Dental
Communication

Comparison Between first and Second Premolar Extraction: Effects on Soft Tissue Profile Changes After Orthodontic Treatment in Patients with Bimaxillary Protrusion

Nasser D. Alqahtani*
Paediatric Dentistry and Orthodontics Department, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

ABSTRACT

Orthodontic corrections involving tooth size arch length discrepancies (TSALD) often require the extraction of premolar teeth, to achieve the desired profile changes. General guidelines, suggest extraction of first premolars when the TSALD source area is primarily in the anterior portion of the arch. However, the basic indication for second premolar extraction is when there is moderate anterior crowding with no protrusion and the patient has good facial balance. Cephalometric radiographs of 60 adult BMP patients who underwent orthodontic retraction of anterior teeth following extraction of all first premolars or all second premolars reporting to a private dental center between January 2013 and January 2019 and fulfilling the inclusion criteria were included for the study. Analysis of the digital cephalometric radiographs was done using Dolphin Imaging® Software, Version 10.0 (Dolphin Imaging and Management Solutions, Chatsworth, California, USA). Paired comparison between pre-treatment and post-treatment cephalometric values, following 1st premolar and 2nd premolar extraction, were done using IBM SPSS Statistics Version 20. The statistical analysis of extracted data revealed that 1st premolar extraction treatment resulted in greatest change in upper and lower incisor inclination per unit change in upper or lower incisor retraction, as predicted through regression analysis. In the present study, the lower incisor retraction and proclination has proved to be a predictor of the need for second premolar extraction ($p< 0.05$). Hence the, decision to extract first or second premolar can be predicted on the pre-treatment position of the lower incisors and the desired amount of lower incisor tooth retraction.

KEY WORDS: ORTHODONTIC CORRECTIONS, CEPHALOMETRIC, PAIRED COMPARISON.

INTRODUCTION

The predominant reason to seek orthodontic treatment in patients with bimaxillary protrusion (BMP) is dental crowding and malalignment (Abdullah 2015). These malocclusions are commonly due to the discrepancies in tooth crown dimensions and the available space of the supporting alveolar arches (Abdullah 2015). In standard orthodontic protocols, extraction of premolars are advised to create space and enable correction of bimaxillary protrusion (Al-Anezi 2011). During orthodontic treatment involving the extraction of teeth, arch dimensional continue to change following active treatment (Ong and Woods 2001). Literature fails to provide a predicable guide to predicting the use of maxillary or mandibular extraction spaces (Aldosari et al., 2020).

Williams and Hosila (1976) showed varying amounts of molar and incisor movement during extraction space closure after first-premolar extraction cases (Keim et al., 2002). As against the conventional practice, extraction of second premolar is sometimes preferred to salvage first premolar when the second premolar has deep caries requiring root canal treatment or with poor prognosis. Once the extraction decision has been made there are several factors that influence how the teeth are aligned in the arches (Albarrak et al., 2019).

Majority of the practicing clinical practitioners advocate that BMP cases require premolar extractions for treatment (Aldosari et al., 2020). Further, it is estimated that one-

Article Information:*Corresponding Author: nasserdm@ksu.edu.sa
Received: 21/04/2021 Accepted after revision: 23/06/2021
Published: 30th June 2021 Pp- 811-821

Article DOI: http://dx.doi.org/10.21786/bbrc/14.2.55

third of all orthodontic patients have such a severe malocclusion that some pattern of premolar extraction is deemed necessary to resolve the problems and align the teeth (Proffit et al., 2013). Tooth size-arch length discrepancy (TSALD) is the most important factor necessitating the decision whether first- or second-premolars should be extracted in the maxilla and/or in the mandible (Correia et al., 2014). In addition, the extent of correction needed in the upper or lower anterior proclination to achieve the desirable profile changes is often considered a major determinant.

General guidelines suggest extraction of the first premolars when the TSALD source area is primarily in the anterior portion of the arch (Alqahtani et al., 2019). Removing the first premolars is the prescribed way to correct anterior crowding, excessive overjet and protrusion (Anthopoulou et al., 2014). This correction works by making space for the alignment of teeth or the retraction of canines and incisors. Extracting premolars close to the area of crowding is beneficial because of the minimal post extraction space that remains to be closed (Alqahtani et al., 2020). The use of premolar extractions for orthodontic treatment is still considered controversial (Akyalcin et al., 2011). Nevertheless, previous works have demonstrated that premolars are the most common teeth removed for orthodontic treatment (Sharma et al., 2014, Ong and Woods 2001). Conveniently located between the anterior and posterior segments, premolars would appear to be the obvious choice for correcting crowding and anterior-posterior discrepancies (Shirazi et al., 2016).

However, the basic indication for second premolar extraction is when there is moderate anterior crowding with no protrusion and the patient has good facial balance (Aljhani and Aldrees 2011). Some subjectivity of these guidelines is shown because de Castro (1974) describes this instance of "moderate" crowding as being when there is a TSALD of 5 mm or more, while Schoppe (1964) describes it as being a TSALD of 7.5 mm or less (Meyer et al. 2014). Other considerations for removing second premolars instead of first premolars include posterior crowding, anterior open bite, Class III correction, and facilitation of intentional anchorage slippage (Sandler et al., 2014). When second or third molars are crowded, ectopic, or impacted, they can be helped by increasing space in the posterior segments.

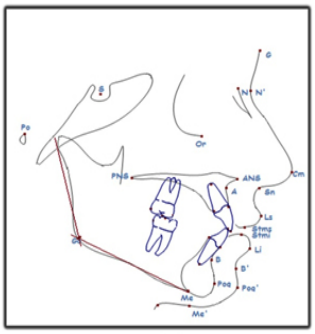
This space is created by extracting second premolars so that the first molar can be migrated mesially (Alqahtani et al. 2019). The dilemma is when the indication for extraction is for the 1st premolars but the 2nd premolars have poor prognosis due to carious lesion or large restoration, or the indication is for extraction of 2nd premolars but the 1st premolars have poor prognosis. Here comes the question of how much difference will it make on the facial profile or on incisors inclinations if extraction of 1st premolars or 2nd premolars will take place. In the present study, we compared the post orthodontic profile changes among patients who underwent first or second premolar extraction and establish the possible predictor variables for premolar extraction.

MATERIAL AND METHODS

Following ethical approval from the Institutional Review Board (CDRC Approval No. FR-0439 / IRB. No. E-18-3029), cephalometric radiographs of adult BMP patients who underwent orthodontic retraction of anterior teeth following extraction of all first premolars or all second premolars were included. The sampling frame included all patients reporting to a dental center between January 2013 and January 2019, and fulfilling the following inclusion criteria:

- Harmonious facial profile with an ANB (A point–Nasion–B point) angle of 3°± 2.3 and an SN-MP (Sella-Nasion to Mandibular plane) angle of 32°± 5.
- Class I molar relationship with an interincisal angle of 110.4° ± 6, overjet of 3 ± 1 mm, and overbite of 1.4 ± 1 mm (Aldrees and Shamlan 2010).
- Treated using fixed orthodontic appliance and availability of pre- and post-treatment cephalometric radiographs of adequate diagnostic quality.
- Absence of functional appliance therapy or orthognathic surgical procedures as a part of treatment.
- Absence of congenitally missing teeth (excluding third molars).
- No medical history of pharyngeal pathology and/or nasal obstruction, snoring, obstructive sleep apnea, adenoidectomy, or tonsillectomy.

