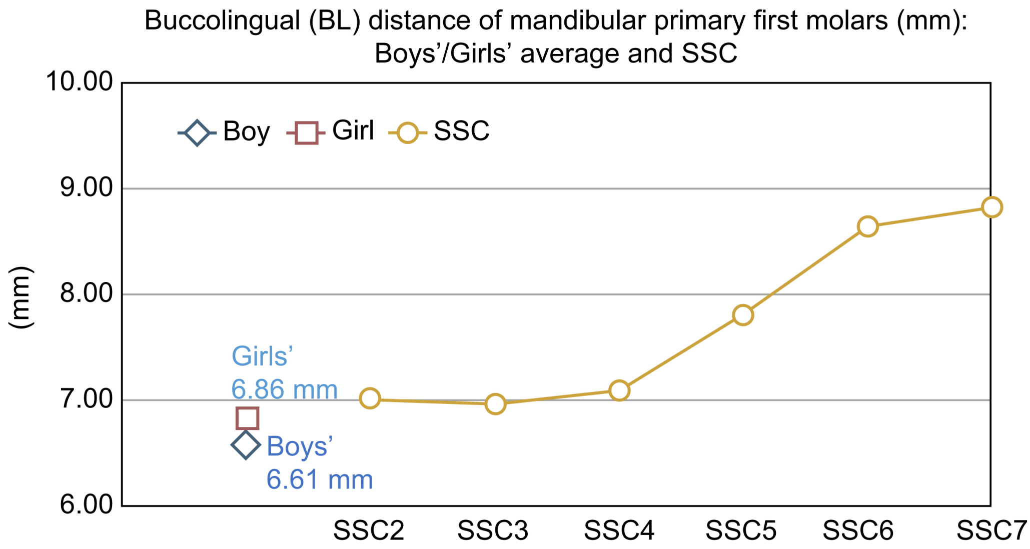

FIGURE 6. Comparison between the buccolingual (BL) distances of mandibular primary first molars in Taiwanese children and stainless steel crowns (SSCs) size 2–7. The average BL distance in both sexes could be covered by all-size SSCs. Therefore, the mesiodistal distance could be used to determine the SSC size for mandibular primary first molars in Taiwanese children. SSC: stainless steel crowns.

TABLE 2. Occlusal morphology of mandibular primary first molars among Taiwanese children.

Class	% (No.)	Mean	MD (mm)	BL (mm)	MD/BL ratio	BO (mm)	OL (mm)
A	26.98 (17)	Mean	7.21	7.14	1.04	4.25	3.11
		SD	0.41	0.68	0.16	0.41	0.29
B	31.75 (20)	Mean	7.54	6.77	1.13	3.52	3.55
		SD	0.30	0.49	0.11	0.32	0.31
C	41.27 (26)	Mean	7.84	6.45	1.23	3.47	3.06
		SD	0.33	0.41	0.10	0.32	0.32
ANOVA			***	***	***	***	***

*ANOVA: analysis of variance; BL: buccolingual distance; BO: the perpendicular distance between the highest point of the buccal contour perpendicular to the MD line; MD: mesiodistal distance; OL: the perpendicular distance between the highest point of the lingual contour perpendicular to the MD line; SD: standard deviation. ***$p < 0.001$.*

TABLE 3. Morphological characteristics of the maxillary primary first molars of Taiwanese children and the corresponding stainless steel crowns.

Maxilla	MD (mm)	BL (mm)	MD/BL ratio	BO (mm)	OL (mm)
SSC2	6.5	6.77	0.96	4.00	4.00
SSC3	6.83	7.59	0.90	4.25	4.25
SSC4	6.91	7.96	0.87	4.50	4.25
SSC5	7.14	8.42	0.85	4.75	4.00
SSC6	7.42	8.87	0.84	5.00	3.75
SSC7	7.91	7.91	1.00	4.25	4.25
Girl					
Mean	6.71	7.72	0.87	4.89	3.96
SD	0.35	0.25	0.06	0.54	0.44
Boy					
Mean	6.77	7.70	0.88	4.96	3.78
SD	0.45	0.30	0.07	0.34	0.34
t-test	0.28 (NS)	0.37 (NS)	0.20 (NS)	0.89 (NS)	0.94 (NS)

BL: buccolingual distance; BO: distance between the highest point of the buccal contour perpendicular to the MD line; MD: mesiodistal distance; NS: not significant; OL: distance between the highest point of the lingual contour perpendicular to the MD line; SD: standard deviation; SSC: stainless steel crown.

