*Original Article*

# Mandibular dental changes following serial and late extraction of mandibular second premolars

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## ABSTRACT

**Objectives:** To determine changes in occlusal curves and dental tipping occurring from mandibular second premolar serial extraction, early extraction of deciduous mandibular second molars with missing second premolars, and late second premolar extraction compared with untreated controls.

**Materials and Methods:** Information was collected from 85 subjects at three time points: T0, prior to serial extraction; T1, after serial extraction and drift prior to orthodontic treatment, and pretreatment for the late premolar extraction patients; and T2, posttreatment. Untreated age- and gender-matched controls were used for comparison. Three occlusal curves were measured on digitized mandibular casts, and dental tipping was assessed using lateral cephalograms.

**Results:** At T0, there were no significant differences among groups. At T1, there was significant steepening of Monson's sphere and the curve of Wilson between early and late extraction and control groups. At T2, the differences in Monson's sphere and the curve of Wilson were fully corrected. At T1, there were significant differences in the tipping of mandibular 6's, 4's, and 3's between the early extraction groups compared with the late extraction and control groups. At T2, these differences in tipping were fully corrected. There were no differences in mandibular incisor tipping between groups at T1 or T2.

**Conclusions:** Serial extraction produced steeper occlusal curves and significant tipping of mandibular first molars, first premolars, and canines after extraction and physiologic drift (T1). Accentuated occlusal curves and tooth tipping were fully corrected following orthodontic treatment (T2). Mandibular incisor position was unchanged by serial or late second premolar extraction. (*Angle Orthod.* 2020;90:187–193.)


**KEY WORDS:** Serial extraction; Second premolars; Deciduous second molars; Occlusal curves; Dental tipping


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## INTRODUCTION

A long-running treatment debate in orthodontics is whether a tooth size arch length discrepancy should be treated with a nonextraction or an extraction approach.[1] Mixed dentition crowding can be resolved with leeway space management, expansion, or serial extraction.[2–5] Mixed dentition serial extraction creates space for the eruption and self-alignment of permanent teeth over basal bone and reduces future permanent dentition orthodontic treatment complexity.[6–10] Proposed benefits of serial extraction include self-alignment of teeth, permanent canines erupting into attached gingiva, shorter active treatment time, and improved stability.[3,9–12] The negative sequelae from serial extractions are residual spacing, tipping, and the need for treatment of any unresolved alignment issues during the postextraction drift phase.[8,10–11,13] Other disadvantages of serial extractions include deepening the overbite, lingual tipping of incisors, distal tipping of

mandibular canines, mesial tipping of molars, creation of a diastema and increased spacing, potential scar tissue buildup in the area of the extraction sites, and alteration of tongue function.[2,14–16]

Modified serial extraction occurs when deciduous second molars and/or second premolars are extracted rather than deciduous first molars and first premolars.[17] Second premolar serial extraction advantages compared with first premolars can then be listed as (1) better root parallelism and marginal ridge contact, (2) limited lingual migration of mandibular anterior teeth, (3) minimal increase in the curve of Spee and overbite, (4) minimal flattening of the facial profile, and (5) increased bodily drift of the first and second molars, which can aid in class II molar correction.[17–19] Another indication for modified serial extraction is congenitally missing mandibular second premolars.[20] Extraction of deciduous second molars with missing second premolars offer several benefits: avoiding prosthetic replacement and reducing or eliminating the need for orthodontic appliances.[19,20] Lindqvist[21] reported that when the deciduous second molars were extracted early, the extraction space spontaneously closed; 4 years after extraction, there was on average less than 1 mm of residual maxillary space and 2 mm of residual mandibular space. Mamopoulou et al.[22] investigated Class I patients with mandibular second premolar agenesis following extraction of deciduous mandibular second molars and maxillary second premolars. Half of the extraction space closed during the first year. After 4 years, 89% of the maxillary extraction space closed and 80% in the mandible, leaving mean residual extraction spaces of 0.9 and 2.0 mm, respectively.[22] The mandibular incisor position was unchanged.[22]

There is limited information on second premolar serial extractions, especially in case-controlled trials. The study hypotheses were as follows:

- Postextraction drift of the serial extraction groups, compared with late second premolar extraction and control groups, would show a deepened curve of Spee, curve of Wilson, and Monson's sphere and significant tipping of the mandibular first molar and first premolar, moderate canine tipping, and minimal incisor tipping.
- Postorthodontic treatment of the serial extraction groups, compared with late second premolar extraction and control groups, would show full correction of the occlusal curves and tooth tipping, such that there would be no difference in final outcomes between serial extraction, late second premolar extraction, and control groups.