Figure 1: Lateral cephalometric tracing dental and soft tissue profile measurements.



Hard Tissue Landmarks

S: *sella*, the center of the sella turcica.
N: *nasion*, the most anterior point of the frontonasal suture.
Po: *porion* (anatomic porion), the midpoint of the upper contour of the external auditory canal.
Or: *orbitale*, the lowest point on the inferior orbital margin.
Pog: *pogonion*, the most prominent point on the hard tissue contour of the chin.
ANS: *anterior nasal spine*, the tip of the anterior nasal spine of the palatal bone in the hard palate.
PNS: *posterior nasal spine*, the tip of the posterior nasal spine of the palatal bone in the hard palate.
Go: *gonion*, point on the curvature of the angle of the mandible, located by bisecting the angle formed by lines tangent to the posterior ramus and the inferior border of the mandible.
A: *point A*, the greatest concavity of the alveolar bone overlying the maxillary incisors.
B: *point B*, the point of greatest concavity of the alveolar bone overlying the mandibular incisors.

Soft Tissue Landmarks

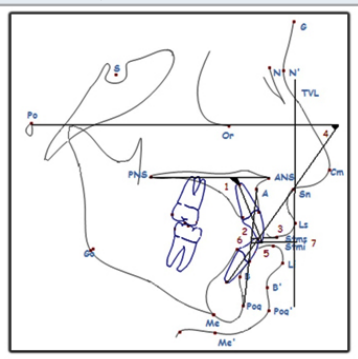
N': *Soft tissue nasion*, the deepest point of the concavity between the forehead and soft tissue contour of the nose.
Pog': *soft tissue pogonion*, the most prominent point on the soft tissue contour of chin.
G': *glabella*, the most prominent point of the soft tissue drape of the forehead, in midsagittal plane.
Cm: *columella*, the most anterior soft tissue point on the columella of the nose.
Sn: *subnasale*, the point where the upper lip meets the inferior border of the nose.
Me': *soft tissue menton*, the lowest point of the soft tissue chin contour.
Stms: *stomion superius*, the lowermost point on the vermilion of the upper lip.
Stmi: *stomion inferius*, the uppermost point on the vermilion border of the lower lip.
Ls: *labrale superius*, the most prominent point in the upper lip.
Li: *labrale inferius*, the most prominent point in the lower lip.
B': *soft tissue point B*, the point of greatest concavity on the contour of the lower between Li and Pg'.

Based on evidence from previously published data (Trisnawaty et al. 2013, Solem et al. 2013, Yasutomi et al. 2006), and assuming a statistical power of 80% with 95% confidence level, the sample size was estimated

to be 30 patients for group I (First premolar extracted) and 30 patients for group II (Second premolar extracted) Patient records identified using the inclusion criteria were assigned unique reference numbers by a blinded operator and were randomly included to the study using an online random number generator (RANDOM.ORG, Dublin, Ireland).

Pre- and post-treatment digital cephalometric radiographs of the study patients were collected for analysis. All the radiographs were obtained using a Planmeca Proline XC CEPH Digital X-Ray Unit (Planmeca OY, Helsinki, Finland) set at 80 kV with total filtration 2.5 mm Al and 1500 VA 50 Hz. Bias arising as a result of differing treatment methodologies was avoided by selecting records of patients treated by a single orthodontist with fixed edgewise (0.022" slot) mechanotherapy using maximum anchorage (Nance appliance) in the upper arch. Analysis of the digital cephalometric radiographs was done using Dolphin Imaging® Software, Version 10.0 (Dolphin Imaging and Management Solutions, Chatsworth, California, USA). The magnification probability was eliminated through calibration of the actual length of the ruler on the head positioner with simultaneous identification of the two ends of the rulers and the anatomical landmarks (Fig. 1 and Fig. 2).

Figure 2: Lateral cephalometric tracing showing the dentoalveolar and angular measurements



Dentoalveolar Measurements

1. **Upper incisor retroclination* (U1-PP)(°):** the angular difference in the pre- and post-treatment inclination of the upper incisors.
2. **Upper incisor retraction (U1-APog) (mm):** the linear difference in the pre- and post-treatment position of upper incisors in relation to A-Pog (point A to pogonion) line.
3. **Upper incisor retraction (U1-TVL) (mm):** the linear difference in the pre- and post-treatment position of the upper incisors in relation to TVL (true vertical line).
4. **Lower incisor retroclination* (LI-FMIA)(°):** the angular difference in the pre- and post-treatment inclination of the lower incisors.
5. **Lower incisor retraction (LI-APog) (mm):** the linear difference in the pre- and post-treatment position of the upper incisors in relation to the A-Pog line.
6. **Lower incisor retraction (LI-TVL) (mm):** the linear difference in the pre- and post-treatment position of the upper incisors in relation to TVL.

** Angular measurements which became more obtuse during following treatment will have a positive value.*

To assure examiner reliability, samples of 10 randomly selected cephalometric radiographs were traced and measured by the same investigator, who would eventually trace all the radiographs. Identification of the cephalometric landmarks and measurement of the variables were carried out in two different sessions separated by a period of two weeks. In order to ascertain the test-retest reliability, the mean values of the variables obtained during the two sessions were compared using paired t-tests. Furthermore, Pearson's correlation was done to evaluate the relationship between the first and second readings and negligible error was assumed for a minimum correlation coefficient (Pearson's r) of 0.85.

Pre- and post-treatment cephalometric data were analyzed using the SPSS PC+ version 21.0 for Windows, (IBM SPSS Statistics, Armonk, NY, USA). Descriptive statistics (mean and standard deviation) were calculated for all the quantitative outcome variables (dental and airway). The pre- and post-test mean values of the quantitative variables were compared using a student's paired t-test, with the resulting difference being the variable of interest. To quantify the correlation between the difference in the pre- and post-treatment values of the variables, Pearson's correlation was used. Linear regression analysis was used to identify the independent predictor variables (changes in dental measurements) for the dependent outcome variables (changes in pharyngeal airway measurements) of interest. The statistical significance of the results was fixed at a p-value < 5% ($\alpha = 0.05$) and at 95% confidence interval.

Statistical analysis: All cephalometric data were exported to a spreadsheet software (MS Excel 2016, Microsoft, Redmond, WA, USA). Data were grouped into dental and soft-tissue related cephalometric variables and duplicates were identified and removed. Descriptive analysis and statistical comparisons assuming a 95% level of significance ($p < 0.05$) were performed using statistical package software (IBM SPSS Statistics Version 20, IBM, Armonk, NY, USA). Shapiro-Wilk test for normality of sample distribution was done for all variables and a p-value less than 0.05 was indicative of non-parametric distribution.

