Case Report

Effectiveness of Extraction of Four First Premolars in the Treatment of Severe Bimaxillary Protrusion: Report of a Clinical Experiences

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Abstract

Bimaxillary protrusion is a malocclusion which is characterized by increased proclination of the upper and lower incisors, marked procumbency of the lips and increased facial convexity. It may be present on a Class I and Class II skeletal base. The aim of this particular case report is to demonstrate the effectiveness of extraction of four first bicuspids as an alternative treatment on a severe Class II skeletal bimaxillary protrusion case. On February 2010, a 12 years old female patient attended the Orthodontics department of the Second Affiliated Hospital of Dalian Medical University, China whose chief complaints were crowding and protrusive lips. Cephalometric values showed, Class II skeletal base (ANB: 5.5°), increased proclinations of the upper and lower incisors (⊥SN: 112°, IMPA: 95°), convex profile and decreased esthetics (Z angle: 53°, UL-E line: +4mm, LL-E line: +4mm). Patient had a high Frankfort Mandibular Plane Angle (FMA: 40°), she presented severe crowding in the lower arch. The patient was treated with extraction of four first bicuspids and a fixed preadjusted edgewise appliance. Reinforced anchorage in the form of lingual arch was used during upper canine retraction. Total treatment time was 23 months, post-cephalometric analysis showed upper and lower incisors uprighting (SN: 101°, IMPA: 91°). No posterior extrusion and increased facial esthetics were noticed. Facial convexity could not be fully resolved due to the severity of the case initially and limited treatment options. Considering the severity of the case, the results obtained are appreciable, we may conclude that the extraction of four first premolars to treat severe bimaxillary protrusion cases may be a feasible option.

Key words: *Bimaxillary protrusion, Extraction*

Introduction

Bimaxillary protrusion[1-4] is a malocclusion which is distinguished by a marked increase of the labial inclinations of the incisors both in the upper and the lower jaws, an increase in the procumbency of the upper and lower lips, a pronounced convexity of the profile. Usually it is associated with a Class I or a Class II molar relationship. Bimaxillary protrusion is categorized as (i) dental (ii) alveolar or it may be a combination of both. Patients usually complain of a marked decrease in esthetics due to an increase in procumbency of the lips.

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Treatment of mild and moderate cases generally involves usage of fixed appliance in conjunction with the extraction of the upper and lower first bicuspid, because maximum lip retraction is desired in order to decrease facial convexity hereafter maximizing esthetics. In very severe cases, an ortho-surgical [5-7] approach may be advised, especially when there is severe vertical maxillary excess in the form of very severe gummy smile [8-12] (gingival display > 4mm) usually a LeFort 1 osteotomy impaction is usually proposed, also if a severe retrognathic mandible, genioplasty or surgical advancement of the mandible will be undertaken. Anchorage during management of bimaxillary protrusion should have a high consideration since maximum anchorage or absolute anchorage will be needed for maximum retraction of the incisors.

Anchorage reinforcement: in the form of two steps retraction, incorporation of the second permanent molar, extra oral anchorage devices (namely headgears, J-hooks and facebows), auxiliaries such as lingual arches, transpatal arches.

Finally absolute anchorage devices such temporary anchorage device [13-17] and mini plates may be used. Treatment results are usually favorable if proper diagnostics and treatment planning have been well formulated. Post treatment results normally show a consequent reduction of the lip procumbency, straight profiles, equal centric occlusion and centric relation, coincident midlines, proper incisal display, normal overjet and overbite. Therefore after orthodontic treatment, the patient usually acquires better esthetics which leads to a better life condition both socially and psychologically.