## MATERIALS AND METHODS

This research was approved by the Research Ethics Board at the University of British Columbia (H16-01763). Patient records were collected from a Vancouver orthodontic practice (DK), where patients completed comprehensive orthodontic treatment between 1984 and 2006. Patients from this practice were retrospectively and consecutively chosen to form three treatment groups: group 1, serial extraction of mandibular second premolars ("early ext 5's," n = 25); group 2, serial extraction of deciduous mandibular second molars when the underlying second premolars were missing ("early ext E's," n = 10); group 3, late extraction of mandibular second premolars ("late ext 5's," n = 25); and group 4, untreated control group from the Oregon Health Sciences University through the American Association of Orthodontists Legacy Collection (n = 25). The deciduous mandibular second molar extraction group had only 10 patients (maximum available) and did not meet the desired sample size; they were included, however, since there is little published information on such cases.

The inclusion criteria for the early extraction groups were serial extraction of both mandibular second premolars or deciduous mandibular second molars with congenitally missing second premolars, at least 1-year drift phase, comprehensive fixed appliance treatment, and complete records (models and lateral cephalometric radiographs). The late extraction group inclusion criteria were extraction of both mandibular second premolars once the patient had all permanent teeth present (except third molars), no drift phase, comprehensive fixed appliance treatment, and complete records. Second premolar extractions were selected when there was a Class I malocclusion with 4 to 8 mm of posterior crowding, a desire to maintain mandibular incisor position, and/or missing second premolars prompting deciduous second molar extractions. Exclusion criteria for the treatment groups were use of space maintenance appliances, missing mandibular teeth other than the congenitally absent mandibular second premolars, Class III malocclusion, craniofacial syndromes, partial treatment, and incomplete records. The inclusion criteria for the control group were no orthodontic treatment and complete records at all three time points. Exclusion criteria for the control group consisted of previous orthodontic treatment, mandibular extractions, missing mandibular teeth, Class III, craniofacial syndromes, and incomplete records.

Data were evaluated at the following three time points: T0, baseline for the control and serial extraction patients; T1, after physiologic drift, prior to orthodontic treatment for the serial extraction patients, and pretreatment for the late premolar extraction patients; and T2, after comprehensive orthodontics. The untreated control group was age matched against the

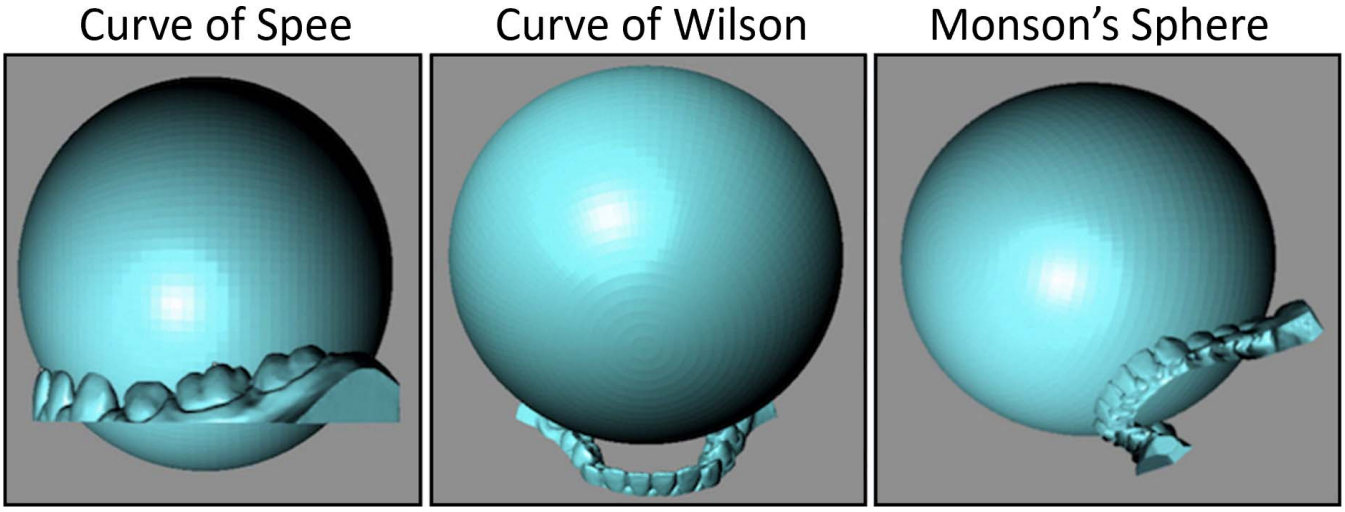


**Figure 1.** Three-dimensional renderings of the spheres representing occlusal curves.

average chronological age of the mandibular second premolar serial extraction group at each time point.