Paired comparison between pre-treatment and post-treatment cephalometric values, following 1st premolar and 2nd premolar extraction, were done using paired samples t-test (normal distribution) and Wilcoxon signed rank test (non-parametric distribution). Magnitude of change following treatment (difference between pre and post-treatment values) by 1st premolar or 2nd premolar extraction was compared using independent samples t-test (normal distribution) and Mann-Whitney-U test (non-parametric distribution). Pearson's correlation based on post-orthodontic treatment change in cephalometric measurements was also performed.

RESULTS AND DISCUSSION

Since time immemorial, practitioners have often compared the efficacy of orthodontic treatment between extraction or non-extraction cases (Keim et al. 2002). However, current day literature analyzes the preferential extraction of first or the second premolar. In our retrospective study we aimed to assess the possible difference in the dental and soft tissue profile changes between the two treatment groups. Premolar extraction is preferred on the basis of its favorable position between the anterior and posterior teeth especially when the focus is on the correction of crowding and anteroposterior discrepancies (Proffit et al., 2006).

Table 1. Normality of sample distribution tested using Shapiro-Wilk test, showing p-values for each variable. A p-value less than 0.05 indicates non-normal distribution.

	1st Premolar Extraction (df = 25)		2nd Premolar Extraction (df = 29)		Pre - Post Treatment Change	
Cephalometric Variables	Pre-Treatment	Post-Treatment	Pre-Treatment	Post-Treatment	1st Premolar Extraction	2nd Premolar Extraction
Dental Variables						
Interincisal Angle (UI-LI) (Deg)	0.759	0.910	0.763	0.242	0.709	0.171
Overbite (mm)	0.239	0.877	0.383	0.995	0.860	0.906
Overjet (mm)	0.974	0.124	0.203	0.869	0.154	0.344
Upper Incisor Protrusion (UI-APog) (mm)	0.152	0.131	0.349	0.519	0.830	0.053
Upper Incisor Inclination (UI-APog) (Deg)	0.215	0.903	0.530	0.385	0.229	0.112
Lower Incisor Protrusion (LI-APog) (mm)	0.433	0.028	0.951	0.012	0.368	0.952
Lower Incisor Inclination (LI-APog) (Deg)	0.743	0.882	0.228	0.643	0.225	0.806
IMPA (LI-MP) (Deg)	0.553	0.067	0.705	0.008	0.398	0.135
FMIA (LI-FH) (Deg)	0.338	0.769	0.291	0.769	0.327	0.934
UI - FH (Deg)	0.028	0.543	0.464	0.235	0.808	0.166
FMA (MP-FH) (Deg)	0.113	0.481	0.501	0.916	0.121	0.208
UI - Occlusal Plane (Deg)	0.289	0.416	0.177	0.283	0.014	0.818
UI - Nasion Perpendicular (Deg)	0.028	0.543	0.464	0.235	0.808	0.166
LI - Occlusal Plane (Deg)	0.141	0.139	0.470	0.655	0.373	0.270
LI - SN (Deg)	0.950	0.011	0.243	0.460	0.394	0.970
LI - GoGn (Deg)	0.278	0.165	0.727	0.005	0.185	0.049
UI - NA (mm)	0.060	0.897	0.587	0.557	0.845	0.162
UI - NA (Deg)	0.084	0.652	0.227	0.114	0.511	0.061
LI - NB (mm)	0.286	0.156	0.173	0.204	0.053	0.636
LI - NB (Deg)	0.923	0.636	0.598	0.506	0.795	0.550
Soft-tissue Variables						
Upper Lip Length (Sn – St sup.) (mm)	0.098	0.139	0.668	0.943	0.954	0.494
Lower Lip Length (St inf. - Me) (mm)	0.932	0.141	0.836	0.630	0.116	0.953
Interlabial Gap (St sup. – St inf.) (mm)	0.045	0.000	0.084	0.229	0.056	0.165
Upper Lip Thickness @ A Point (mm)	0.372	0.082	0.249	0.000	0.943	0.055
Upper Lip Thickness @ Ver. Border (mm)	0.959	0.293	0.645	0.429	0.618	0.066
Upper Lip to E-Plane (mm)	0.498	0.178	0.874	0.217	0.893	0.095
Lower Lip to E-Plane (mm)	0.529	0.302	0.326	0.076	0.775	0.007
Superior Sulcus Depth (mm)	0.385	0.484	0.837	0.052	0.934	0.140
Subnasale to H-Line (mm)	0.543	0.879	0.909	0.054	0.752	0.683
Lower Lip to H-Line (mm)	0.332	0.525	0.613	0.992	0.593	0.047
Inferior Sulcus to H-Line (mm)	0.619	0.995	0.551	0.692	0.550	0.954
Soft-tissue Facial Angle (FH-N'Pog') (Deg)	0.143	0.065	0.420	0.990	0.234	0.059
Convexity (A-NPog) (mm)	0.170	0.391	0.777	0.975	0.071	0.897
Convexity (NA-APog) (Deg)	0.305	0.502	0.467	0.681	0.072	0.667

UI – Upper incisor; LI – Lower incisor; APog – Point A-Pogonion line; IMPA – Incisor mandibular plane angle; MP – Mandibular plane; FMIA – Frankfort mandibular incisal angle;
FH – Frankfort horizontal; FMA – Frankfort mandibular angle; SN – Sella-Nasion line; GoGn – Gonion-Gnathion line; NA – Nasion-Point A line; NB – Nasion-Point B line; Sn – Subnasale; St sup. – Stomion superior; St inf. – Stomion inferior; Ver. Border – Vertical border; NPog – Nasion-Pogonion line; N'Pog' – Soft-tissue Nasion-Soft-tissue Pogonion line

In general, extraction of first premolars is advised when the conditions like anterior crowding, excessive overjet and severe protrusion of teeth prevail. In the other hand, clinical scenarios with mild anterior crowding, posterior crowding or an anticipated loss of molar anchorage is needed then extraction of 2nd premolars is needed (Alqahtani et al., 2020). Out of the 60 patients enrolled in the study, a total of 25 patients completed orthodontic treatment with 1st premolar extraction and 29 patients completed treatment with 2nd premolar extraction. Pre- and post-treatment cephalometric data of all the patients who completed treatment were available in the form of digitized patient records. The pre-treatment, post-treatment and magnitude of change data were predominantly normally distributed for most of the variables (Table 1).