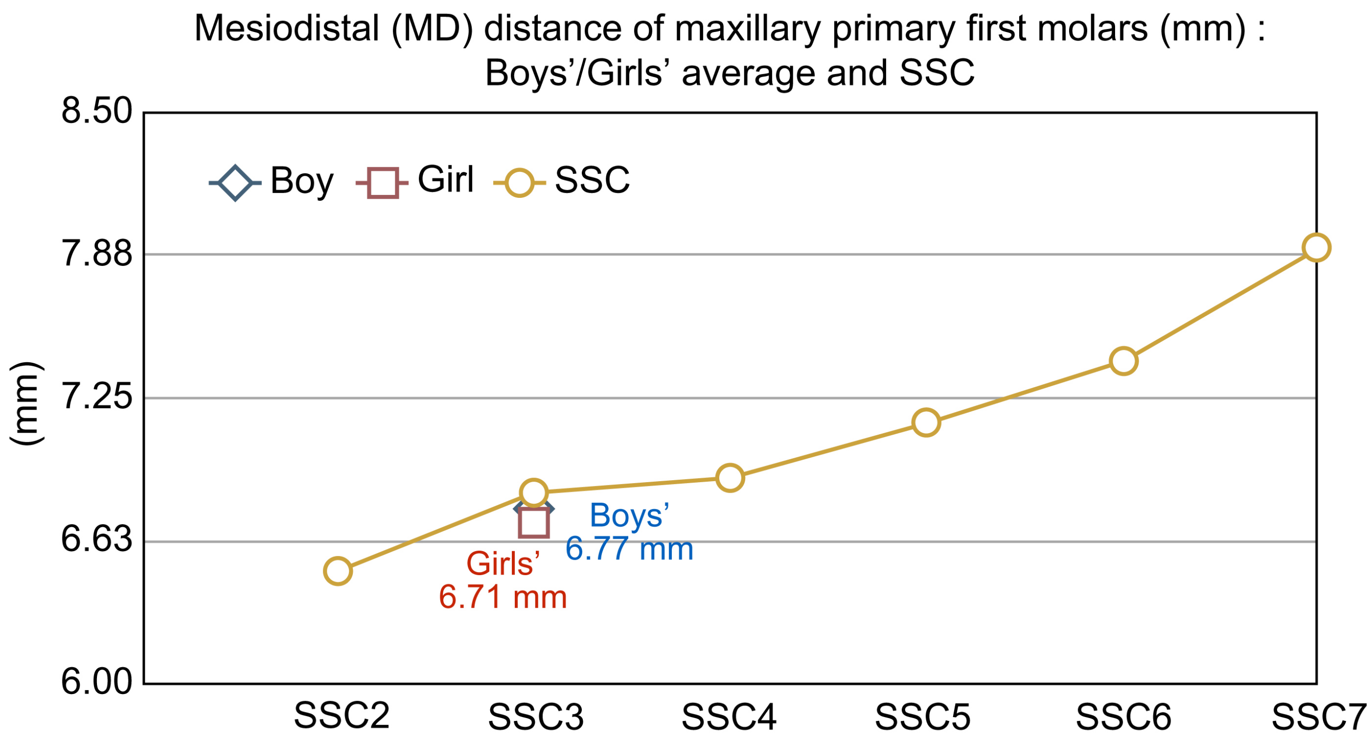

FIGURE 7. Comparison between the mesiodistal (MD) distances of maxillary primary first molars in Taiwanese children and stainless steel crowns (SSCs) size 2–7. The average MD distance was higher in boys than that in girls. In both cases, the average MD distance could be covered by SSCs size 3. SSC: stainless steel crowns.