To measure the occlusal curves, stone dental models were scanned using a computer program, Ortho Insight 3D (version 4.0; MotionView Software, Chattanooga, TN), into .stl digital files that were then opened in a separate computer program, Rhinoceros (version 5.0; Robert McNeel & Associates, Seattle, WA), to create best-fit spheres that were placed on the models, and the resulting radii were measured.[16] The sphere radii corresponded to the depth of the occlusal curvatures: the steeper the curvature, the smaller the radius. Three separate spheres were produced (Figure 1) according to the following landmarks: the curve of Spee: MB and DB cusps of mandibular first molars and incisal edges of the four mandibular incisors; the curve of Wilson: MB, ML, DB, and DL cusps of the mandibular first molars; and Monson's spheres: MB, ML, DB, and DL cusps of the mandibular first molars and incisal edges of the four mandibular incisors.[16]

Cephalometric radiographs were scanned to create digital copies, and using Rhinceros 3D, vertical lines were digitally drawn through the long axes of the mandibular first molars, first premolars, canines, and central incisors, and the angle relative to the palatal plane was measured. The palatal plane (ANS-PNS) was the chosen reference plane as it could be located precisely and was easily reproducible; it is located close to the areas under consideration and experiences minimal change over time compared with other possible reference planes such as the mandibular plane or Sella-Nasion.[23,24] The palatal plane was also used in previous, separate studies by Yoshihara et al.[25] and Feldman et al.,[16] both of whom noted that there was no influence of growth changes at Nasion, there was no influence of rotation of the jaws, and the inclination of the occlusal plane by dental effects was excluded.

### Statistical Analyses

A power calculation was performed for detecting differences in tooth tipping and the occlusal curves: 90% power and $\alpha = .05$ required 22 patients in each group. SPSS version 25.0 was used for all statistical analyses, and the threshold for the statistical significance for all tests was set at $P < .05$. For the collected data, assumptions for both normality and equality of variances were fulfilled. Measurements were acquired for each time point: T0, T1, and T2, including the mean and standard deviation for each group measuring the occlusal curves and each group measuring the dental tipping. Since the assumptions for normality and homogeneity of variance were fulfilled, a one-way analysis of variance (ANOVA) with a Tukey post hoc adjustment was used to detect significant differences among groups. A one-way ANOVA test assessed whether the age-based matching among all groups was fulfilled at time points T0, T1, and T2. The intraexaminer agreement was tested with intraclass correlation based on duplicate recordings of 10 randomly selected records 1 month apart.

## RESULTS

The intraexaminer agreement was tested based on duplicate recordings of 10 randomly selected samples. The intraclass correlation coefficients for occlusal curves were as follows: curve of Spee: 0.865; Monson's sphere: 0.931; curve of Wilson: 0.990; combined data of occlusal curves: 0.986. For the tipping measurements, the corresponding values were PP-L1: 0.962; PP-L3: 0.932; PP-L4: 0.879; PP-L6:

**Table 1.** Summary of Ages at T0, T1, and T2[a]

| Age | No. of Patients | Male | Female | Mean (SD) | | |
|---|---|---|---|---|---|---|
| | | | | Age at T0 | Age at T1 | Age at T2 |
| Group 1: Early ext 5's | 25 | 10 | 15 | 10.7 (1.2) | 13.1 (1.1) | 15.5 (1.3) |
| Group 2: Early ext E's | 10 | 5 | 5 | 10.0 (1.8) | 13.0 (1.2) | 15.5 (1.1) |
| Group 3: Late ext 5's | 25 | 10 | 15 | — | 12.6 (1.3) | 15.4 (1.3) |
| Group 4: Control | 25 | 11 | 14 | 10.8 (0.9) | 12.9 (0.9) | 15.6 (1.1) |

[a] Unit of measurement is in years.

0.774; and combined data for tipping: 0.971. These findings demonstrated that all measurements were acquired with a high degree of intraexaminer reliability.