Table 2. Paired samples comparison (paired t-test) of pre-treatment and post-treatment values for dental and soft-tissue cephalometric variables, in patients with 1st premolar extraction orthodontic treatment. (n = 25)

Cephalometric Variables	Pre - Treatment		Post-Treatment		Mean Difference	Significance (p-value)
	Mean	S.D.	Mean	S.D.		
Dental Variables						
Interincisal Angle (UI-LI) (Deg)	108.360	6.753	120.250	6.205	-11.888	0.000
Overbite (mm)	1.120	1.793	0.896	1.184	0.224	0.424
Overjet (mm)	4.316	1.419	3.424	0.877	0.892	0.014
Upper Incisor Protrusion (UI-APog) (mm)	10.300	1.946	6.460	2.086	3.840	0.000
Upper Incisor Inclination (UI-APog) (Deg)	39.132	5.110	31.316	4.057	7.816	0.000
Lower Incisor Protrusion (LI-APog) (mm)*	5.964	2.127	3.080	2.060	2.884	0.000
Lower Incisor Inclination (LI-APog) (Deg)	32.520	4.700	28.420	4.335	4.100	0.001
IMPA (LI-MP) (Deg)	101.220	6.406	96.504	6.151	4.716	0.000
FMIA (LI-FH) (Deg)	45.892	6.377	49.712	5.341	-3.820	0.001
UI - FH (Deg)*	117.520	6.172	109.460	5.732	8.060	0.000
FMA (MP-FH) (Deg)	32.892	7.252	33.788	5.531	-0.896	0.252
UI - Occlusal Plane (Deg)	128.960	4.434	124.130	4.966	4.824	0.001
UI - Nasion Perpendicular (Deg)*	27.520	6.172	19.460	5.732	8.060	0.000
LI - Occlusal Plane (Deg)	57.328	5.283	64.388	4.192	-7.060	0.000
LI - SN (Deg)*	39.332	5.735	44.272	5.755	-4.940	0.000
LI - GoGn (Deg)	103.980	6.368	99.456	5.825	4.520	0.000
UI - NA (mm)	6.576	3.301	3.052	2.466	3.524	0.000
UI - NA (Deg)	28.920	7.209	22.192	6.326	6.728	0.000
LI - NB (mm)	8.500	2.016	6.008	2.091	2.492	0.000
LI - NB (Deg)	38.040	5.037	32.940	4.966	5.100	0.000
Soft-tissue Variables						
Upper Lip Length (Sn – St sup.) (mm)	21.384	2.586	20.592	2.504	0.792	0.021
Lower Lip Length (St inf. - Me) (mm)	37.948	3.523	38.956	3.593	-1.008	0.103
Interlabial Gap (St sup. – St inf.) (mm)*	7.060	3.391	3.304	1.315	3.756	0.000
Upper Lip Thickness @ A Point (mm)	14.228	2.402	13.636	2.046	0.592	0.258
Upper Lip Thickness @ Ver. Border (mm)	10.500	1.672	10.764	1.631	-0.264	0.449
Upper Lip to E-Plane (mm)	-0.536	2.200	-2.464	2.300	1.928	0.000
Lower Lip to E-Plane (mm)	2.684	3.086	-0.280	2.679	2.964	0.000
Superior Sulcus Depth (mm)	2.876	1.436	1.252	1.352	1.624	0.000
Subnasale to H-Line (mm)	7.148	2.045	5.188	2.307	1.960	0.000
Lower Lip to H-Line (mm)	3.032	2.140	1.344	1.467	1.688	0.000
Inferior Sulcus to H-Line (mm)	3.524	1.566	3.444	1.522	0.080	0.752
Soft-tissue Facial Angle (FH-N'Pog') (Deg)	86.712	4.340	85.700	3.366	1.012	0.138
Convexity (A-NPog) (mm)	4.584	3.038	4.244	2.530	0.340	0.430
Convexity (NA-APog) (Deg)	10.200	6.722	9.136	5.329	1.064	0.284

*Non-parametric paired comparison using "Wilcoxon signed rank test".
UI – Upper incisor; LI – Lower incisor; APog – Point A-Pogonion line; IMPA – Incisor mandibular plane angle; MP – Mandibular plane; FMIA – Frankfort mandibular incisal angle; FH – Frankfort horizontal; FMA – Frankfort mandibular angle; SN – Sella-Nasion line; GoGn – Gonion-Gnathion line; NA – Nasion-Point A line; NB – Nasion-Point B line; Sn – Subnasale; St sup. – Stomion superior; St inf. – Stomion inferior; Ver. Border – Vertical border; NPog – Nasion-Pogonion line; N'Pog' – Soft-tissue Nasion-Soft-tissue Pogonion line

Table 3. Paired samples comparison (paired t-test) of pre-treatment and post-treatment values for dental and soft-tissue cephalometric variables, in patients with 2nd premolar extraction orthodontic treatment. (n = 29)

Cephalometric Variables	Pre - Treatment		Post-Treatment		Mean Difference	Significance (p-value)
	Mean	S.D.	Mean	S.D.		
Dental Variables						
Interincisal Angle (UI-LI) (Deg)	109.340	5.872	122.100	7.527	-12.759	0.000
Overbite (mm)	0.997	1.651	0.841	0.939	0.155	0.553
Overjet (mm)	3.986	1.439	3.259	0.921	0.728	0.030
Upper Incisor Protrusion (UI-APog) (mm)	10.224	1.873	6.335	1.639	3.890	0.000
Upper Incisor Inclination (UI-APog) (Deg)	38.638	4.443	30.783	4.868	7.855	0.000
Lower Incisor Protrusion (LI-APog) (mm)*	6.228	2.016	3.124	1.928	3.104	0.000
Lower Incisor Inclination (LI-APog) (Deg)	32.031	4.660	27.110	4.523	4.921	0.000
IMPA (LI-MP) (Deg)*	100.540	6.996	94.928	6.359	5.612	0.000
FMIA (LI-FH) (Deg)	47.028	5.463	51.279	5.407	-4.252	0.000
UI - FH (Deg)	117.680	5.146	109.190	6.443	8.493	0.000
FMA (MP-FH) (Deg)	32.445	5.477	33.793	5.351	-1.348	0.009
UI - Occlusal Plane (Deg)	129.120	3.801	123.770	4.985	5.348	0.000
UI - Nasion Perpendicular (Deg)	27.679	5.146	19.186	6.443	8.493	0.000
LI - Occlusal Plane (Deg)	58.448	4.968	65.872	4.666	-7.424	0.000
LI - SN (Deg)	39.517	5.118	45.314	5.670	-5.797	0.000
LI - GoGn (Deg)*	103.590	6.895	98.059	6.250	5.531	0.000
UI - NA (mm)	6.545	2.828	2.990	2.465	3.555	0.000
UI - NA (Deg)	28.593	6.713	21.797	6.517	6.797	0.000
LI - NB (mm)	8.731	1.951	5.779	1.706	2.952	0.000
LI - NB (Deg)	37.514	4.495	31.735	5.239	5.779	0.000
Soft-tissue Variables						
Upper Lip Length (Sn – St sup.) (mm)	21.972	2.697	20.928	2.693	1.045	0.004
Lower Lip Length (St inf. - Me) (mm)	37.683	4.197	38.872	4.291	-1.190	0.019
InterLabial Gap (St sup. – St inf.) (mm)	7.603	3.584	3.555	0.767	4.048	0.000
Upper Lip Thickness @ A Point (mm)*	13.886	1.722	13.517	1.928	0.369	0.179
Upper Lip Thickness @ Ver. Border (mm)	10.552	1.438	10.628	1.473	-0.076	0.810
Upper Lip to E-Plane (mm)	-0.483	2.247	-2.717	2.411	2.234	0.000
Lower Lip to E-Plane (mm)	3.017	2.946	-0.107	2.467	3.124	0.000
Superior Sulcus Depth (mm)	3.028	1.565	0.935	1.478	2.093	0.000
Subnasale to H-Line (mm)	7.597	2.120	5.331	2.384	2.266	0.000
Lower Lip to H-Line (mm)	3.366	1.993	1.735	1.329	1.631	0.000
Inferior Sulcus to H-Line (mm)	3.083	1.454	3.179	1.401	-0.097	0.655
Soft-tissue Facial Angle (FH-N'Pog') (Deg)	87.100	3.357	85.638	3.361	1.462	0.000
Convexity (A-NPog) (mm)	4.541	2.787	4.176	2.706	0.366	0.245
Convexity (NA-APog) (Deg)	10.035	6.140	8.990	5.709	1.045	0.147