Etiology and Diagnosis

A female patient aged 12 years old attended the second affiliated hospital of Dalian Medical University, China in February 2010. The patient's chief complaint was crooked teeth and protrusive lips. Extraorally the patient didn't present any facial asymmetry, she had a convex profile. At rest she showed a slight mentalis strain upon lip closure. Incisal display was normal at rest. The pretreatment photographs showed that she had both lips well beyond the E-line.[18] Intraorally patient had both upper and lower ovoid shaped arch forms, she had bilateral Angle Class II (cusp to cusp) molar relationship. She had an overjet of 8mm & overbite of 3mm. In the upper arch she had flared upper incisors. The upper right second premolar was still erupting. On the left side there was crowding in the mid arch section, the second premolar was bucally placed relative to the first premolar. In the lower arch, severe crowding in the anterior segment was present, the lower right second premolar presented a slight mesiodistal rotation and the tongue was of normal size. The lower incisors showed an increased proclination. The canine relationship on both sides was Class I. The curve of Spee was 4mm and 3mm deep on left and right sides respectively. Upper and lower midlines were coincident with the facial midline. There were no signs of TMJ dysfunctions. Patient had no history of allergies or medical disorders. Pre-treatment orthopantomogram (OPG) confirmed the presence of complete permanent dentition including the four developing third molars. The following anatomic and derived cephalometric landmarks were used for cephalometric analysis:

S: Midpoint of Sella Turcica.

N: Frontonasal suture at the bridge of the nose.

ANS: The anterior nasal spine, the most anterior point on the maxilla at the level floor of the nose.

PNS: Posterior, the most posterior point on the maxilla, usually the meeting point of the superior and inferior point of the hard palate.

A: Deepest point on the anterior contour of the maxilla between ANS and the alveolar crest.

B: Deepest point on the anterior contour of the mandible between the chin and the alveolar crest.

Pog: The most anterior point on the curvature of bony chin.

Me: The most inferior point on the mandibular symphysis.

Go: The most inferior posterior point on the angle of the mandible.

UL: The most anterior point of the upper lip profile.

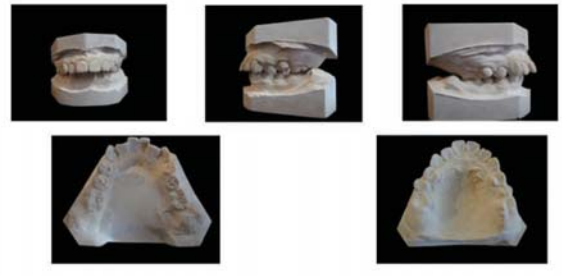
Soft Tissue Pogonion: The most anterior point on the profile of soft tissue chin.

Or: The lowest point of the bony orbit.

Po: The top of the external auditory meatus.

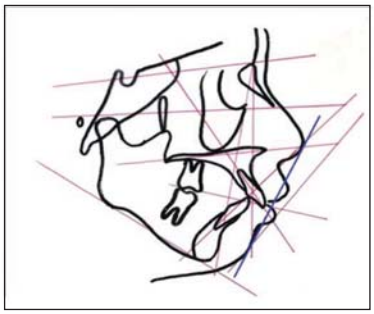
Pretreatment facial views

Pretreatment Intraoral views



Pretreatment Study casts

Pretreatment Radiographs



Pretreatment cephalometric tracing

Cephalometric Records	Pretreatment Values	Standard Values
SNA (°)	79°	82.8±4.0°
SNB (°)	73.5°	80.1±3.9°
ANB (°)	5.5°	2.7±2.0°
NA (°)	32°	22.8±5.9°
NA(mm)	9 mm	5.1±2.4mm
NB (°)	32°	30.3±5.8°
NB (mm)	9 mm	6.7±2.4mm
Interincisal angle (°)	108°	124.4±8.2°
SN(°)	112°	105.7±6.3°
FMA (°)	40°	31.3±5.0°
FMIA (°)	45°	54.5±6.1°
IMPA (°)	95°	93.9±6.3°
AOBO (mm)	3 mm	0-1mm
Posterior Facial Height (PFH mm)	35 mm	45mm
Anterior Facial Height (AFH mm)	65 mm	65mm
Facial Height Index (FHI) PFH/AFH	0.54	0.65-0.68
Z angle	53°	72-78°
Upper lip (UL mm)	13 mm	-
Total Chin (TC mm)	14 mm	-
Occlusal Plane (OP °)	16°	8-12°
UL-E line	+4 mm	-4 mm
LL-E line	+4 mm	-2 mm