No significant age-related differences were found among any groups at T0, T1, or T2. The age range at T0 was 10.0–10.8 years old, 12.6–13.1 years old at T1, and 15.4–15.6 years old at T2. Table 1 lists the ages for all groups at each specific time point along with the sex distribution per group. Differences in tooth angulation and occlusal curves between groups at each time point were assessed using a one-way ANOVA test with a Tukey post hoc adjustment for multiple comparisons. Results are presented in Table 2.

### Occlusal Curves Comparison at Three Time Points (Table 2)

At T0, there were no significant differences ($P > .050$) in occlusal curves among groups. From T0 to T1, all three occlusal curves steepened in the two early extraction groups, while the control group had minimal flattening (Table 2). At T1, there were significant differences in Monson's sphere and curve of Wilson between the early and late extraction groups as the occlusal curves steepened in the early extraction groups (Table 2; Figures 2 and 3). The box plot graphs demonstrate the distribution patterns regarding occlusal curves among the groups at T0, T1, and T2 (Figures 2–4). Lines in the boxes represent median values. The box values represent values for 50% of the group, with upper whiskers indicating the 25% of cases with the highest values and lower whiskers representing the 25% of cases with the lowest values. Values covered by both whiskers and the box represent the intragroup variation.

From T1 to T2, both the Monson's sphere (Figure 2) and curve of Wilson (Figure 3) flattened in all four groups, most notably in the two early extraction groups. From T1 to T2, the curve of Spee steepened in all four groups (Figure 4). At T2, the differences in Monson's sphere and the curve of Wilson were fully corrected by flattening of the occlusal curves. There were no significant differences between any groups at T2, except for the curve of Spee between the early extraction of second premolars and control groups.

### Dental Tipping Comparison at Three Time Points (Table 2)

At T0, there were no significant differences in tooth angulation among groups. From T0 to T1, the mandibular 6's tipped mesially while the mandibular 4's and 3's tipped distally and the mandibular 1's tipped lingually in the two early extraction groups, whereas the control group had minimal changes (Table 2). At T1, there were significant differences in the angulation of mandibular 6's, 4's, and 3's among groups (Table 2). The only tooth inclination without significant differences at T1 among all groups was the mandibular central incisor.

From T1 to T2, the mandibular 6's tipped distally while the mandibular 4's and 3's tipped mesially and mandibular 1's tipped labially in both early extraction groups. The mandibular incisors tipped lingually a minimal amount in the late extraction and control groups. At T2, the differences in tipping of all teeth were fully corrected in the early extraction groups. There were no significant differences between any groups at T2, except for a significant difference in the angulation of mandibular first premolars between the late extraction of second premolars and control groups.

## DISCUSSION

No past studies have evaluated occlusal curve changes in patients with serial extraction of mandibular second premolars or deciduous mandibular second molars when the second premolars were missing. The significant steepening of occlusal curves of both Monson's sphere and the curve of Wilson from before serial extraction (T0) to after extraction and physiologic drift (T1) were fully corrected by fixed orthodontic treatment (T2).

Both early extraction groups showed significant tipping of the mandibular first molars, first premolars, and canines from before extraction (T0) to after extraction and physiologic drift (T1). There were no significant mandibular incisor inclination differences between any groups at T1. The significant tipping of the mandibular first molars, first premolars, and canines was fully corrected by fixed orthodontic treatment. Posttreatment, there were no significant