*Non-parametric paired comparison using "Wilcoxon signed rank test".
UI – Upper incisor; LI – Lower incisor; APog – Point A-Pogonion line; IMPA – Incisor mandibular plane angle; MP – Mandibular plane; FMIA – Frankfort mandibular incisal angle; FH – Frankfort horizontal; FMA – Frankfort mandibular angle; SN – Sella-Nasion line; GoGn – Gonion-Gnathion line; NA – Nasion-Point A line; NB – Nasion-Point B line; Sn – Subnasale; St sup. – Stomion superior; St inf. – Stomion inferior; Ver. Border – Vertical border; NPog – Nasion-Pogonion line; N'Pog' – Soft-tissue Nasion-Soft-tissue Pogonion line.

Literature reveals that clinical scenarios where the TSALDs and anterior protrusion are the treatment objective, first premolar extraction is considered ideal (Qamaruddin et al., 2018). In addition, dental and skeletal anteroposterior discrepancies is commonly treated with extraction of premolars (Sheerah et al., 2019). However, there is lack of advocacy and standard protocol regarding the preference between first and second premolar extraction (Akyalcin et al., 2011). Varying patterns of extraction are adopted with the primary aim of creating space for desired tooth movement (Aljhani and Zawawi 2010). The current study evaluated the profile changes through pre and post treatment occlusal records of two treatment groups with bimaxillary protrusion treated with first and second premolar extraction to show how much changes in the incisors inclination between the

groups and how much effect on the facial profile. In future perspective this assessment can provide a reference guide for clinicians towards expected treatment outcomes based on the determined teeth will be extracted.

Table 4. Independent samples comparison (independent t-test) of magnitude of post-treatment change for dental and soft-tissue cephalometric variables, following 1st premolar and 2nd premolar extraction orthodontic treatment.

Cephalometric Variables	Post Treatment Change				Mean Difference	Significance (p-value)
	Pre - Treatment		Post-Treatment			
	Mean	S.D.	Mean	S.D.		
Dental Variables						
Interincisal Angle (UI-LI) (Deg)	-11.888	8.366	-12.759	9.189	0.871	0.719
Overbite (mm)	0.224	1.376	0.155	1.390	0.069	0.856
Overjet (mm)	0.892	1.677	0.728	1.714	0.164	0.724
Upper Incisor Protrusion (UI-APog) (mm)	3.840	1.876	3.890	1.464	-0.050	0.913
Upper Incisor Inclination (UI-APog) (Deg)	7.816	4.882	7.855	4.948	-0.039	0.977
Lower Incisor Protrusion (LI-APog) (mm)	2.884	2.078	3.103	1.844	-0.219	0.683
Lower Incisor Inclination (LI-APog) (Deg)	4.100	5.343	4.921	5.494	-0.821	0.582
IMPA (LI-MP) (Deg)	4.716	4.292	5.614	4.756	-0.898	0.473
FMIA (LI-FH) (Deg)	-3.820	5.010	-4.252	5.209	0.432	0.759
UI - FH (Deg)	8.060	6.683	8.493	5.828	-0.433	0.800
FMA (MP-FH) (Deg)	-0.896	3.815	-1.348	2.598	0.452	0.609
UI - Occlusal Plane (Deg)*	4.824	6.327	5.348	5.799	-0.524	0.822
UI - Nasion Perpendicular (Deg)	8.060	6.683	8.493	5.828	-0.433	0.800
LI - Occlusal Plane (Deg)	-7.060	5.060	-7.424	5.423	0.364	0.801
LI - SN (Deg)	-4.940	4.440	-5.797	4.861	0.857	0.505
LI - GoGn (Deg)*	4.520	4.372	5.528	4.556	-1.008	0.828
UI - NA (mm)	3.524	3.201	3.555	2.472	-0.031	0.968
UI - NA (Deg)	6.728	7.407	6.797	6.205	-0.069	0.971
LI - NB (mm)	2.492	1.795	2.952	1.776	-0.460	0.350
LI - NB (Deg)	5.100	4.139	5.779	4.832	-0.679	0.585
Soft-tissue Variables						
Upper Lip Length (Sn – St sup.) (mm)	0.792	1.605	1.045	1.773	-0.253	0.588
Lower Lip Length (St inf. - Me) (mm)	-1.008	2.970	-1.190	2.566	0.182	0.810
InterLabial Gap (St sup. – St inf.) (mm)	3.756	3.219	4.048	3.463	-0.292	0.751
Upper Lip Thickness @ A Point (mm)	0.592	2.555	0.369	2.019	0.223	0.722
Upper Lip Thickness @ Ver. Border (mm)	-0.264	1.713	-0.076	1.680	-0.188	0.686
Upper Lip to E-Plane (mm)	1.928	1.237	2.235	1.132	-0.306	0.346
Lower Lip to E-Plane (mm)	2.964	1.752	3.124	1.634	-0.160	0.730
Superior Sulcus Depth (mm)	1.624	1.399	2.093	1.329	-0.469	0.213
Subnasale to H-Line (mm)	1.960	1.592	2.266	1.339	-0.306	0.447
Lower Lip to H-Line (mm)	1.688	1.336	1.631	1.285	0.057	0.874
Inferior Sulcus to H-Line (mm)	0.080	1.251	-0.097	1.152	0.177	0.592
Soft-tissue Facial Angle (FH-N'Pog') (Deg)	1.012	3.294	1.462	1.965	-0.450	0.538
Convexity (A-NPog) (mm)	0.340	2.117	0.366	1.656	-0.026	0.961
Convexity (NA-APog) (Deg)	1.064	4.859	1.045	3.774	0.019	0.987

*Non-parametric comparison using "Mann-Whitney U test".