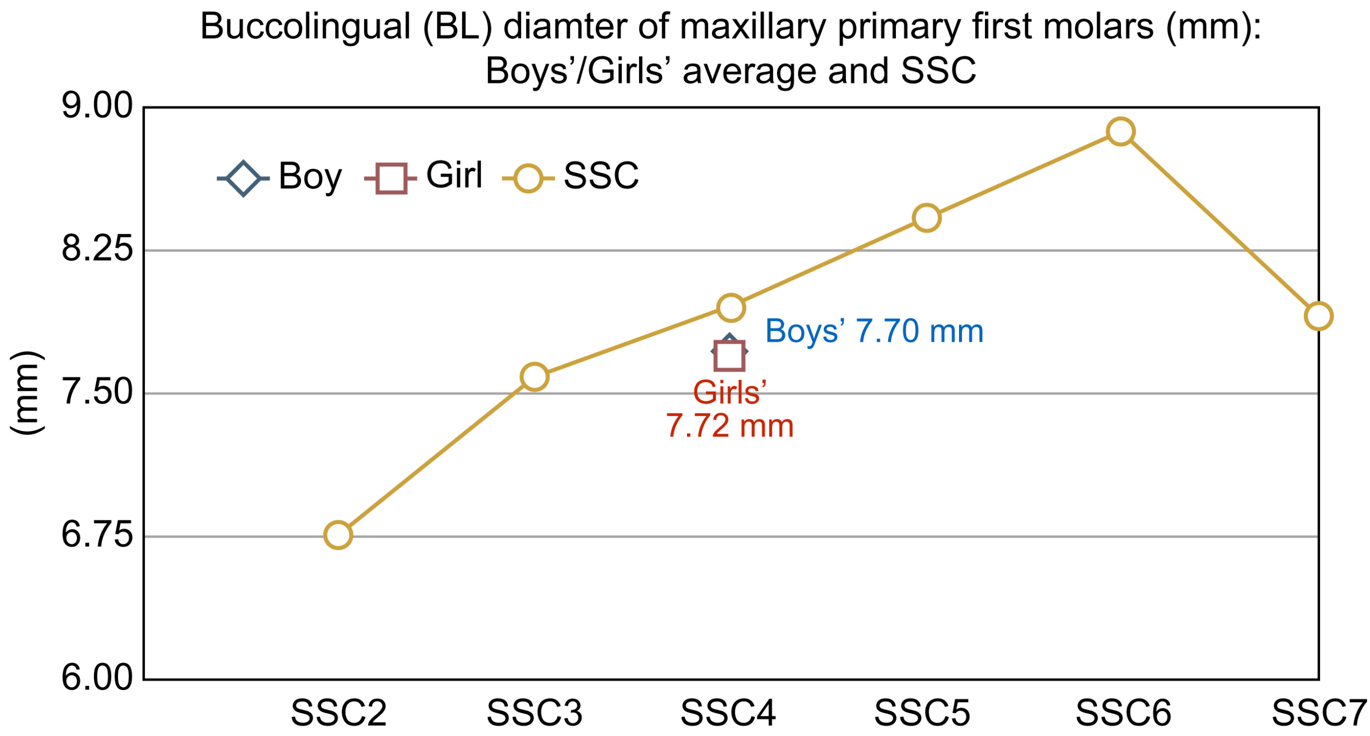

FIGURE 8. Comparison between the buccolingual (BL) distances of maxillary primary first molars in Taiwanese children and stainless steel crowns (SSCs) size 2–7. The average MD distance in both sexes could be covered by SSCs size 4, which should be therefore considered as the first choice when rehabilitating maxillary primary first molars in Taiwanese children. SSC: stainless steel crowns.