From the pretreatment lateral cephalometric analysis results confirmed that the patient had a convex face profile & skeletal Class II relationship (ANB 5.5°). The mandible was retrognathic (SNB 73.5°). The upper incisors were excessively proclined beyond normal limits (SN 112°). The interincisal angle (108°) was acute which reveals the raised proclination of both upper and lower incisors.

The patient had a very steep mandibular plane, hence the Frankfort mandibular plane angle (FMA 40°). She had an increased lower ⅔ facial height (FHI 0.54). Esthetic imbalance was present since the Z angle (53 °) was well below the standard norms. Finally excessive lip procumbency was confirmed as the upper and lower lips were well beyond the E Line (UL-E line: 4mm, LL-E line: 4mm).

A space analysis was performed on the pretreatment study model to evaluate space discrepancies.

	Tooth material (mm)	Arch Length (mm)	Arch Discrepancy (mm)
Upper Arch	78.5mm	76mm	-2.5mm

	Left Interpretation(mm)	Right (mm)	Space required to level per side(mm) (L+R/2)+0.5
Curve of Spee	4mm	3mm	4mm

The mandible showed severe arch discrepancy: 14mm deficiency.

A Bolton analysis [19, 20] was performed by using the software "Bolton Calculator 2002 Version 3.21e (developed by Rodrigo M.Boos)", the followed results were obtained.

Interpretation	Anterior relationship norm (77.2%)	82.8%
	General Relationship (Norm: 91.3%)	93.16%
	Sum of the 12 upper teeth	95mm
	Sum of the 12 lower teeth	88.5mm
	Sum of the 6 upper anteriors	46.5mm
	Sum of the 6 lower anteriors	38.5mm
	Excess detected on lower 12 (Distributed over the whole arch)	1.77mm
	Excess on lower anteriors (Distributed over the anterior 6)	2.6mm

Usage of the differential diagnostic analysis system 21 is appropriate for diagnosis of virtually any malocclusion and its attendant underlying skeletal pattern.

Craniofacial Analysis	Cephalometric Value	Difficulty factor	Difficulty
FMA (22-28)°	40°	5	60
ANB (1-5)°	5.5°	15	7.5
Z angle (72-78)°	53°	2	38
Occlusal plane (8-12)°	16°	3	12
SNB (78-82)°	73.5°	5	22.5
FHI (PFH/AFH) (0.65-0.75)	0.54	3	33
Craniofacial total			**173**

Total space analysis	Measured values	Difficulty factor	Difficulty
Anterior			
Tooth arch discrepancy	6	1.5	9
Headfilm discrepancy	16	1	16
Soft tissue modification	1	0.5	0.5
Total	**23**	**-**	**25.5**
Mid arch			
Tooth arch discrepancy	3.5	-	-
Curve of Spee	8	-	-
Total	**11.5**	**1**	**11.5**
Occlusal disharmony **10** (Class II or class III)	–	**2**	**20**
Posterior			
Tooth arch discrepancy	10	-	-
Expected Increase (-ve)	6	-	-
Total	**4**	**0.5**	**2**
Space analysis total	**38.5**	**Space Analysis Difficulty Total**	**59**
Craniofacial Difficulty Total	173	Index Difficulty Mild: 0-60	
Space Analysis Difficulty Total	59	Moderate: 60-120	
Total Difficulty	**232**	Severe: > 120	

From the following differential diagnostic analysis system we may conclude that it is a severe bimaxillary protrusion on a Class II skeletal base.

