ORIGINAL RESEARCH

Do Hall Technique Crowns Affect Intra-arch Dimensions? A Split-mouth Quasi-experimental Non-randomized Feasibility Pilot Study

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Abstract

Aim and background: The Hall technique preformed metal crowns (HT-PMCs) are allegedly oversized, temporarily altering inter-arch relationships. Intra-arch dimensions and leeway space (LWS) HT effects are unknown.

Aim: To study single HT-PMC intra-arch effects and treated tooth dimensional changes.

Materials and methods: Split-mouth, quasi-experimental, non-randomized feasibility pilot study. Intraoral scans (iTero II®) were taken preorthodontic separator placement (scan^1), immediately post single HT-PMCs (scan^2) in 13 children, and 1 month later (scan^3) in eight children. Control and study quadrants' lengths ("arcs") and HT-PMCs/control tooth dimensions [mesiodistal (MD), buccopalatal/lingual (BP/L), diagonal (Diag1/Diag2)] were recorded in mm (OrthoCAD® software). Paired *t*-test, repeated analysis of variance (ANOVA) *post hoc* analysis statistics ($p < 0.05$).

Results: Compared to scan^1, the mean study arc increased by 0.7 mm (±0.5) ($n = 13$, *t*-test, $p < 0.001$) at scan^2, while at scan^3, it increased by 0.8 mm (±0.34) ($n = 8$, repeated ANOVA, $p = 0.008$). The HT-PMCs-treated tooth mean dimensions increased at scan^2 by 0.9 mm (MD), 0.8 mm (BP/L), 0.5 mm (Diag1), and 0.7 mm (Diag2) (*t*-test, $p < 0.001$) with similar observations at scan^3. There were no significant changes in the control arc or the control tooth measurements.

Conclusion: One single HT-PMC increased the intra-arch quadrant length by approximately up to <1 mm. The HT-PMC-treated tooth was marginally oversized. This pilot study paves the way for a more robust study with a larger sample size.

Keywords: Children, Dental caries, Hall technique, Preformed metal crowns, United Arab Emirates.

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Introduction

One of the methods that has appeared in the field of pediatric dentistry in the past two decades for managing caries in the primary molars and used extensively by general dental practitioners (GDPs), is the Hall technique (HT).[1] This involves placement of a standard preformed metal crown (PMC) over an asymptomatic nonpulpally involved carious primary molar,[2] without tooth crown high-speed bur preparation, nor local anesthesia (LA). The HT has successfully been used globally,[2–4] and was, in the recent epidemic of COVID-19, recommended as part of a battery of dental treatment methods that were not considered aerosol-generating procedures (AGPs).[5]

As high-speed drill-centered occlusal reduction is avoided in the HT, a discrepancy in the occlusion and occlusal vertical dimension (OVD) is expected, but the occlusion in children reestablishes within a few weeks (15–30 days) following placement of a HT-PMC,[6] in addition to equilibrium of other aspects of the occlusal apparatus.[3,7,8] While as equally successful in comparison to conventionally placed PMCs (C-PMCs),[4] the HT implies the use of slightly larger-than-tooth PMCs compared to the conventional method.[9] This issue, pertaining to the size of the HT-PMCs, was unfoundedly said to be "ethically unacceptable" in an opinion letter by Croll et al.,[9] due to it being "oversized" with unsupported clinical concerns of inadequate seal and leakage,[10] poor retention of the PMCs, and other issues preventing its use by some pediatric dentists.[2] There is no robust evidence to support the hypothesis that HT-PMCs are oversized, although it may be reasonable to consider this possibility a priori, pending supportive evidence. Although overhanging margins from HT-PMCs have been reported in cases to affect erupting teeth,[11] gingival inflammation is seen in all types of PMCs.[12,13]

Although there is a variation of the HT[14] that involves high-speed drilling of 1 mm proximal slices mesially and distally with occlusal cusp reduction and, surprisingly, the use of LA (known as the "modified HT technique"), the HT usually involves placement of

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elastomeric orthodontic separators (EOSs)[15] to create interdental spaces. The placement of a potentially larger-than-tooth PMC and EOSs could, in theory, impact the intra-arch dimensions, further affecting the existing intra-arch dimensions and the "leeway space (LWS)" (LWS measuring around 0.9 mm in the upper arch and 1.7 mm in the lower arch, although this varies in different populations).[16] Thus shifting the focus from the inter-arch changes following the HT[3,7,17] to intra-arch changes post-HT. Intra-arch changes can be assessed by any means, manual or digital,[18] such as models, intraoral photos, conventional or digital orthodontic calipers, or intraoral scanners.[19]

To the best of the authors' knowledge, no published study has looked at the intra-arch changes following the placement of the HT-PMC. Sometimes, it is necessary to test preliminary hypotheses of associations between variables, which, if found promising, may lead to intervention development or other preliminary work. If these associations are observed, then further future research can be planned.[20] With a view of setting a non-randomized feasibility pilot study and with a view to test the preliminary hypotheses of association,[20] the authors of this paper set the null hypothesis as:

- The treatment of a single primary molar with a HT-PMC had no effect on the horizontal intra-arch dimensions in the ipsilateral quadrant compared with the contralateral control quadrant.
- There were no changes in the dimensions of the HT-treated tooth post-crown fitting.
- The HT crowns used were not oversized compared to a nontreated tooth.

Therefore, the main aims were to (1) conduct a feasibility pilot study to test a hypothesis, (2) to compare the preoperative and postoperative intra-arch dimensional changes following a single HT crown placement in children, (3) compare the intra-arch dimensional changes of ipsilateral quadrant treated with HT with the controlled nontreated contralateral quadrant; (4) to assess the dimensions of the exact treated tooth pre- and post-HT crown placement (mesiodistal, buccal lingual/palatal, diagonally) in comparison to an exact contralateral control tooth, and finally (5) to investigate if HT-PMCs were oversized as claimed and if so, by how much.