**Table 2.** Comparison of Occlusal Curves and Tooth Angulation Among Groups at T0, T1, and T2[a]

| | | Observation Times | | | |
|---|---|---|---|---|---|
| | | T0 | T1 | T2 | |
| | n | Mean (SD) | Mean (SD) | Mean (SD) | Significance[b] |
| Occlusal curves | | | | | |
| M spheres, mm | | | | | |
| Early ext 5's | 25 | 54.0 (4.4) | 51.6 (4.5) | 55.4 (3.5) | .007 |
| Early ext E's | 10 | 52.8 (5.2) | 48.5 (3.5) | 55.5 (2.8) | .002 |
| Late ext 5's | 25 | — | 56.8 (5.7) | 57.5 (4.1) | .620 |
| Control | 25 | 53.8 (2.7) | 54.1 (4.0) | 54.6 (4.5) | .756 |
| Significance[b] | | .7121 | <.001 | .0706 | |
| COW spheres, mm | | | | | |
| Early ext 5's | 25 | 58.2 (5.9) | 56.6 (5.5) | 61.1 (4.1) | .011 |
| Early ext E's | 10 | 55.2 (6.7) | 53.8 (4.8) | 61.1 (3.8) | .010 |
| Late ext 5's | 25 | — | 61.4 (7.6) | 63.8 (4.7) | .186 |
| Control | 25 | 58.5 (3.6) | 59.1 (5.3) | 60.1 (5.9) | .527 |
| Significance[b] | | .223 | .004 | .055 | |
| COS spheres, mm | | | | | |
| Early ext 5's | 25 | 30.7 (4.6) | 29.9 (4.9) | 25.0 (4.3) | <.001 |
| Early ext E's | 10 | 32.6 (4.6) | 29.8 (3.3) | 28.4 (6.6) | .182 |
| Late ext 5's | 25 | — | 31.5 (3.8) | 26.4 (3.7) | <.001 |
| Control | 25 | 28.7 (4.7) | 29.4 (4.4) | 28.8 (4.1) | .832 |
| Significance[b] | | .070 | .343 | .017 | |
| Tooth angulation | | | | | |
| L6 to PP, ° | | | | | |
| Early ext 5's | 25 | 68.1 (4.1) | 62.1 (4.3) | 72.2 (5.0) | <.001 |
| Early ext E's | 10 | 70.4 (7.9) | 64.1 (6.1) | 73.6 (5.0) | .009 |
| Late ext 5's | 25 | — | 69.1 (6.7) | 71.4 (4.8) | .169 |
| Control | 25 | 68.8 (4.7) | 70.2 (5.0) | 70.9 (5.0) | .310 |
| Significance[b] | | .491 | <.001 | .484 | |
| L4 to PP, ° | | | | | |
| Early ext 5's | 25 | 72.9 (7.2) | 86.4 (5.8) | 72.5 (4.3) | <.001 |
| Early ext E's | 10 | 73.5 (9.6) | 85.2 (5.6) | 73.8 (4.6) | .001 |
| Late ext 5's | 25 | — | 73.7 (6.7) | 71.3 (5.2) | .164 |
| Control | 25 | 75.4 (6.2) | 76.5 (4.2) | 75.9 (4.4) | .741 |
| Significance[b] | | .465 | <.001 | .006 | |
| L3 to PP, ° | | | | | |
| Early ext 5's | 25 | 67.9 (6.5) | 75.1 (6.6) | 66.9 (5.6) | <.001 |
| Early ext E's | 10 | 71.1 (8.2) | 76.2 (7.8) | 69.6 (4.8) | .112 |
| Late ext 5's | 25 | — | 64.8 (4.7) | 67.1 (5.1) | .104 |
| Control | 25 | 67.0 (6.2) | 69.6 (5.7) | 69.6 (5.0) | .179 |
| Significance[b] | | .265 | <.001 | .168 | |
| L1 to PP, ° | | | | | |
| Early ext 5's | 25 | 60.6 (7.7) | 61.8 (5.4) | 58.7 (6.6) | .256 |
| Early ext E's | 10 | 62.1 (10.2) | 64.6 (10.3) | 64.2 (9.2) | .833 |
| Late ext 5's | 25 | — | 58.2 (5.8) | 60.8 (5.2) | .102 |
| Control | 25 | 58.7 (7.5) | 60.9 (8.2) | 62.3 (8.5) | .289 |
| Significance[b] | | .486 | .090 | .156 | |

[a] COS indicates curve of Spee; COW, curve of Wilson; L1, lower incisors; L4, lower first premolars; L3, lower canines; L6, lower first molars; M, Monson's spheres; PP, palatal plane.
[b] Analysis of variance with Tukey post hoc adjustment.

differences in mandibular incisor inclination among groups. When mandibular second premolars, or deciduous mandibular second molars without successors, were extracted early, there was no significant difference in final mandibular incisor inclination compared with delaying extraction until the full permanent dentition. To summarize the important findings comparing serial extraction of mandibular 5's or E's versus mandibular 4's serial extraction[16]: there was less lingual tipping of mandibular incisors, similar tipping of canines, and more mesial tipping of first molars following physiologic drift when 5's or E's were extracted.[16,25] These results confirmed Logan's[26] findings that second premolar extraction reduced excessive lingual movement of mandibular incisors and prevented the "concaving" of the lower face.