Treatment Objectives

Five treatment objectives were identified.
1) Reduction of overjet
2) Obtain a Class I molar and canine relationship
3) Relieve of crowding both in upper and lower jaws
4) Leveling of the curve of Spee
5) Establishment of well balanced esthetics.

Methods of Treatment

After the atraumatic extraction of the four first bicuspids, another impression together with the upper bands in place for the preparation of the upper lingual arch (1.1mm), a fixed preadjusted edgewise appliance[22-28] was placed in February 2010 (Equilibrium 2, Dentaurum , Germany), MBT[29-34] prescription was used. Both upper and lower opening arch wires' sizes were 0.012" Niti round, ovoid form, medium size (NIC, China). Lacebacks [35-37] were placed from the hook of the first molar band directly to the canine bracket. The size of the wire increased upto 0.016" Niti round wire during the first 3 months of treatment, Lace backs were permanently present, during the whole of the leveling and alignment stage. After 3 months, a Niti 0.016" x 0.022" rectangular arch wire was used to proceed for the final detailed leveling and alignment. After 5 months of leveling and alignment, lower bondable molar tubes were bonded to the lower second molars which were already fully erupted. A reverse curve of Spee on the rectangular Niti wire was added to the lower arch wire for levelling the Curve of Spee. In September 2010, a rectangular 0.016" x 0.022" stainless steel arch wire (Ormaer) was inserted in position, then canine retraction was initiated using elastic chains (Ormaer, closed size), which was extended from the first molars to half of the canine brackets wings. It should also be noted that the lingual arch was in place so as to reinforce anchorage. The retraction of the upper and lower canines durated for 3 months upto a Class I canine relationship was attained.

In December 2010, space closure stage was instigated. Both in the upper and lower arches, stainless steel arch wires of size 0.016" x 0.022" were used. Both arch wires integrated 2 closing loops of "teardrop" shapes (size 7mm x 3mm upper arch and 6.5mm x 3mm) , they were positioned 1.5 mm distal to the lateral incisors. The closing loops are usually activated not more than 1.5 mm per appointments. Class II elastics of size "3/8" (3oz) were delivered to the patient. The patient was advised to change the elastics every day. The elastics were hooked from the upper closing loops to the hooks of the lower first molar bands.

Anterior teeth were secured together with stainless steel ligature wires (0.025") so as they act as a single body, whereas the anchored portion which consisted of the molars, premolars and canine were secured together as a whole anchor segment. The closing loops were activated by bend back distal to the terminal molars. Also the lingual arch was removed prior space closure was being started, this was simply done by using a fissure bur to cut away on the soldering site lingually to the molar band. Space closure stage continued for 5 months until improvement of the overjet and profile was attained.

Finishing stages stated from August 2011 with an upper and lower stainless steel archwire 0.016" x 0.022". Molar relationship was adjusted with light short Class II elastics size "5/16" (3oz). The Class II elastics extended from the crimpable hook distal to the upper lateral incisors to the lower first molars.

Finishing triangular elastics size "3/16" (3oz) were used for final inter cuspation of the upper and lower jaws. The triangular elastics were attached to Kobayashi hooks placed on the upper second premolar and lower second premolar and first molar. We may note that the triangular elastic has also a Class II vector. Finishing and detailing durated for another 6 months. At the start of mid of January 2012, normal overjet and overbite was obtained, profile was pleasant. The patient was scheduled for bracket removal. Patient was delivered an upper and a lower Hawley retainer, labial bows were made of stainless steel round wires (0.8mm) and C-clasps on the upper terminal molars and occlusal rests on the lower second molars were made of 0.9mm stainless steel wires. Post treatment orthopantomograms (OPG), cephalometric X rays and facial photos were taken.

Leveling & alignment stage

Canine retraction with lingual arch in place

Space closure with tear drop shaped closing loops

Finishing & detailing

Results

Following the completion of treatment, the overjet was reduced to 2.5 mm; Overbite became 2 mm, Class I molar and Class I canine relationships were attained bilaterally. Post Treatment Cephalometric analysis showed that normal values were obtained.