Materials and Methods

Study Design and Location

This study was a split-mouth quasi-experimental non-randomized feasibility pilot study as defined by Lancaster and Thabane.[20] It followed the standard pilot studies checklist as per the STROBE statement for pilot feasibility studies.[20] Split-mouth designs are frequently used in dental clinical research,[21] where a mouth is divided into two or more experimental segments that are randomly assigned to different treatments. It has the distinct advantage of removing a lot of intersubject variability from the estimated treatment effect.[21] The study was conducted in the Pediatric Dentistry Department of Dubai Dental Hospital (DDH) at Hamdan Bin Mohammed College of Dental Medicine (HBMCDM) in Mohammed bin Rashid University of Medicine and Health Sciences (MBRU) in Dubai Academic Health Corporation, United Arab Emirates (UAE).

Participants

Fit and healthy child patients who were already indicated for the treatment of a single HT as per the HT criteria,[1] for whom parental consent was obtained, were enrolled with at least one nonpulpally involved asymptomatic carious primary molar (NPACPM) requiring treatment with the HT. Therefore, the treatment decision to use the HT was independent of the study. Child patients were enrolled in DDH from 8th January 2022 to 1st December 2022. The inclusion criteria were fit and healthy cooperative children aged between 3 and 9 years with a primary molar clinically and radiographically indicated for the HT, who strictly needed the use of two EOSs to create space for the HT-PMC. While the exclusion criteria were—children who were in pain; those who needed more than one HT-PMC in a single appointment; in modified HT cases; molars that became contraindicated for the HT during the study; patients undergoing orthodontic treatment; patients who had existing space maintainers; patients with limited mouth openings; patients with a gag reflex; child patients who may be indicated for the HT but have a known allergy to nickel; children with missing teeth in the arch (for example, exfoliated primary teeth or unerupted permanent teeth); children in the mixed dentition where first permanent molars were partially erupted and covered with opercula, rendering measurement impossible; those who had a mobile tooth exfoliating within 2 months; in cases where only one EOS was required to create space for the HT; and finally, in patients where there were absent teeth on the control side. This study was conducted in full conformance with the principles of the "Declaration of Helsinki," Good Clinical Practice (GCP), and within the laws and regulations of the UAE. The ethical approval was obtained from the Internal Review Board of MBRU under number MBRU IRB-2021-71.

Intervention

The intervention involved the placement of one HT-PMC in a child as per the standard protocol reported by Innes et al.[1] and the use of a standard intraoral three-dimensional scanner.

Sample Power Calculation

There were no published studies pertaining to HT-PMC size using intraoral scanners; therefore, sample size calculation was not conducted. When designing a clinical trial, an appropriate justification for the sample size should be provided. However, there are instances in pilot trials where no prior information is available on which to base a sample size.[22] For such pilot studies, the recommendation is a sample size of 12 per group.[22] The justifications for this sample size are based on rationale about feasibility, precision of the mean and variance, and regulatory considerations. For a main trial designed with 90% power and two-sided 5% significance, it is recommended that pilot trial sample sizes per treatment arm range from 75 to 10 for standardized effect sizes that are extra small (≤0.1), small (0.2), medium (0.5), or large (0.8).[23] Therefore, a sample size of 12 subjects (teeth 24) was chosen due to the split-mouth design.

Randomization

Blinding was not possible in this study due to its design nature. There was no sequence generation, allocation concealment mechanism, randomization implementation, nor blinding in this non-randomized convenience sample.

Potential Harms

The HT is known to be a very safe method of treatment with a very high success rate. There were no recorded or expected side effects in this pilot study.

Study Process

The study subject had four appointments (see Fig. 1 for flowchart and Fig. 2):

- First (for discussion and consent).
- Second (first HT treatment visit—fitting the EOSs).
- The arch was scanned (scan[1]) *via* an intraoral scanner (iTero II® - Align Technology, San Jose, Calif, United States of America) on the same visit prior to separator placement.
- The third visit (5 days later) was to remove the EOSs and place the HT crown. The crown chosen was the minimally sized one to fit the tooth, to reduce the risk of the crown being oversized. The arch was scanned again (scan[2]) after cementation of the HT-PMC using the same iTero II® intraoral scanner.
- The fourth visit was at the patient's 1-month recall visit; the arch was scanned for the third time (scan[3]) *via* the iTero II® scanner. Measurements were carried out using OrthoCAD® software (Cadent iTero® intraoral scanner, Carlstadt, New Jersey) for both the control and treatment sides.