SSCs for this present study as they make up about 90% of the market share in Taiwan. Our findings demonstrated clinically significant differences in MD distance of the mandibular first molars between boys and girls, whereby the distance in boys was close to the SSC size No. 4 and that of girls was close to SSC size No. 3. The SSC size No. 4 SSC is commonly used and has also been examined in previous studies in Korea and USA [7, 25]. In other races and ethnicities, the MD distance of the mandibular primary first molars was reported to be longer; therefore, clinicians are advised to select SSC sizes greater than No. 4 for better coronal coverage. The results of our study demonstrated that the BL distance of all sizes of SSCs was larger than the average BL distance of the mandibular primary first molars of Taiwanese children. Since the larger BL distance of SSCs can often provide complete coverage of the BL distance of the abutment tooth, clinicians should consider MD distance rather than BL distance when selecting a crown size for Taiwanese children.

Additionally, our results showed no statistically significant difference between boys and girls in terms of BL distance of the mandibular primary first molars, similar to a previous study from Taiwan [10]. In contrast, a study on the same primary tooth in Indians [23], Aboriginal Australians [22] and African Americans [19] revealed a greater BL distance in boys than in girls. These contrasting results suggest the distinctiveness of Taiwanese dental morphology, although differences due to the use of different measuring methods should also be considered.

Many studies have documented the difficulty in preparing SSCs for primary first molars due to the prominent mesiobuccal cervical bulges of both the maxillary and mandibular primary first molars [25, 27, 28]. Our study showed that the BO distance of Taiwanese girls was greater than boys at the occlusal surface, while little difference was observed in BL distance between them. These results suggest that the buccal contour might be more pronounced in girls than in boys. In cases where the SSC does not fit the mandibular primary first molar, particularly for Taiwanese girls, the clinician could consider accommodating the mesiobuccal cervical bulges to reduce the BO distance. Clinicians can also use crown-contouring pliers to extend and contour the buccal surface of the crown to cover the outstanding point of the tooth to achieve marginal sealing. In cases requiring SSC trimming, clinicians could consider preserving the buccal margin of the crown. However, it should be noted that trimming the crown to a length shorter than the BO distance of the mandibular primary first molar in Taiwanese individuals might compromise the marginal seal.

Conventional pediatric dentistry literature, such as "McDonald and Avery's Dentistry for the Child and Adolescent" and "Fundamentals of Pediatric Dentistry," describes the occlusal surface of the mandibular primary first molars as being rhomboid [27, 28]. A rhomboidal occlusal surface has two distinctive features: (1) an MD distance greater than the BL distance, and (2) almost equal distance between the lingual height of the contour and MD axis to that between the buccal height of the contour and the MD axis, which is comparable to BO/BL $\approx$ 1 in this study. Unlike size 2–7 SSCs, which have a rhomboidal occlusal surface, the occlusal surfaces of the molars of Taiwanese children included in this study tended to be square, rectangular, rhomboidal, trapezoid, quadrilateral or triangular (Fig. 9), confirming our hypothesis that the shape of the mandibular primary molars of Taiwanese children is equivalent to that of their corresponding SSCs.

Our study classified all mandibular primary first molars as Classes A, B and C. Based on the descriptions in major textbooks, rhomboidal molars belong to Class C. Our results showed no significant differences in all three classes between boys and girls, while the MD/BL ratio across the three classes was statistically significant ($p < 0.001$), indicating that the criteria for our classification were relevant. The MD distance was the largest in Class C, followed by Classes B and A, and the differences between the three classes were statistically significant ($p < 0.001$), indicating that Class C molars had not only a larger MD/BL ratio but also the largest MD distance. The BL distance was largest in Class A, followed by Classes B and C, and the mean BL distance among the three classes was statistically significant ($p < 0.001$). Class A and B molars (58.73% in our study) had the largest BL distance, and the shapes of Classes A and B were usually rhomboid, triangular, squared or rectangular, unlike a rhomboidal SSC. A similar result was reported in Iranian children [9], whereby the MD/BL ratio in more than one-third of primary mandibular first molars in Iranian children was dissimilar to that of mandibular SSCs [9], which may lead to unfavorable crown adaptation during clinical practice. Since it is almost impossible to change the MD dimension of SSCs, the required adaptation and adjustments are usually made on the SSC margin or abutment tooth [9]. Additionally, reducing the BL length of Class A and B molars or extending the buccal contour of the SSCs using crown contouring pliers might be considered, and trimming the mesial and distal metal margins of SSCs could help create a relatively long buccal margin. Clinicians could also choose a crown suitable for the corresponding tooth from the opposite arch and contralateral side [4, 9, 25]. For instance, if they cannot find a suitable fit for a mandibular right first primary molar, a crown for a maxillary left first primary molar could be a good fit [4, 25]. A greater BL distance and narrower MD distance of a contralateral maxillary left first primary molar can be more easily adapted to Class A or B molars [9]. However, the results of this study did not support our second hypothesis, which related to no specific need for tooth preparation technique when making an SSC for a mandibular primary first molar due to wide shape variation among Taiwanese children.