Cephalometric Values	Measured Values	Standard Values
SNA (°)	82°	82.8±4.0°
SNB (°)	77.5°	80.1±3.9°
ANB (°)	5.5°	2.7±2.0°
NA (°)	18°	22.8±5.9°
NA(mm)	5mm	5.1±2.4mm
NB (°)	29°	30.3±5.8°
NB (mm)	7mm	6.7±2.4mm
Interincisal angle (°)	126°	124.4±8.2°
SN(°)	101°	105.7±6.3°
FMA (°)	38°	31.3±5.0°
FMIA (°)	51°	54.5±6.1°
IMPA (°)	91°	93.9±6.3°
AOBO (mm)	2mm	0-1mm
Posterior Facial Height (PFH mm)	42mm	45mm
Anterior Facial Height (AFH mm)	75mm	65mm
Facial Height Index (FHI) PFH/AFH	0.56	0.65-0.68
Z angle	55°	72-78°
Upper lip (UL mm)	14 mm	-
Total Chin (TC mm)	14mm	-
Occlusal Plane (OP °)	15°	8-12°
UL-E line	+2 mm	-4 mm
LL-E line	+3 mm	-2 mm

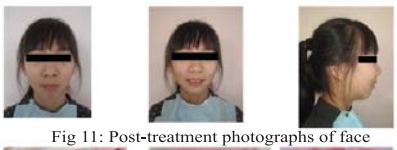


Fig 11: Post-treatment photographs of face

Fig 12: Post-treatment intra oral photographs

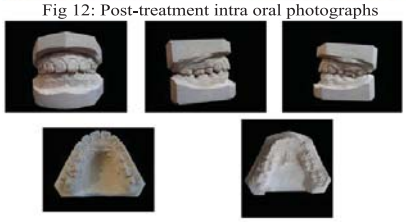


Fig 13: Post-treatment cast

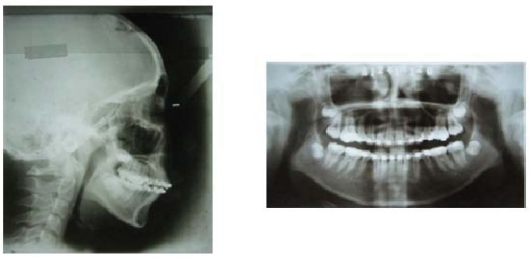


Fig 14 : Post-treatment Radiographs

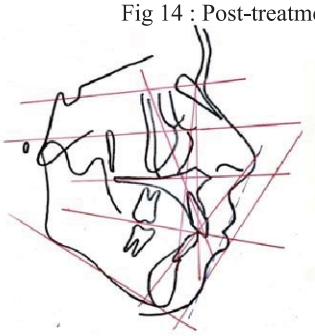


Fig 15: Post-treatment Cephalometric Tracing

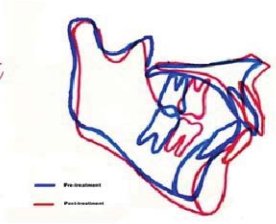


Fig 16: Superimpositions of pre- and post treatment

Discussion

Since maximum decrease in profile convexity was desired, extraction of four first bicuspids was undertaken. Upper space obtained from extraction of the first premolars was used mainly to decrease facial convexity, and to minimize the anterior flaring, therefore maximizing lip retraction and overjet reduction. Expansion would not be considered since getting outside the transverse boundaries of the denture may lead to instability and relapse, also the interdigitation of the maxillary suture might be fully fused hence unwanted buccal tipping would be produced more than any skeletal effect, which may lead to hanging of the upper molar palatal cusp therefore causing a clockwise rotation of the mandible which might give a "long face syndrome". In the lower jaw, the extraction spaces were mainly used for the relief of the crowding present, uprighting of the lower incisors over the apical base, leveling the curve of Spee and to decrease the lip procumbency.