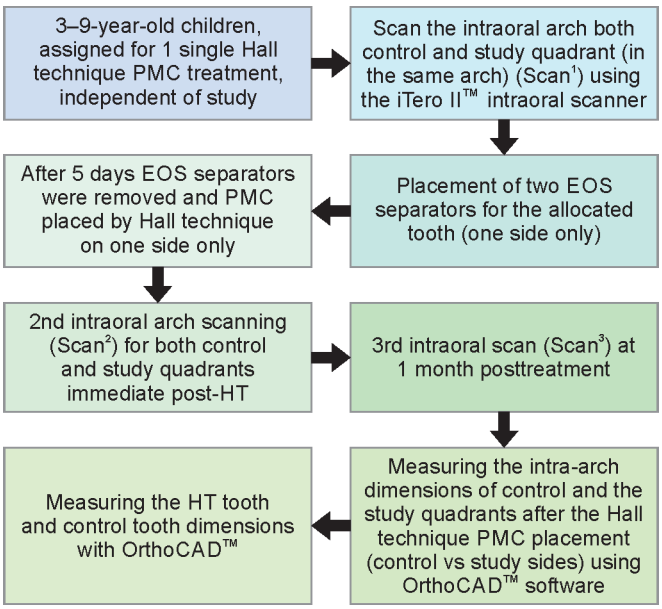


Fig. 1: Flowchart and process of the study

Calibration and Training

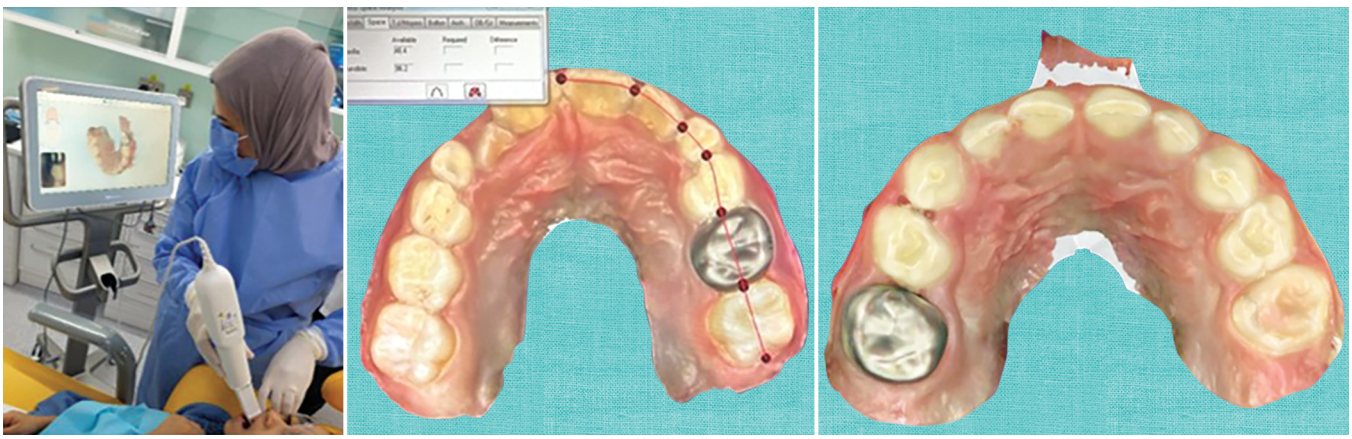
The principal investigator (PI:BA) attended a workshop on the use of the iTero II® scanner and OrthoCAD® software, presented by a clinical trainer from iTero-Align Technology™ in Dubai. The PI was further trained and calibrated by an expert orthodontist (Co-supervisor: AG) who was familiar with the scanner. The PI familiarized herself with the components of the iTero II® scanner and underwent training in the use of the OrthoCAD® software, including points of measurement. The iTero II® intraoral camera was piloted for use on models with and without PMCs to assess feasibility and image clarity. Subsequently, the PI trialed the system on a patient not receiving treatment (with parental consent) to measure tooth sizes using the intraoral camera. The PI underwent inter- and intra-examiner calibration to demonstrate reproducibility and reliability in obtaining eight measurements at a 1-week interval. The results showed good to excellent correlation and agreement (*t*-test, $p = 0.76$ and $p = 0.802$, respectively).

Outcomes and Outcome Measures

The measurements were performed *via* the OrthoCAD® program after scanning the arch. The primary outcome was tooth and intra-arch (quadrant) dimensional changes following the HT treatment. Specifically, the study aimed to measure the preoperative and postoperative intra-arch dimensional changes following a single HT crown placement in children, assess the tooth dimensions of the treated tooth pre- and post-HT crown placement, and compare the intra-arch dimensional changes of the ipsilateral quadrant treated with HT with the controlled nontreated contralateral quadrant. The outcome measures were the intraoral scan measurements in millimeters as measured by the OrthoCAD® software.

Variables and Measurements

At scan[1] (preoperative), scan[2] (immediate postoperative) and scan[3] (1 month follow-up), the following arch variables were measured (Fig. 3). The treatment quadrant in the arch—from the midline/mesial aspect of the first tooth in the quadrant (incisor tooth) to the distal aspect of the last tooth in the quadrant. This was called "the study arc." The control quadrant in the arch—from the midline/mesial aspect of the first tooth in the quadrant



Figs 2A and B: (A) Images show the iTero-II® in use on a child by the principal investigator and an example outcome scan with OrthoCAD™ software measuring half of the intraoral arch; (B) Shows an example of the space created by the placement of two EOSs on tooth 54, to highlight the potential increase in intra-arch length. Note that the upper right E (#55) has become distalized, potentially affecting the unerupted 16. The primate space has not been affected

(such as the incisor tooth) to the distal aspect of the last tooth in the control nontreatment quadrant. This was called "the control arc."

At scan[1], scan[2] and scan[3], both the specific HT tooth (before and after treatment) and a contralateral tooth on the control side had the following measurements taken (Fig. 4). Mesial distal (MD) width—this is defined as the maximum MD width possible in this dimension in a line drawn from the mesial to distal surfaces passing through the center of the tooth. Buccal lingual/palatal (BP/L) width—this is defined as the maximum BP/L width possible in this dimension in a line drawn from the buccal to palatal/lingual surfaces passing through the center of the tooth. Diagonal 1 (Diag1) width (mesiobuccal to distopalatal/lingual) (Diag1)—this is defined as the maximum width possible in this dimension in a line drawn from the tip of the mesiobuccal corner to the tip of the distopalatal/lingual corner passing through the center of the tooth. Diagonal 2 (Diag2) width (mesial lingual/palatal to distobuccal) (Diag2)—this is defined as the maximum width possible in this dimension in a line drawn from the tip of the mesial lingual/palatal corner of the tooth to distobuccal corner passing through the center of the tooth.

The difference between the pre- and postoperative measurements was calculated by the calibrated assessor on both sides (control and treatment) in mm using OrthoCAD®. The measurements were verified independently by a principal supervisor (IH) to assess accuracy.

Statistical Analysis

Data were entered into a computer using Statistical Package for the Social Sciences (SPSS) for Windows version 28.0 (SPSS Inc., Chicago, Illinois). The continuous variables were described using measures of central tendency and measures of dispersion, and normality was tested using the Shapiro–Wilk test. For paired continuous dependent variables (scan[1] and scan[2]), they were analyzed using paired *t*-tests. For comparing repeated continuous measurements (scan[1], scan[2], scan[3]), a repeated measures analysis of variance (ANOVA) model with *post hoc* analysis using the least significant