UI – Upper incisor; LI – Lower incisor; APog – Point A-Pogonion line; IMPA – Incisor mandibular plane angle; MP – Mandibular plane; FMIA – Frankfort mandibular incisal angle; FH – Frankfort horizontal; FMA – Frankfort mandibular angle; SN – Sella-Nasion line; GoGn – Gonion-Gnathion line; NA – Nasion-Point A line; NB – Nasion-Point B line; Sn – Subnasale; St sup. – Stomion superior; St inf. – Stomion inferior; Ver. Border – Vertical border; NPog – Nasion-Pogonion line; N'Pog' – Soft-tissue Nasion-Soft-tissue Pogonion line

Paired samples comparison of cephalometric variables before and after 1st premolar extraction treatment, showed significant change for almost all the dental and soft-tissue variables, except overbite, FMA, lower lip length, upper lip thickness (both at A-Point and Vertical border), inferior sulcus to H-line distance, soft tissue facial angle and convexity (both linear and angular) (Table 2). Earlier researches revealed that

there were significant changes in arch width and depth with extraction orthodontics (Bindayel 2019). Among the predictive variables the most commonly assessed in previous literature like Upper Incisor Protrusion (UI-APog), Upper Incisor Inclination (UI-APog), Lower Incisor Protrusion (LI-APog), Lower Incisor Inclination (LI-APog), IMPA (LI-MP) and FMIA (LI-FH) was tabulated for evaluation (Aljhani and Aldrees 2011, Anthopoulou et al., 2014). Further, when comparing the first and second premolar extractions, incisor retraction in first premolar extraction group was more significant (Aldrees et al., 2015, Aljhani and Zawawi 2010).

Table 5. Correlation based on post-orthodontic treatment change in 1st premolar Extraction group

Predictor Variable	Dependent Variables	r	P- value	r^2	Predicted change in dependent variable per unit change in predictor variable
Upper Incisor Retraction (UI - Nasion Perp.) (Deg)	Upper Incisor Protrusion (UI-APog) (mm)	0.567	0.003	29.2%	2.715 mm
	Upper Incisor Inclination (UI-APog) (Deg)	0.811	<0.001	64.3%	3.633 Deg
	Lower Incisor Protrusion (LI-APog) (mm)	0.375	0.065*	-	-
	Lower Incisor Inclination (LI-APog) (Deg)	0.523	0.007	24.2%	1.150 Deg
Lower Incisor Retraction (LI – GoGn) (Deg)	Upper Incisor Protrusion (UI-APog) (mm)	0.395	0.051*	-	-
	Upper Incisor Inclination (UI-APog) (Deg)	0.224	0.281*	-	-
	Lower Incisor Protrusion (LI-APog) (mm)	0.578	0.002	30.6%	1.916 mm
	Lower Incisor Inclination (LI-APog) (Deg)	0.743	<0.001	53.2%	0.905 Deg

*No significant correlation between predictor and dependent variable

Table 6. Correlation based on post-orthodontic treatment change 2nd Premolar Extraction Group

Predictor Variable	Dependent Variables	r	P- value	r^2	Predicted change in dependent variable per unit change in predictor variable
Upper Incisor Retraction (UI - Nasion Perp.) (Deg)	Upper Incisor Protrusion (UI-APog) (mm)	0.584	0.001	31.7%	2.790 mm
	Upper Incisor Inclination (UI-APog) (Deg)	0.850	<0.001	71.1%	1.450 Deg
	Lower Incisor Protrusion (LI-APog) (mm)	0.485	0.008	20.7%	1.954 mm
	Lower Incisor Inclination (LI-APog) (Deg)	0.655	<0.001	40.8%	0.296 Deg
Lower Incisor Retraction (LI – GoGn) (Deg)	Upper Incisor Protrusion (UI-APog) (mm)	0.398	0.032	12.7%	3.311 mm
	Upper Incisor Inclination (UI-APog) (Deg)	0.606	<0.001	34.3%	4.877 Deg
	Lower Incisor Protrusion (LI-APog) (mm)	0.618	<0.001	35.9%	1.971 mm
	Lower Incisor Inclination (LI-APog) (Deg)	0.871	<0.001	75.1%	0.165 Deg

In agreement, in the present study also 0.4 mm more incisor retraction was evident in first premolar extraction group as against the second premolar treatment group. Further, 2nd premolar extraction treatment resulted in significant post-treatment change for most cephalometric variables except, overbite, upper lip thickness (both at A-Point and Vertical border), inferior sulcus to H-line distance, and convexity (both linear and angular) (Table 3). Based on paired comparison of cephalometric variables, the outcomes of 1st and 2nd premolar extraction orthodontic treatment showed statistically significant post-treatment change for the dental variables like Upper Incisor Protrusion (UI-APog), Upper Incisor Inclination (UI-APog), Lower Incisor Protrusion (LI-APog) and Lower Incisor Inclination (LI-APog). In both the study groups soft tissue variables like Interlabial gap, upper lip and lower lip length to E-plane were also shown to change significantly. However, FMA angle and soft tissue angle were significantly altered only in the 2nd premolar group.

On the contrary, upper lip thickness at the level of vertical border and at point A, were more pronounced in the 1st premolar group. Comparing the change in convexity, minimal change was evidenced in both groups which was statistically insignificant. This was further confirmed by the results of the independent samples comparison test. This was in agreement with earlier study by Tae-Kyung Kim et al., who found insignificant change in facial vertical dimension in both groups. He proposed

that decision on extraction of 1st and 2nd premolar could be rather based on the need for incisor retraction, area of crowding, dimension of teeth and conditions of the premolar teeth aimed for extraction (Kim et al., 2005).

Statistically comparing the magnitude of change following 1st and 2nd premolar treatment showed no significant difference in the amount of post-treatment change between the two groups for any dental or soft-tissue cephalometric variables (Table 4). In orthodontic corrections of class II discrepancies, greater incisor retraction is generally expected in the upper arch due to the enhanced retraction of the anterior segment to reduce the overjet and less retraction of lower anterior teeth but more protraction in lower posterior teeth to achieve Class I molar relationship (Aljhani and Zawawi 2010). The present study illustrated (Table 4) compared all the dental and soft tissue variables of profile changes between the first and second premolar groups. Although post treatment data comparisons should differences between 1st premolar and 2nd premolars groups, these differences are statistically insignificant. In both the 1st and 2nd premolar groups upper incisors were retracted by an average of 3.8 mm, however insignificant statistical (p=0.913) comparison was observed.

Nevertheless, lower incisors retraction for the 1st premolar group was 0.2 mm less than the 2nd premolar group. This difference however proved statistically insignificant (p=0.683). This is in concurrence with the research outcomes of Ong and Woods (Ong and Woods 2001). In another study comparing the first and second premolar extraction, incisor crowding was found to be definitively predictive of incisor retraction (Elnour et al., 2016). This is attributed to the closure of both inter-dental spacing and premolar extraction space by the retraction of the protrusive incisor.

Pearson's correlation based on post-orthodontic treatment change in cephalometric measurements, revealed significant positive correlation between several cephalometric variables, in both the 1st premolar and 2nd premolar extraction groups. Highly significant positive correlation was observed between upper and lower incisor retraction and upper and lower incisor protrusion and inclination, respectively, in both 1st premolar and 2nd premolar extraction groups (Table 5 and Table 6). This was further confirmed through linear regression, which indicated statistically significant predictability (Table 5 and Table 6).