The upper lingual arch was planned so as to reinforce anchorage but care should be taken that the wire does not make any contact during the retraction "pathway" of the canine. The lingual arch was designed in such a way that it made contact with the second bicuspid and incisors only so as reactive force could be spread uniformly. During the leveling and alignment stages, the small diameter of the opening wire was used so as to provide light and continuous forces[38-41], preventing undermining and root resorptions.

The Laceback was used so as to counteract the effect of the increased mesial tipping in the canine bracket, thus preventing anchorage loss and also some retraction effects were observed, since the root of the canine, has a rebound effect, therefore a slight canine retraction of about 1.5 mm was obtained that decreasing the treatment time to some extent. The leveling of the curve of Spee was more effective when including the lower second molar. A reverse Curve of Spee42-44 bend was inserted on the archwire distal to the canine bracket and unwanted lingual torque was neutralized, following the results obtained on the post treatment picture and cephalometric analysis we can say that relative intrusion was very effective.

Two steps[45,46] retractions were used during anterior retraction because it created less stress on the anchorage unit. Also when the canine was fully retracted, the anchorage value was increased, therefore, anterior retraction was progressed without consequent anchorage loss. Closing loop mechanics were used because minimization of friction was desired, and also adequate loop activation of 1.5 mm was enough so as to avoid any deleterious effects to the periodontal membrane. No gable bends were added to the archwire during retraction because some lingual tipping was desired for the upper anteriors which resulted in normal value of the angle of compensation ($\angle$SN).

At the end of the anterior retraction, the profile showed some improvement (UL-E line +2mm, LL- E line +3mm), but facial convexity was not fully resolved because the case was a severe bimaxillary protrusion on a Class II skeletal base. But comparison made to the initial and final facial photographs showed some decrease in the profile. This was possible since the upper lip lied on ⅔ of the clinical crown of the upper incisors whereas the lower anterior normally lied on the incisal ⅓ of the upper incisors. In the mandible by uprighting the lower incisors (IMPA 91°) over the basal bone, more stability would be anticipated. The curve of Spee was flattened so as to obtain a better centric occlusion and centric relation, hence temporo-mandibular dysfunction could be minimized. From the post treatment cephalometric analysis, the FMA angle (38°) was maintained so clockwise rotation (backward and downward) and molar extrusion was avoided, therefore no elongation of the lower facial height was observed and it was confirmed by the constant value of the facial height index. During the whole treatment, good compliance from the side of the patient, hence elastic wearing was permanent for the final finishing and settling of the dentition. On both sides proper Class I molar relationship, Class I canine relationship and also the intercanine widths were stable contributing to a less tendency of relapse.

Upper & lower Hawley retainers were delivered since the patient was still growing and also the Hawley retainers were more hygienic compared to fixed counterparts, moreover the patient presented good cooperation. The overjet (2.5mm) and overbite (3mm) were normal at the end of the treatment. Incisal display was optimal which provided better esthetics.

Conclusion

Following our results, we may conclude that the extraction of four first bicuspids to resolve a severe case of bimaxillary protrusion is an optimum solution if orthognathic surgery is not considered, where long term stability of the denture and esthetics will be achieved because limits of dimensions were preserved according to the Tweed-Merrifield Philosophy.

References

1. Sved, A., A further study of Tweed's basic principles and the reduction of bimaxillary protrusion without extraction. Am J Orthod, 1947.33(6): p. 363-87.

2. Vaden, J.L., Angle's class II, division I with bimaxillary protrusion: a case report. J Charles H. Tweed Int Found, 1982. 10: p. 75-86.