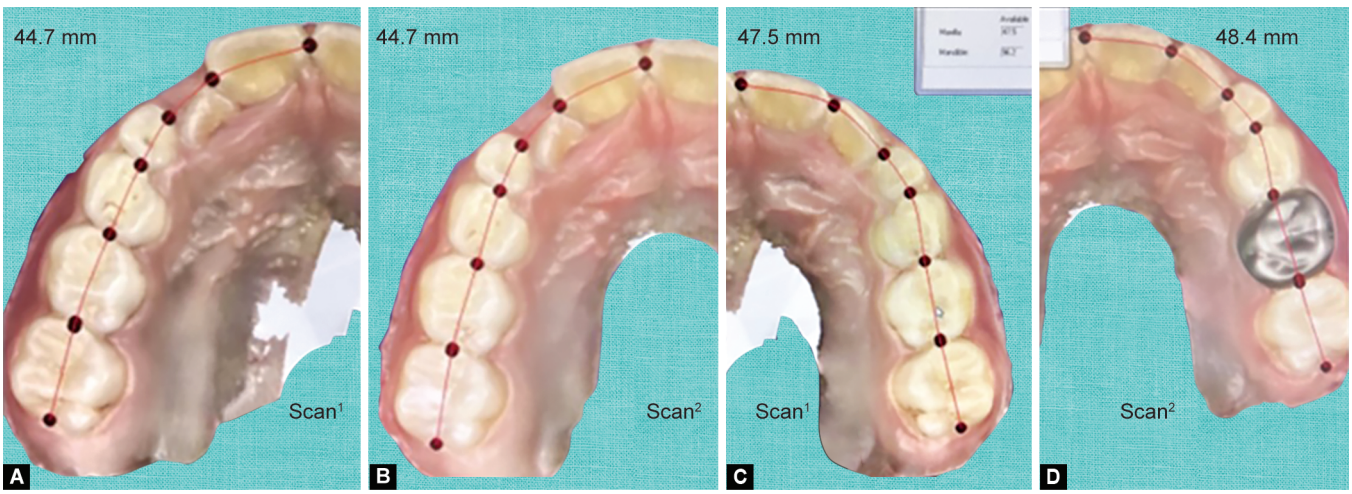


Fig. 3A to D: Shows arch measurements: (A and B) Control quadrant (the control arc pre- and postimmediate); (C and D) Treatment quadrant (the study arc pre- and postimmediate). Measurements are in mm. Note that there is no change in the control arc while there is a difference in the treatment arc

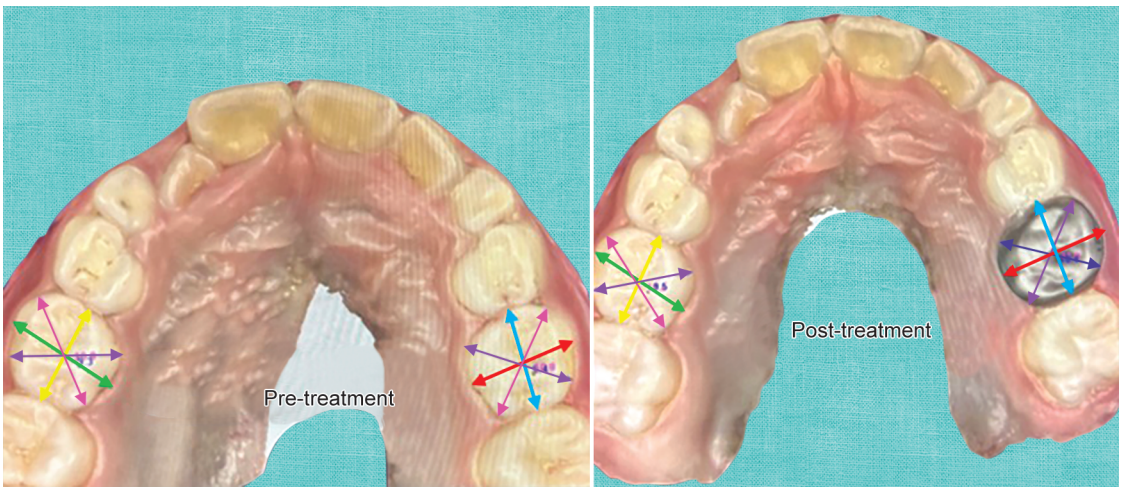


Fig. 4: The measurements of the HT tooth and the contralateral tooth at scan[1] (pre-treatment) and scan[2] (immediate post-treatment). MD width (MD blue and yellow), buccal lingual/palatal width (MP/L red and green), diagonal 1 width (mesiobuccal to disto/palatal lingual) (Diag1) diagonal 2 width (mesial lingual/palatal to distobuccal) (Diag2)

difference was employed for pairwise comparisons. A *p*-value of <0.05 was considered significant in all statistical analyses.

Results

Recruitment and Participants Flow

A total of 13 patients aged (3–9) years old [mean age 6.3 ± standard deviation (SD) of 1.6] were enrolled in this study. From those patients, seven were females (53.8%). A total of 13 patients attended both scan[1] and scan[2], while eight only attended scan[3] on time. While the remainder attended much later appointments, we did not repeat the intraoral scans as they were out of the pilot window period. There were, however, no complaints with their PMCs.