In regard to maxillary primary first molars, the mean MD distance of boys was larger than girls, while no significant differences were observed in other morphological features. In contrast, previous studies on the morphological characteristics of maxillary primary first molars indicated that males had larger BL and MD distances than females across different races and ethnicities [9], including Taiwanese [10], African Americans [19], Jordanians [21], Aboriginal Australians [22], Indians [23] and Hong Kongese [24]. The disparity between the results of this study and those of previous studies could be attributed to different measurement approaches or the smaller sample size of this present study. Thus, future studies should include larger sample sizes to determine the morphological differences in the maxillary primary first molars between males and females.

The MD distances of the maxillary primary first molars of Taiwanese children were shorter than children from Beijing, Hong Kong [24], Iceland and Sweden, as well as Aboriginal Australians [22], and only American Caucasians had a shorter mean MD distance than Taiwanese children [24]. Our results demonstrated that the MD distance of the maxillary primary first molars of Taiwanese boys and girls could be covered by SSC size No. 3 while the BL distance required an SSC size No.4. As previously mentioned, an SSC size No. 4 is often used [7, 25] and also recommended for maxillary primary first molars. Generally, the MD distance of the abutment tooth serves as the basis for determining the required SSC size. The analogous SSCs for maxillary primary first molars often matched the MD distance in Taiwanese children but failed to offer complete coverage owing to unsuitable BL distance. Clinicians are often faced with the dilemma of spending more time in tooth preparation of the maxillary primary first molars compared to second molars to ensure an adequate fit of SSC to its corresponding tooth [11]. This study highlights that, when constructing SSCs for the maxillary primary first molars of Taiwanese children, an extension of the BL distance of the crown or reduction of the BL distance of the tooth could help achieve a good fit more quickly.

Clinicians generally rely on visual estimation to determine the appropriate SSC size and minimize the amount of tooth structure during SSC preparation [25]. Our study employed the Microscribe 3D digitizer (Immersion Inc.), which has been used in numerous studies on dental morphology [15–18]. Despite its simplicity, the device boasts high measurement precision. The stone casts and SSCs in this study had a precision metric of 0.38 mm, implying that modifying the arm configurations led to a standard deviation <0.38 mm, indicating an excellent standard for scientific measurement [18]. Graph-R is an indispensable software for 3D modeling in dental studies that helps clinicians determine the difference between all classifications of first primary molars. Since the size of primary molars and their corresponding SSCs are relatively small, using 2D measurements from photographs could lead to inaccuracies [7]. Comparatively, the Microscribe digitizer's probe penetrates the dental embrasures of stone casts, and the digitizer enables the magnification of small objects on the screen [7], which helps visualize irregular and small objects in 3D images [7, 18]. In this present study, the 50 reference points used by the two professional pediatric dentists provided the details and variations in teeth shape from the 3D Graph-R system. The advantages of the Microscribe 3D digitizer make it a more favorable option compared to traditional 2D devices such as calipers and photographs.