3. Celli, D., et al., Bimaxillary protrusion treated without extractions. J ClinOrthod, 2007.41(1): p. 33-8.

4. Leonardi, R., et al., Soft tissue changes following the extraction of premolars in non growing patients with bimaxillary protrusion. A systematic review.Angle Orthod, 2010.80(1): p. 211-6.

5. Lew, K.K., et al., Profile changes following anterior subapical osteotomy in Chinese adults with bimaxillary protrusion. Int J Adult Orthodon Orthognath Surg, 1989. 4(3): p. 189-96.

6. Langberg, B.J. and A. Todd, Treatment of a Class I malocclusion with severe bimaxillary protrusion. Am J Orthod Dentofacial Orthop, 2004. 126(6): p. 739-46.

7. Chu, Y.M., L. Bergeron, and Y.R. Chen, Bimaxillary protrusion: an overview of the surgical-orthodontic treatment. Semin Plast Surg, 2009. 23(1): p. 32-9.

8. Levine, R.A. and M. McGuire, The diagnosis and treatment of the gummy smile. Compend Contin Educ Dent, 1997. 18(8): p. 757-62, 764; quiz 766.

9. Fowler, P., Orthodontics and orthognathic surgery in the combined treatment of an excessively "gummy smile". N Z Dent J, 1999. 95(420): p. 53-4.

10. Redlich, M., Z. Mazor, and N. Brezniak, Severe high Angle Class II Division 1 malocclusion with vertical maxillary excess and gummy smile: a case report. Am J Orthod Dentofacial Orthop, 1999. 116(3): p. 317-20.

11. Lin, J.C., et al., Treatment of skeletal-origin gummy smiles with miniscrew anchorage. J Clin Orthod, 2008.42(5): p. 285-96

12. Costa, M.R., et al., Correction of severe overbite and gummy smile in patients with bimaxillary protrusion. J Clin Orthod, 2010. 44(4): p. 237-44; quiz 251.

13. Prosterman, B., et al., The use of implants for orthodontic correction of an open bite. Am J Orthod Dentofacial Orthop, 1995. 107(3): p. 245-50.

14. Mah, J. and F. Bergstrand, Temporary anchorage devices: a status report. J Clin Orthod, 2005. 39(3): p. 132-6; discussion 136; quiz 153.

15. Chen, C.H., et al., The use of microimplants in orthodontic anchorage. J Oral Maxillofac Surg, 2006. 64(8): p. 1209-13.

16. Anka, G., Use of miniscrews as temporary anchorage devices in orthodontic practice. II--Case reports. Aust Orthod J, 2007. 23(2): p. 137-46.

17. Wahl, N., Orthodontics in 3 millennia. Chapter 15: Skeletal anchorage. Am J Orthod Dentofacial Orthop, 2008. 134(5): p. 707-10.

18. Ricketts, R.M., Esthetics, environment, and the law of lip relation. Am J Orthod, 1968. 54(4): p. 272-89.

19. Wayne A. Bolton (1958) Disharmony In Tooth Size And Its Relation To The Analysis And Treatment of Malocclusion*. The Angle Orthodontist: July 1958, Vol. 28, No. 3, pp. 113-130.

20. Wayne A. Bolton The clinical application of a tooth-size analysis American Journal of Orthodontics Volume 48, Issue 7, Pages 504-529, July 1962.

21. Merrifield, L.L., H.A. Klontz, and J.L. Vaden, Differential diagnostic analysis system. Am J Orthod Dentofacial Orthop, 1994. 106(6): p. 641-8.

22. Andrews, L.F., The six keys to normal occlusion. Am J Orthod, 1972. 62(3): p. 296-309.

23. Andrews, L.F., The straight-wire appliance arch form, wire bending & an experiment. J Clin Orthod, 1976. 10(8): p. 581-8.

24. Andrews, L.F., The straight-wire appliance: “Extraction, brackets and classification of treatment". J Clin Orthod, 1976. 10(5): p. 360-79.