Baseline Data and Numbers Analyzed

In the 13 patients (Table 1), there was an increase in the study arc length between scan[1] and scan[2] after the application of the HT-PMC, but not exceeding 1 mm. This increase was measured to be around 0.7 ± 0.5 mm and was significant (*t*-test, $p < 0.001$). The mean control arc (the no treatment quadrant) of the 13 subjects showed no significant change between scan[1] and scan[2] (*t*-test, $p > 0.05$). When assessing the 13 subjects' HT-treated tooth dimensions, preoperatively (at scan[1]) and immediately postoperative (at scan[2]), there was an increase in all the measurements following the insertion of the HT crown—for example, the mean MD width of the HT-treated tooth increased by 0.9 mm ± 0.5, the mean BP/L width increased by 0.3 ± 0.1 mm; the mean Diag1 width increased by 0.6 ± 0.3 mm the mean Diag2 width of the HT treated increased by 0.7 ± 0.4 mm. All were significant (*t*-test, $p < 0.001$). In comparison, the control (nontreated) tooth dimensions (MD, BP/L, Diag1 and Diag2) measurements showed no change between scan[1] and scan[2] (*t*-test, $p > 0.05$). In the eight patients who attended all three appointments, a similar pattern was noticed for this subgroup, which was analyzed separately (Table 2). The placement of a single HT-PMC increased the intra-arch length of the treated quadrant by 0.8 ± 0.5 mm (repeated ANOVA, $p = 0.008$) after 1 month in comparison to the control quadrant that received no treatment. At the same time, there was no significant change in the control arc after 1 month (repeated ANOVA, $p = 0.195$). When assessing the eight patients HT treated tooth dimensions, preoperatively (at scan[1]) and 1-month postoperative (at scan[3]), there was an increase in all the HT tooth dimensions. The mean MD width of the HT-treated tooth increased by 0.9 mm ± 0.5, and this was significant (repeated ANOVA, $p = 0.005$); the mean BP/L width of the HT-treated tooth significantly increased by 0.7 ± 0.4 mm (repeated ANOVA, $p < 0.001$); the mean Diag1 width of the HT treated tooth increased significantly by 0.6 ± 0.3 mm (repeated ANOVA, $p < 0.001$); and finally the mean Diag2 width of the HT treated tooth increased by 0.6 ± 0.3 mm (repeated ANOVA, $p < 0.001$). In comparison, the control (nontreated) tooth dimensions showed no significant changes between scan[1] and scan[3] (repeated ANOVA, $p > 0.05$). As the repeated ANOVA showed significant changes with the study variables (in comparison to the control variables, which showed no changes), a *post hoc* analysis was conducted (Table 2; # and ^ symbols). No *post hoc* analysis was conducted for the control variables because of the lack of significant differences. The *post hoc* analysis was conducted for the results of the three scans (scan[1], scan[2], and scan[3]) for each of the—(1) study arc, (2) HT-treated tooth MD width, (3) HT-treated tooth BP/L width, (4) HT-treated tooth

Table 1: The control and treatment quadrants (study arcs) with control tooth and HT-treated tooth measurements at scan[1] and scan[2] for the 13 patients

Scan	Measured unit	Mean (in mm)	N	Standard deviation	Standard error	Mean difference between scan[1] and scan[2]	Difference standard deviation (±)	Difference standard error mean	95% confidence interval of the difference		Significance (two-sided t-test)
									Lower	Upper	
Scan[1]	Study arc	39.6	13	6.34	1.76	0.69	0.54	0.15	1.02	0.36	**$p < 0.001$***
Scan[2]	Study arc	40.3	13	6.37	1.76						
Scan[1]	Treated tooth MD	7.8	13	0.93	0.25	0.86	0.53	0.14	1.18	0.53	**$p < 0.001$***
Scan[2]	Treated tooth MD	8.7	13	0.72	0.20						
Scan[1]	Treated tooth BP/L	8.8	13	0.87	0.24	0.8	0.28	0.07	0.97	0.62	**$p < 0.001$***
Scan[2]	Treated tooth BP/L	9.6	13	0.93	0.25						
Scan[1]	Treated tooth Diag1	9.3	13	0.69	0.19	0.53	0.32	0.09	0.73	0.34	**$p < 0.001$***
Scan[2]	Treated tooth Diag1	9.9	13	0.79	0.22						
Scan[1]	Treated tooth Diag2	8.3	13	0.82	0.22	0.69	0.35	0.09	0.90	0.47	**$p < 0.001$***
Scan[2]	Treated tooth Diag2	9.1	13	1.01	0.28						
Scan[1]	Control arc	40.1	13	4.81	1.33	0.001	0.04	0.01	0.02	0.02	$p = 1$
Scan[2]	Control arc	40.1	13	4.79	1.35						
Scan[1]	Control tooth MD	7.9	13	0.74	0.20	0.01	0.02	0.01	0.01	0.02	$p = 0.337$
Scan[2]	Control tooth MD	7.9	13	0.73	0.20						
Scan[1]	Control tooth BP/L	9.1	13	0.64	0.17	0.03	0.08	0.02	0.02	0.08	$p = 0.219$
Scan[2]	Control tooth BP/L	9.2	13	0.66	0.18						
Scan[1]	Control tooth Diag1	9.4	13	0.41	0.11	0.06	0.19	0.05	0.05	0.17	$p = 0.275$
Scan[2]	Control tooth Diag1	9.5	13	0.48	0.13						
Scan[1]	Control tooth Diag2	8.4	13	0.70	0.19	0.08	0.16	0.04	0.01	0.18	$p = 0.085$
Scan[2]	Control tooth Diag2	8.3	13	0.72	0.20						

*Bold values indicate significant values, *t*-test paired samples statistics; B, buccal; D, distal; Diag1, mesiobuccal to disto/palatal/lingual width; Diag2, mesial lingual/palatal to distobuccal width; L, lingual; M, mesial; P, palatal; Numbers in mm rounded up to closest 0.1 unit

Table 2: The control and treatment quadrants (study and control arcs) with control tooth and HT-treated tooth measurements at scan[1], scan[2] and scan[3] for eight patients who attended the three scan appointments