Recently, various innovative approaches were proposed for the restoration of primary molars. One of them is the Hall technique, which focuses on cementing SSCs on teeth to preserve tooth integrity in the management of carious primary molars without caries removal or any tooth reduction [3, 25, 28–30]. Without tooth preparation, it is difficult for clinicians to determine the appropriate crown size to cover cervical margins [25, 28–30]. The use of the Microscribe 3D digitizer and Graph-R can help clinicians determine the pattern of a tooth and the required crown size to achieve a good marginal seal. This present study proposes the utilization of a maxillary SSC from the opposite arch or side that is appropriate for the corresponding tooth for the rehabilitation of Class A and B

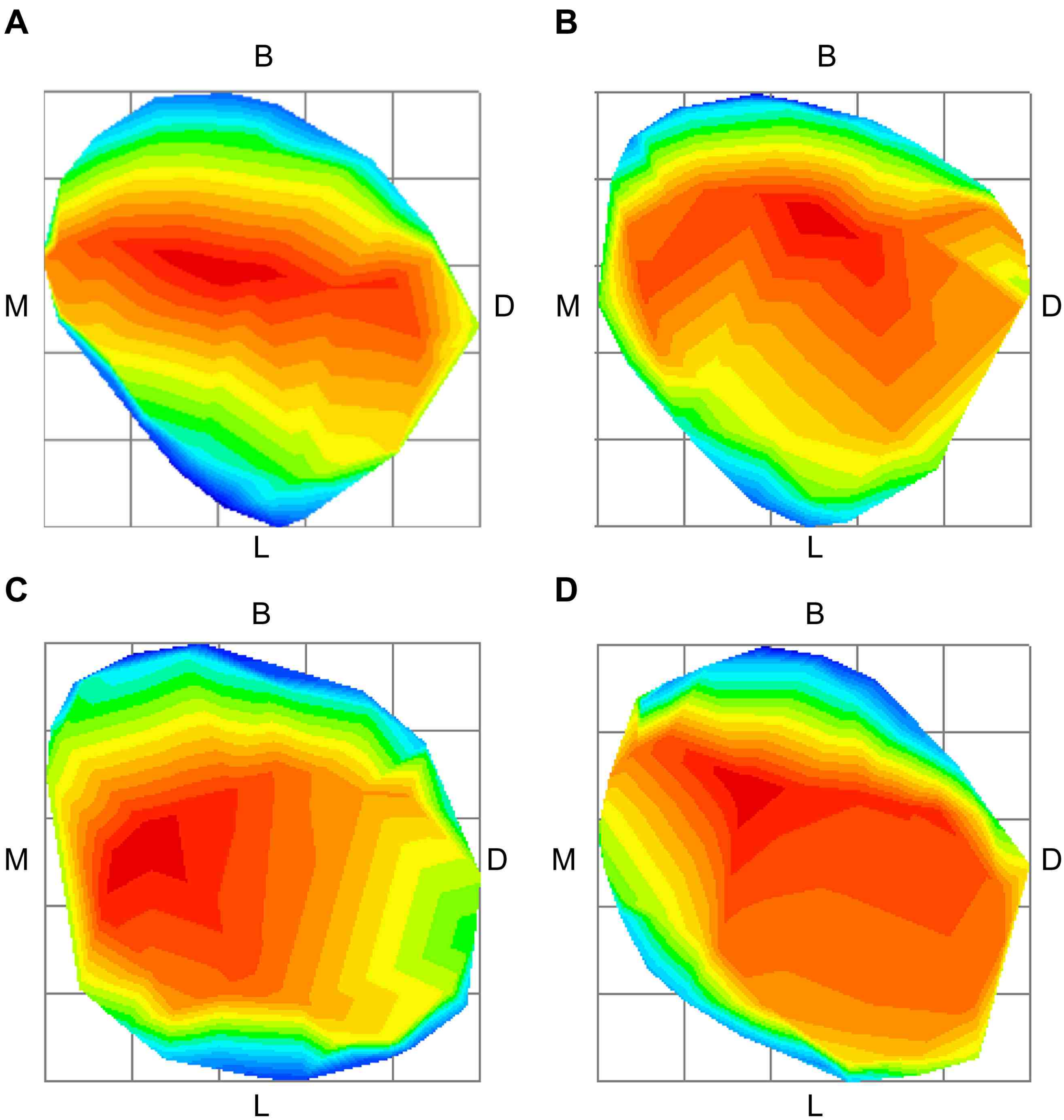

FIGURE 9. Different appearances of occlusal surfaces of the mandibular primary first molars of Taiwanese children. (A) A trapezoidal occlusal surface. (B) A triangle occlusal surface. (C) A squared or rectangular occlusal surface. (D) A rhomboidal surface. Textbooks on pediatric dentistry portraying the occlusal surface of the mandibular primary first molars as a rhomboid. The 3M stainless steel crowns (SSCs) size 2–7 mimic a rhomboidal occlusal surface, and in cases where occlusal surfaces tend to be trapezoid, squared, rectangular or triangular, clinicians should reshape the SSCs to fit the primary molars.