25. Andrews, L.F., The straight-wire appliance. Case histories: non-extraction. J Clin Orthod, 1976. 10(4): p. 282-303.

26. Andrews, L.F., The straight-wire appliance. Explained and compared. J Clin Orthod, 1976. 10(3): p. 174-95. 27. Andrews, L.F., The straight-wire appliance, origin, controversy, commentary. J Clin Orthod, 1976. 10(2): p. 99-114.

28. Andrews, L.F., The straight-wire appliance. Br J Orthod, 1979. 6(3): p. 125-43.

29. McLaughlin, R.P. and J.C. Bennett, The transition from standard edgewise to preadjusted appliance systems. J Clin Orthod, 1989. 23(3): p. 142-53.

30. Bennett, J.C. and R.P. McLaughlin, Controlled space closure with a preadjusted appliance system. J Clin Orthod, 1990. 24(4): p. 251-60.

31. McLaughlin, R.P. and J.C. Bennett, Anchorage control during leveling and aligning with a preadjusted appliance system. J Clin Orthod, 1991. 25(11): p. 687-96.

32. McLaughlin, R.P. and J.C. Bennett, Finishing and detailing with a preadjusted appliance system. J Clin Orthod, 1991. 25(4): p. 251-64.

33. Bennett, J.C. and R.P. McLaughlin, Overjet reduction with a preadjusted appliance system. J Clin Orthod, 1992. 26(5): p. 293-309.

34. McLaughlin, R.P. and J.C. Bennett, The extraction-nonextraction dilemma as it relates to TMD. Angle Orthod, 1995. 65(3): p. 175-86.

35. Irvine, R., S. Power, and F. McDonald, The effectiveness of laceback ligatures: a randomized controlled clinical trial. J Orthod, 2004. 31(4): p. 303-11; discussion 300.

36. Khambay, B.S., S. McHugh, and D.T. Millett, Magnitude and reproducibility of forces generated by clinicians during laceback placement. J Orthod, 2006. 33(4): p. 270-5; discussion 256.

37. Sueri, M.Y. and T. Turk, Effectiveness of laceback ligatures on maxillary canine retraction. Angle Orthod, 2006. 76(6): p. 1010-4.

38. Andreasen, G.F., Variable continuous forces. Aust Dent J, 1970. 15(1): p. 10-15.

39. Andreasen, G.F. and D. Zwanziger, A clinical evaluation of the differential force concept as applied to the edgewise bracket. Am J Orthod, 1980. 78(1): p. 25-40.

40. Owman-Moll, P., Orthodontic tooth movement and root resorption with special reference to force magnitude and duration. A clinical and histological investigation in adolescents. Swed Dent J Suppl, 1995. 105: p. 1-45.

41. Pilon, J.J., A.M. Kuijpers-Jagtman, and J.C. Maltha, Magnitude of orthodontic forces and rate of bodily tooth movement. An experimental study. Am J Orthod Dentofacial Orthop, 1996. 110(1): p. 16-23. 42. Ferguson, J.W., Lower incisor torque: the effects of rectangular archwires with a reverse curve of Spee. Br J Orthod, 1990. 17(4): p. 311-5

43. Hamdan, A.M. and W.P. Rock, The effects of archwire forces on incisor intrusion. Br J Orthod, 1995. 22(2): p. 155-60.

44. Clifford, P.M., J.F. Orr, and D.J. Burden, The effects of increasing the reverse curve of Spee in a lower archwire examined using a dynamic photo-elastic gelatine model. Eur J Orthod, 1999. 21(3): p. 213-22.

45. Heo, W., D.S. Nahm, and S.H. Baek, En masse retraction and two-step retraction of maxillary anterior teeth in adult Class I women. A comparison of anchorage loss. Angle Orthod, 2007. 77(6): p. 973-8.

46. Martel, D., Two-step vs En Masse retraction in space closure procedures, a literature review. Int J Orthod Milwaukee, 2010. 21(1): p. 51-2.