Scan	Measured unit	Mean (in mm) with post hoc	Standard deviation	Standard error	Difference mean (scan[1] and scan[3])	Difference standard deviation (±)	Difference standard error mean	95% confidence interval of the difference		Significance (repeated ANOVA)
								Lower	Upper	
Scan[1]	Study arc	41.4[#,^]	5.70	2.01	0.78	0.57	2.02	3.17	4.74	***p* = 0.008***
Scan[2]	Study arc	42.05[#]	5.569	2.02						
Scan[3]	Study arc	42.2[^]	5.72	2.02						
Scan[1]	Treated tooth MD	7.8[#,^]	0.98	0.34	0.90	0.84	0.29	0.31	1.48	***p* = 0.005***
Scan[2]	Treated tooth MD	8.8[#]	0.79	0.28						
Scan[3]	Treated tooth MD	8.7[^]	0.68	0.24						
Scan[1]	Treated tooth BP/L	9.3[#,^]	0.34	0.12	0.72	0.48	0.16	0.39	1.05	***p* < 0.001***
Scan[2]	Treated tooth BP/L	10.03[#]	0.58	0.23						
Scan[3]	Treated tooth BP/L	10.03[^]	0.58	0.20						
Scan[1]	Treated tooth Diag1	9.7[#,^]	0.61	0.24	0.60	0.60	0.21	0.18	1.01	***p* < 0.001***
Scan[2]	Treated tooth Diag1	10.2[#]	0.59	0.19						
Scan[3]	Treated tooth Diag1	10.3[^]	0.59	0.21						
Scan[1]	Treated tooth Diag2	8.8[#,^]	0.59	0.21	0.63	0.69	0.24	0.15	1.11	***p* < 0.001***
Scan[2]	Treated tooth Diag2	9.4[#]	0.76	0.23						
Scan[3]	Treated tooth Diag2	9.3[^]	0.77	0.27						
Scan[1]	Control arc	39.5	4.61	1.63	0.43	0.58	0.20	0.92	0.04	*p* = 0.195
Scan[2]	Control arc	39.65	4.58	1.26						
Scan[3]	Control arc	39.98	4.88	1.72						
Scan[1]	Control tooth MD	7.7	0.88	0.31	0.17	0.32	0.11	0.44	0.09	*p* = 0.175
Scan[2]	Control tooth MD	7.6	0.87	0.22						
Scan[3]	Control tooth MD	7.8	0.95	0.33						
Scan[1]	Control tooth BP/L	9.4	0.24	0.14	0.22	0.46	0.16	0.61	0.16	*p* = 0.216
Scan[2]	Control tooth BP/L	9.3	0.24	0.19						
Scan[3]	Control tooth BP/L	9.5	0.60	0.22						
Scan[1]	Control tooth Diag1	9.6	0.41	0.18	0.28	0.49	0.17	0.70	0.12	*p* = 0.144
Scan[2]	Control tooth Diag1	9.6	0.41	0.19						
Scan[3]	Control tooth Diag1	9.8	0.63	0.30						
Scan[1]	Control tooth Diag2	8.7	0.52	0.8	0.33	0.67	.23	0.90	0.22	*p* = 0.201
Scan[2]	Control tooth Diag2	8.8	0.52	0.8						
Scan[3]	Control tooth Diag2	9.05	0.85	0.21						

*Bold values indicate statistically significant values, repeated ANOVA test statistics; # and ^ denotes *post hoc* analysis and significant difference between scans within a group; B, buccal; D, distal; Diag1, mesiobuccal to disto/palatal/lingual width; Diag2, mesial lingual/palatal to distobuccal width; L, lingual; M, mesial; P, palatal; Numbers in mm rounded up to closest 0.1 unit

Diag1 width and finally; and (5) HT-treated tooth Diag2 width. This analysis showed that the results of scan[1] were significantly different from each of scan[2] and scan[3], respectively, for all the aforementioned variables (ANOVA *post hoc*, $p < 0.001$). Therefore, compared to preoperative variables, the HT-PMC increased all the variables immediately postoperative, and the 1-month follow-up results had increased compared to the preoperative variables. The results of scan[2] were not significantly different from those of scan[3] (ANOVA *post hoc*, $p > 0.05$). This meant that no major changes were seen in the 1-month follow-up in comparison to the immediate postoperative readings (Figs 5A to E).

In summary of the results, the findings showed that on the HT-treated side, the treated arch mesiodistal length increased by 0.7–0.9 mm (mean of 0.8 mm). At the treated tooth level, all measured dimensions (mesiodistal, buccolingual, Diag1, and Diag2) increased after the cementation of the HT-PMC. No changes occurred on the control side or control tooth.

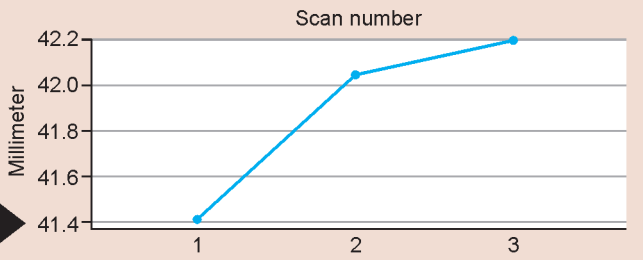
Discussion

This feasibility pilot study was used to test the methodology and the null hypothesis outlined above. It assessed the size of PMCs and their dental arch effect in the context of a very topical issue in contemporary pediatric dentistry, namely the HT.[24–27] The HT has been assessed for its clinical success, for patient/parent/dentist perception,[1] for microleakage,[28] for effect on exfoliation,[29] pain procedural perception,[30] and finally, its effects on the occlusion (especially the OVD).[17] The latter studies related to dental inter-arch relationships but not intra-arch changes. Although conventional PMCs have been compared to HT-PMCs,[31] this pilot study was novel in that it was the first to analyze and measure the intra-arch quadrant length changes resulting from the use of the HT. According to this pilot study, the HT-PMC is marginally oversized; there was a dimensional increase in the size of the treated tooth and treated quadrant, which is a previously unproven side effect of the child-

A

	Mean	Std. deviation	N
Study arc Scan[1]	41.413	5.7010	8
Study arc Scan[2]	42.050	5.5629	8
Study arc Scan[3]	42.200	5.7296	8

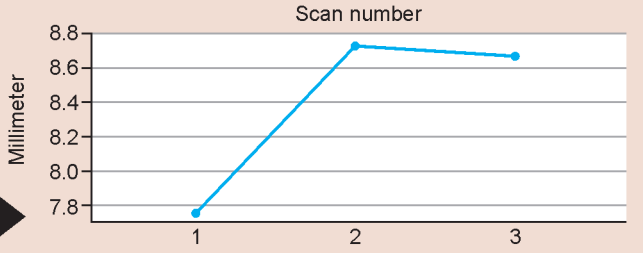
Study arc length means over time of all three scans



B

	Mean	Std. deviation	N
HT tooth MD Width Scan[1]	7.763	0.9812	8
HT tooth MD Width Scan[2]	8.725	0.7996	8
HT tooth MD Width Scan[3]	8.663	0.6802	8

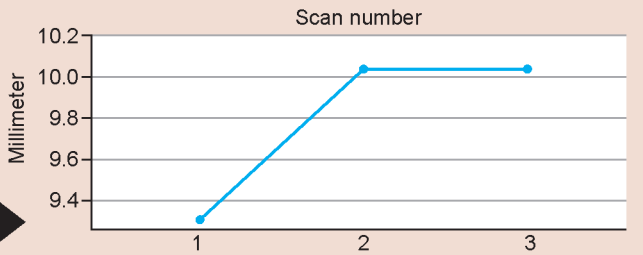
MD mean width changes over time of all three scans