mandibular primary first molars using the Hall technique.

Despite their advantageous attributes, the utilization of SSCs is associated with several drawbacks, including their unappealing esthetic appearance [3, 5, 25, 28, 31]. Pediatric zirconia crown is a novel modality that may help overcome this challenge as they offer full coverage primary molar crowns with improved esthetic outcomes. However, unlike an SSC, the margins of zirconia crowns cannot be recontoured to provide mechanical retention and adapt the crown margin to the tooth surface [25, 27]. Additionally, because pediatric zirconia crowns have a greater thickness (0.3–0.8 mm) than SSCs (0.2 mm) and a passive fit, excessive reduction of the tooth structure and repetitive tooth preparations are required, which can be time-consuming [11, 25, 26, 31]. The use of digital models of teeth or crowns created through 3D scanning using technology such as the Microscribe 3D Digitizer and Graph-R may provide a means of dental modeling in future research, clinical practice and the application of new methods, such as the Hall technique and pediatric zirconia crowns.

Our study had some limitations. First, it only highlighted the morphological features of primary first molars from an occlusal perspective. Further research encompassing all surface morphological characteristics of each primary tooth would allow us to further understand the detailed morphological attributes of these teeth to improve the care of primary first molars in clinical practice. Second, the sample size used in our study may be considered a limitation, considering varying individual characteristics and clinical experiences among participants. Further works are underway to clarify the statistical differences between SSCs and primary first molars based on the same standards. In addition, zirconia crowns have emerged as a promising alternative to SSCs or other restorative materials in the field of pediatric dentistry [31]. Hence, an analysis of the size and shape of the first primary molars and corresponding zirconia crowns may be warranted. Moreover, guidelines for the selection of the various sizes and shapes of zirconia crowns and tooth preparation should be developed to further advance the field.

5. Conclusions

In summary, Taiwanese boys had a greater MD distance of the mandibular primary first molars than girls. On the other hand, no significant difference was observed in the MD distance of the maxillary primary first molars between the sexes. Sexual dimorphism in the crown diameter of primary first molars of Taiwanese children only existed among the mandibular first primary molars. According to the average MD distance of the mandibular primary first molars, dentists can choose SSC size 4 and 3 for Taiwanese boys and girls, respectively. SSC size 4 corresponds to the average MD and BL distances of maxillary primary first molars, regardless of sex. The prominent mesiobuccal cervical bulges of the mandibular primary first molars usually make it difficult for clinicians to prepare SSCs. Due to the varying MD/BL ratio of the maxillary and mandibular primary first molars in Taiwanese children, fitting and complete coverage of the abutment teeth of different shapes might be difficult using pretrimmed SSCs. Thus, avoiding trimming the buccal margins of maxillary and mandibular SSCs might help achieve marginal sealing of the crown in Taiwanese children. The use of 3D Microscribe G2 digitizers and the 3D Graph-R Project system can assist clinicians in determining tooth patterns and the required crown size to reduce microleakage from crown margins and improve its retention and survival rate.

AVAILABILITY OF DATA AND MATERIALS

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

AUTHOR CONTRIBUTIONS

TTC and HHT—conceived and designed the research study. TTC—collected the data, performed the analysis, wrote the manuscript. HHT—contributed data and analysis tools. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Written informed consent was obtained from participants' parents or legal guardians. The study was performed in accordance with the Declaration of Helsinki and was approved by the institutional review board of MacKay Memorial Hospital (approval number: 22MMHIS400e).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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