In both, the 1st premolar and 2nd premolar extraction groups, upper incisor retraction showed greater predictability of changes in upper incisor inclination (1st premolar "r^2" – 64.3%; 2nd premolar "r^2"– 71.1%), than changes in upper incisor protrusion (1st premolar "r^2" – 29.2%; 2nd premolar "r^2" – 31.7%). Similarly, greater predictability of changes in lower incisor inclination (1st premolar "r^2" – 53.2%; 2nd premolar "r^2"– 75.1%) than lower incisor protrusion (1st premolar "r^2" – 30.6%; 2nd premolar "r^2" – 35.9%), were observed with lower incisor retraction. Interestingly, changes in upper and lower incisor protrusion in response to upper and lower incisor retraction, respectively, were almost similar after 1st and 2nd premolar extraction orthodontic treatment (Figure 3 and Figure 4).

Figure 3: Change in upper incisor protrusion in response to change in upper incisor retraction

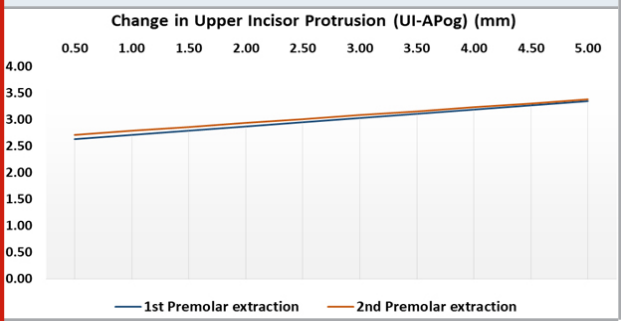


Figure 4: Change in upper incisor inclination in response to change in upper incisor retraction

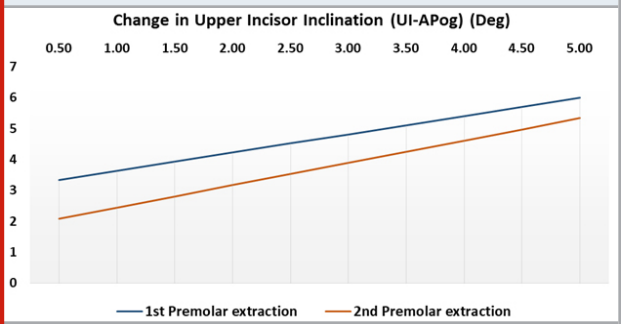
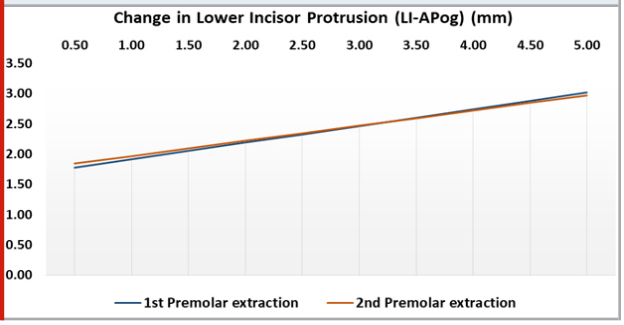


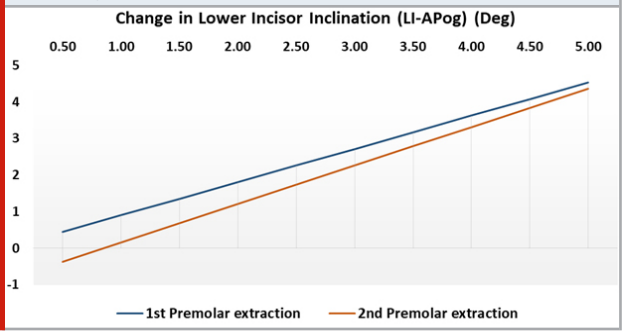
Figure 5: Change in lower incisor protrusion in response to change in lower incisor retraction



On the contrary, 1st premolar extraction treatment resulted in greatest change in upper and lower incisor inclination per unit change in upper or lower incisor retraction, as predicted through regression analysis (Figure 5 and Figure 6). Based on the present study data, unit change in the upper incisor retraction measured angularly by the "UI – Nasion perpendicular angle", predicted a 3.63 degree change in upper incisor inclination (UI – APog angle) following 1st premolar extraction orthodontic treatment (r^2– 64.3%). While similar unit change in "UI – Nasion perpendicular angle" after 2nd premolar extraction treatment, predicted only 1.45 degree change in upper incisor inclination (UI – APog angle) (r^2 – 71.1%). Similarly, unit change in

lower incisor retraction measured angularly based on "LI – Gonion/Gnathion angle" predicted a greater lower incisor inclination following 1st premolar extraction (0.91 degree; r^2 – 53.2%), than after 2nd premolar extraction (0.17 degree; r2 – 75.1%) (Tables 5 and 6).

Figure 6: Change in lower incisor inclination in response to change in lower incisor retraction



These findings imply that the decision to extract first or second premolar should be based on the pre-treatment position of the upper and lower incisors and the desired amount of upper and lower incisor inclination required post-treatment. Therefore, in a clinical scenario demanding greater amount of incisor retroclination, extraction of the 1st premolars could be considered. Our findings are in accordance with the study of Ziad et al, 2018 wherein lower incisor retraction was advocated as a predictor of premolar extraction(Omar et al. 2018). In comparison, Nance et al proposed soft tissue profile change of the lips to be a more appropriate predictor of need for first premolar extraction (Ahmad et al. 2018).

CONCLUSION

Dental malocclusions can involve arch-size tooth-size discrepancies and are often managed by premolar extraction as a preferred line of treatment. The present study compared the amounts of dental and soft tissue changes after orthodontic treatment in two common extraction patterns of 1st and 2nd premolar. There was no statistical significant difference between the amount of upper and lower incisors retraction and retroclination between the 1st premolars and 2nd premolars groups. Also, there was no statistical significant difference at the soft tissue changes between the 1st premolars and 2nd premolars groups. However, there was a positive, linear relationship observed between the amount of change in the position (retraction) of the maxillary incisor teeth and the amount of change (retrusion) in profile First premolar extraction is advised when upper incisor retraction in BMP is recommended. The results of the present study need to be considered based on the geographical limitations of the study populations. However, future studies in differing populations should be considered prior to clinical extrapolation of the findings.

REFERENCES

Abdullah, W. A. (2015) Changes in quality of life after orthognathic surgery in Saudi patients The Saudi Dental Journal, 27(3), 161-164.

Ahmad, A. J., Parekh, S. and Ashley, P. F. (2018) Methods of space maintenance for premature loss of a primary molar: a review, European Archives of Paediatric Dentistry, 19(5), 311-320.

Akyalcin, S., Erdinc, A. E., Dincer, B. and Nanda, R. S. (2011). Do long-term changes in relative maxillary arch width affect buccal-corridor ratios in extraction and nonextraction treatment? American Journal of Orthodontics and Dentofacial Orthopedics, 139(3), 356-361.