C

	Mean	Std. deviation	N
HT tooth BP/L Width Scan[1]	9.313	0.3441	8
HT tooth BP/L Width Scan[2]	10.038	0.5854	8
HT tooth BP/L Width Scan[3]	10.038	0.5854	8

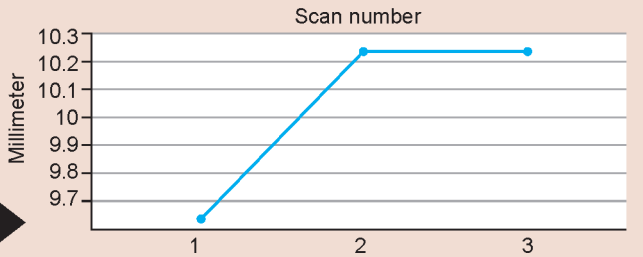
BP/L mean width changes over time of all three scans



D

	Mean	Std. deviation	N
HT tooth Diagonal 1 Scan[1]	9.638	0.6116	8
HT tooth Diagonal 1 Scan[2]	10.238	0.5902	8
HT tooth Diagonal 1 Scan[3]	10.238	0.5902	8

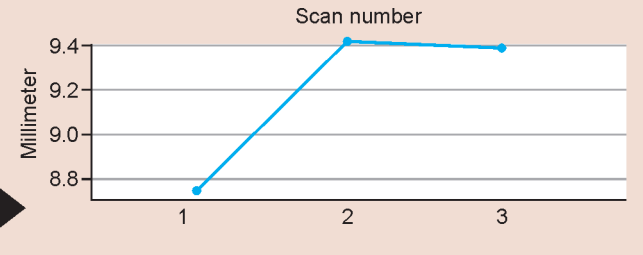
Diag1 mean changes over time of all three scans



E

	Mean	Std. deviation	N
HT tooth Diagonal 2 Scan[1]	8.750	0.5976	8
HT tooth Diagonal 2 Scan[2]	9.413	0.7605	8
HT tooth Diagonal 2 Scan[3]	9.388	0.7754	8

Diag2 mean width changes over time of all three scans



Figs 5A to E: Treated and control tooth arch measurements change over time (subgroup *post hoc* analysis) (A) Study arc; (B) HT-PMC MD width; (C) HT-PMC B P/L width; (D) HT-PMC Diag1 width; (E) HT-PMC Diag2 width. The Y-axis is mm, while the X-axis represents visits

friendly HT. This pilot study could pave the way for a more robust study with a larger sample size.

Choosing the appropriate size of a PMC for primary molars in pediatric dentistry remains an ongoing challenge. Even when placed conventionally, there is evidence that practitioners struggle to achieve a correct PMC fit, even after multiple attempts.[32] In the HT, this could be because the minimum fit HT-PMC is oversized anyway, or there is a real failure to choose the best fit PMC because of a preexisting mismatch between stock PMCs and primary molars.[33] Efforts have been made to improve PMC size predictability for the final selection size for the restoration of primary molars by various techniques, for example, using

preoperative radiographic measurements.[32] However, recently published research showed that pediatric dentists thought there was no clear radiographic difference between HT and conventional PMCs on bitewings radiographs.[34] Indicating that detecting an HT-PMC radiographically, due to it being oversized, was not that easy.

However, having a marginally oversized HT-PMC does not suggest it contributes to the failure of the HT. On the contrary, the HT enjoys a very high success rate of >95% over 2 years.[2] However, a single HT-PMC appears to encroach on the existing LWS, increasing this intra-arch unit by between 0.7 and 0.9 mm. The clinical significance of this effect, or lack thereof, is something that would need further research and assessment, especially when multiple crowns are used.

Does an oversized HT-PMC have any unfavorable physical effects? An oversized HT-PMC may appear to go against recommended expert opinion, as the chief goal of full coronal restorations using PMCs is the exact "replication of normal crown form" and function.[35] Nevertheless, even conventional PMCs are known to cause premature contacts[36] and increase the OVD and physical vertical stress[37] to the tooth structure and underlying bone. Due of this, a cycle of fatigue of PMC metal can occur, whether it is continuously strained or swinging, potentially causing breakdown or deformation of the crown; indeed, PMC perforation has been reported in the literature.[4] It is anecdotally suggested that this stress may increase in the case of HT compared to C-PMCs.[37] However, the effect of HT-PMCs, luted with glass ionomer cement, generating lateral stresses (because of being oversized) has not been researched. Interestingly, PMCs' linear vertical static stress has been found to be influenced by cement types used in HT-PMCs. Waly et al.[38] concluded that using stiffer cement materials increased tooth structure stresses and reduced crown body stresses and deformations, while the bone was nearly insensitive to cement type.[38] It had been proven that HT-PMC causes vertical intrusion of the treated tooth,[19,37] and subsequently, concerns have been raised that this may contribute to the induction of early exfoliation of HT-treated primary molars, but the latter point was recently dismissed.[29]

Another aspect of having oversized crowns is the potential introduction of speech deficiencies, as less space becomes available for full lateral tongue phonation. However, more research is required to assess if such crowns affect phonation physiology.[39] Although there is an association[40] between occlusion anomalies and speech defects,[41] it may be recommended that dentists should screen for speech anomalies[42] after placement of HT-PMCs. It should be stated that there is no evidence to date to suggest that PMCs, whether conventionally placed or by using the HT, are associated with speech defects in children.

Finally, although HT is considered a child-friendly procedure by avoiding injections and drills (sources of pain and dental anxiety[43]), it has recently been suggested this is not always the case.[30] If the oversized HT-PMC generates lateral pressure and lateral forces/stresses affecting the adjacent teeth and the periodontium around the tooth, this may contribute to some "procedural discomfort" (as reported by Boyd et al.[30] recently). There is a lack of studies on this aspect at present, and this warrants further investigations.