There were some study limitations. The study tried to represent the typical curve of Spee from a two-

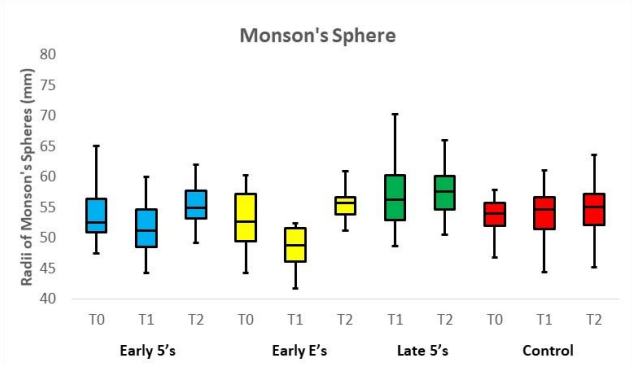


**Figure 2.** Comparison of Monson's spheres among study groups at T0, T1, and T2. The radii of Monson's spheres were similar at T0 for all groups. There was significant steepening in the early extraction groups at T1, followed by similar radii among all groups at T2.

dimensional linear measurement to that of a representative three-dimensional sphere. A potential reason for the decrease in the curve of Spee in all groups from T1 to T2 may have been due to the shortening of the dental arch following extraction and space closure. Another potential limitation was the effect of mandibular crowding on changes in occlusal curves or tooth angulation. Measurement of crowding could better assess its impact on the amount of dental change in occlusal curves or tipping. Despite the lack of power in the missing second premolar group, the results still provided some indication of what might be expected.

The advantages of second premolar serial extraction are spontaneous space closure with mesial first permanent molar drift with an unchanged mandibular incisor position.[19,21,22] The disadvantages are the need to upright the curve of Spee and curve of Wilson and to correct dental tipping during active fixed orthodontic treatment. Since the side effects were fully corrected by orthodontic treatment, future studies assessing treatment efficiency may help determine the clinical

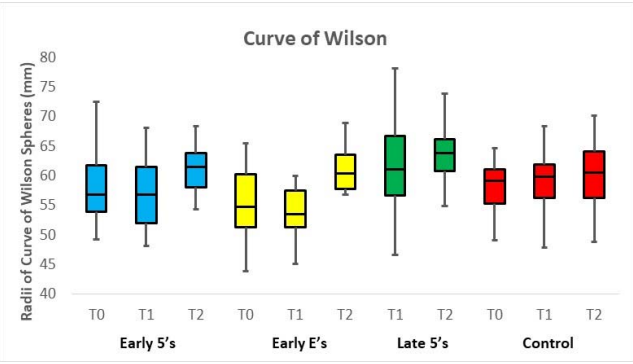


**Figure 3.** Comparison of curve of Wilson spheres among study groups at T0, T1, and T2. The radii of the curve of Wilson spheres were similar at T0 for all groups, with significant steepening in the early extraction groups at T1, followed by similar radii among all groups at T2.

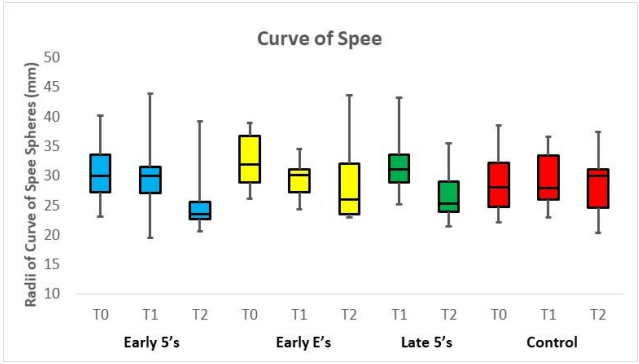


**Figure 4.** Comparison of curve of Spee spheres among study groups at T0, T1, and T2. The radii of the curve of Spee spheres were similar at T0 for all groups, with no significant changes in the early extraction groups at T1, followed by similar radii among all groups at T2 except for the radii of the early extraction of 5's group.

decision for serial extraction of second premolars, similar to O'Shaugnessy et al.[10]

## CONCLUSIONS

- Serial extraction of the mandibular second premolars produced steeper occlusal curves and significant tipping of the mandibular first molars, first premolars, and canines after extraction and physiologic drift.
- After serial extraction, the accentuated occlusal curves of Monson's sphere and the curve of Wilson and the tipping of teeth were fully corrected following comprehensive fixed orthodontic treatment.
- Serial extractions involving mandibular second premolars did not cause any significant mandibular incisor lingual uprighting following physiologic drift. There was no significant difference in mandibular incisor inclination between serial extraction of mandibular second premolars, late extraction of second premolars, and control groups after comprehensive fixed orthodontic treatment

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