Al-Anezi, S. A. (2011). Class II malocclusion treatment using combined Twin Block and fixed orthodontic appliances – A case report', The Saudi Dental Journal, 23(1), 43-51.

Albarrak, A. A., AlRumaih, H. S., Al-Humaidan, A., Al-Thobity, A. M. and Alshahrani, F. A. (2019) 'Multidisciplinary approach with predictable esthetics: A case report', The Saudi Dental Journal, 31, S89-S95.

Aldosari, M. A., Alqasir, A. M., Alqahtani, N. D., Almosa, N. A., Almoammar, K. A. and Albarakati, S. F. (2020. Evaluation of the airway space changes after extraction of four second premolars and orthodontic space closure in adult female patients with bimaxillary protrusion – A retrospective study', The Saudi Dental Journal, 32(3), 142-147.

Aldrees, A. M. and Shamlan, M. A. (2010). Morphological features of bimaxillary protrusion in SaudisSaudi Med J, 31(5), 512-9.

Aldrees, A. M., Tashkandi, N. E., AlWanis, A. A., AlSanouni, M. S. and Al-Hamlan, N. H. (2015) 'Orthodontic treatment and referral patterns: A survey of pediatric dentists, general practitioners, and orthodontists', The Saudi Dental Journal, 27(1), 30-39.

Aljhani, A. and Zawawi, K. H. (2010). The use of mini-implants in en masse retraction for the treatment of bimaxillary dentoalveolar protrusion The Saudi Dental Journal, 22(1), 35-39.

Aljhani, A. S. and Aldrees, A. M. (2011) Orthodontic treatment of an anterior openbite with the aid of corticotomy procedure: Case reportThe Saudi Dental Journal, 23(2), 99-106.

Alqahtani, N., Alqasir, A., Al-Jewair, T., Almoammar, K. and Albarakati, S. (2020). Dental and soft tissue changes following extraction of second premolars in females with bimaxillary protrusion: A retrospective study', Nigerian Journal of Clinical Practice, 23, 1109.

Alqahtani, N., Alshammari, R., Almoammar, K., Almosa, N., Almahdy, A. and Albarakati, S. (2019). Post-orthodontic cephalometric variations in bimaxillary protrusion cases managed by premolar extraction – A retrospective study', Nigerian Journal of Clinical Practice, 22, 1530.

Anthopoulou, C., Konstantonis, D. and Makou, M. (2014) Treatment outcomes after extraction and nonextraction treatment evaluated with the American Board of

Orthodontics objective grading system, American Journal of Orthodontics and Dentofacial Orthopedics, 146(6), 717-723.

Bindayel, N. A. (2019). Clinical evaluation of short term space variation following premature loss of primary second molar, at early permanent dentition stage', The Saudi Dental Journal, 31(3), 311-315.

Correia, G. D., Habib, F. A. and Vogel, C. J. (2014). Tooth-size discrepancy: a comparison between manual and digital methods', Dental Press J Orthod, 19(4), 107-13.

Elnour, M., Khabeer, A. and AlShwaimi, E. (2016) 'Evaluation of root canal morphology of maxillary second premolars in a Saudi Arabian sub-population: An in vitro microcomputed tomography study', The Saudi Dental Journal, 28(4), 162-168.

Keim, R. G., Gottlieb, E. L., Nelson, A. H. and Vogels, D. S., 3rd (2002) '2002 JCO study of orthodontic diagnosis and treatment procedures. Part 1. Results and trends', J Clin Orthod, 36(10), 553-68.

Kim, T. K., Kim, J. T., Mah, J., Yang, W. S. and Baek, S. H. (2005) 'First or second premolar extraction effects on facial vertical dimension', Angle Orthod, 75(2), 177-82.

Meyer, A. H., Woods, M. G. and Manton, D. J. (2014) 'Maxillary arch width and buccal corridor changes with orthodontic treatment. Part 1: Differences between premolar extraction and nonextraction treatment outcomes', American Journal of Orthodontics and Dentofacial Orthopedics, 145(2), 207-216.

Omar, Z., Short, L., Banting, D. W. and Saltaji, H. (2018) 'Profile changes following extraction orthodontic treatment: A comparison of first versus second premolar extraction', Int Orthod, 16(1), 91-104.

Ong, H. B. and Woods, M. G. (2001) 'An occlusal and cephalometric analysis of maxillary first and second premolar extraction effects', Angle Orthod, 71(2), 90-102.

Proffit, W. R., Fields Jr, H. W. and Sarver, D. M. (2006) Contemporary orthodontics, Elsevier Health Sciences.

Proffit, W. R., Jackson, T. H. and Turvey, T. A. (2013) 'Changes in the pattern of patients receiving surgical-orthodontic treatment', Am J Orthod Dentofacial Orthop, 143(6), 793-8.

Qamaruddin, I., Alam, M. K., Shahid, F., Tanveer, S., Umer, M. and Amin, E. (2018) 'Comparison of popular sagittal cephalometric analyses for validity and reliability', The Saudi Dental Journal, 30(1), 43-46.

Sandler, J., Murray, A., Thiruvenkatachari, B., Gutierrez, R., Speight, P. and O'Brien, K. (2014) 'Effectiveness of 3 methods of anchorage reinforcement for maximum anchorage in adolescents: A 3-arm multicenter randomized clinical trial', American Journal of Orthodontics and Dentofacial Orthopedics, 146(1), 10-20.

Sharma, K., Shrivastav, S., Sharma, N., Hotwani, K. and Murrell, M. D. (2014) 'Effects of first premolar extraction on airway dimensions in young adolescents: A retrospective cephalometric appraisal', Contemporary clinical dentistry, 5(2), 190-194.

Sheerah, H., Othman, B., Jaafar, A. and Alsharif, A. (2019) 'Alveolar bone plate measurements of maxillary anterior teeth: A retrospective Cone Beam Computed Tomography study, AlMadianh, Saudi Arabia', The Saudi Dental Journal, 31(4), 437-444.

Shirazi, S., Kachoei, M., Shahvaghar-Asl, N., Shirazi, S. and Sharghi, R. (2016) Arch width changes in patients with Class II division 1 malocclusion treated with maxillary first premolar extraction and non-extraction method', Journal of clinical and experimental dentistry, 8(4), e403-e408.

Solem, R. C., Marasco, R., Guiterrez-Pulido, L., Nielsen, I., Kim, S. H. and Nelson, G. (2013) 'Three-dimensional soft-tissue and hard-tissue changes in the treatment of bimaxillary protrusion', Am J Orthod Dentofacial Orthop, 144(2), 218-28.

Trisnawaty, N., Ioi, H., Kitahara, T., Suzuki, A. and Takahashi, I. (2013) 'Effects of extraction of four premolars on vermilion height and lip area in patients with bimaxillary protrusion', Eur J Orthod, 35(4), 521-8.

Yasutomi, H., Ioi, H., Nakata, S., Nakasima, A. and Counts, A. L. (2006) 'Effects of retraction of anterior teeth on horizontal and vertical lip positions in Japanese adults with the bimaxillary dentoalveolar protrusion', Orthodontic Waves, 65(4), 141-147.