Is an increase in intra-arch length; unfavorable or favorable? This present study suggested that the intra-arch length suffers an increase (on average 0.8 mm) as PMCs are placed on treated primary molars, the latter of which naturally contribute to the LWS. The LWS could be negatively compromised (reduced)[44] when approximal caries in primary molars and tooth destruction occur. As the present study anticipated a 0.8 mm increase in the intra-arch length after placing PMC *via* the HT, this could be beneficial where space loss had already occurred due to approximal caries. Thus, it could be speculated that the HT-PMC could act as a space management tool to prevent further loss of the arch length (or even as a simple space-regaining device). Interestingly, it had been anecdotally reported that ectopic impaction of the first permanent molar against the distal aspect of an HT-PMC crowned upper second primary molar had occurred.[11] This could be due to the effect of increased arch length and tooth dimension, potentially distalizing a second primary molar in addition to using an oversized PMC; however, this needs further research. This increase may have the potential to contribute to the impaction of unerupted first permanent molars, especially if more than one PMC is used in the quadrant/arch. Although the latter point was not studied in this pilot, it warrants further investigation.

On the contrary, in cases where there is no loss in interproximal spaces between primary canines and molars or where there is existing anterior orthodontic crowding in the arch, adding approximately up to 1 mm may unnecessarily load the arch, increasing crowding. In cases of "All Hall,"[11] where 8 HT-PMCs are placed, this increase could amount to 3.6 mm per arch.

An important aspect to discuss here is that the patients in this study received two standard EOSs (mesially and distally to the treated tooth). The use of two EOSs could be considered the initial instigator of the increase in arch length. However, this is not always the case in HT patients, as many require only one EOS, and occasionally no EOSs are required at all. Whether there is a difference in the increase in arch length when using one or two EOSs in the HT requires further research. In addition, in cases where the modified HT[14] is used, there is no use of the EOSs. It may be speculated that there is less of an increase in the arch length as such, but this needs further research.

Pediatric dentists can adjust the size of a suitable (but oversized) PMC to some extent. The most commonly used PMCs in the market, such as 3M® ESPE and MIB®, are typically festooned, pretrimmed, and precrimped. These crowns already have a suitable contour, which minimizes the need for additional crimping. However, dentists may still make minor adjustments to ensure a better fit, especially in cases where the PMC is slightly oversized.[45] However, many dentists still adjust the mesiodistal or buccolingual contour by further squashing or crimping them to obtain a better fit with the tooth structure. However, there is no precise information about the effectiveness of recrimping or the extent to which recrimping may improve the marginal fit or reduce the overall dimensions of the selected crown size. According to the Afshar et al. study, it has been demonstrated that the marginal circumference of precrimped PMCs showed a significant decrease after crimping. Specifically, the mean marginal circumference of precrimped PMCs decreased by 7.3% following crimping, and the marginal thickness of the PMC increased by an average of 18µ after crimping.[45] Therefore, it could be suggested that all HT-PMCs should be precrimped where possible to reduce their size (at least in the MD dimension) in crowded dentitions.

Although HT is proposed to be a child-friendly procedure because there is no drilling or LA injections (both causes of dental anxiety and phobia in children[43]), the technique is less demanding for children than conventional treatment. When the first randomized controlled study of the HT came out in 2007,[1] it reported that children preferred the HT over conventional

restorations and specifically mentioned that they had less pain.[1] However, Boyd et al.,[30] recently highlighted the fact that some children found the HT to be as painful as the conventional PMC. Maybe an oversized crown impinging the gingiva and compressing adjacent teeth are some of the factors causing this procedural pain. Hence, further research should address the multiple reasons for such pain and discomfort.

Study Limitations

This was a pilot study with a small sample, and unfortunately, several patients were lost to follow-up, although clear significant results were obtained. A more extensive study with a larger sample size is planned. There was no possibility to blind the treatment side. Although the primary supervisor carried out *ad hoc* checks and verifications of the measurements, a single primary investigator conducted all the scans and measurements after calibration, which could have introduced bias. Additionally, future research could improve by comparing HT-PMC-treated teeth not only to untreated teeth (acting as controls) but also to conventional PMC sizes or modified HT-PMCs.

Conclusion

In this pilot feasibility study, a single HT-PMC increased the intra-arch quadrant length by up to, but not exceeding, approximately 1 mm. The HT-PMC rendered the treated tooth marginally oversized in all dimensions compared to a nontreated control tooth. This pilot study paves the way for a more robust follow-up study.

Clinical Significance

This study was presented at the British Society of Paediatric Dentistry Conference, in September 2023, and the abstract was published in the International Journal of Paediatric Dentistry.[46]

- The HT, a valid method for managing the asymptomatic nonpulpally involved carious primary molar, ultimately uses a marginally oversized crown.
- Caution should be exercised in crowded dental arches, especially in the cases of multiple HT-PMCs and potential ectopic eruption of first maxillary permanent molars, especially in cases of multiple crowns in one arch.
- This change or effect on the crowding may be temporary, as when the tooth exfoliates, the space could be regained.

Declaimer Statement Regarding Plagiarism

An unedited non-peer reviewed preliminary version of this manuscript has been published as a preprint on Research Square (link: HYPERLINK "https://ind01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.researchsquare.com%2Farticle%2Frs-3884283%2Fv1&data=05%7C02%7Cnitisha.goyal%40jaypeebrothers.com%7C2235b0ac27d14faae67408dca65eb89d%7C9e7fa850fd9547b7bda2a51c357d60ae%7C0%7C0%7C638568172967030078%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C%7C&sdata=Rvt%2BMFAkoTJIh9k5ydeb9B%2FT7apC4H9HrwW8izCbpvw%3D&reserved=0" https://www.researchsquare.com/article/rs-3884283/v1) prior to its formal publication in the International Journal of Clinical Pediatric Dentistry.

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We applied the "first-last-author- emphasis" norm (FLAE) for the sequence and credit of authors' contributions. Author no. 1 conducted the research data collection and wrote the initial drafts of the paper. Authors no. 2, 3, 4, and 5 contributed to the design, supervision, and write-up of the paper. Author no. 5 conducted the statistical analysis. Author no. 6 trained and calibrated the PI. Author no. 7 supervised the conceived idea, overall design, and supervision of the project, as well as the write-up of the paper and the corresponding author.

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