Frontal Cephalometrics: Practical Applications, Part I

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Aims: *Many clinicians have not employed the frontal perspective. Therefore, the purposes of this paper are to: (1) update the findings in morphology and growth in the transverse dimension; (2) simplify evaluation of facial asymmetry using the Ricketts and Grummons frontal analyses; and (3) describe practical clinical applications of anteroposterior images and analysis.* **Methods**: *Maxillary width variations, frontal (anteroposterior) anatomic landmark locations, and frontal tracing methods are specified. Asymmetry conditions are differentially treated.* **Results**: *Utilizing frontal facial information, therapeutic approaches are more specific and effective, while directed toward particular etiology. Occlusal plane, midline, chin location, and smile esthetics are primarily addressed. Beautiful facial proportions and smile harmony are demonstrated. Asymmetry of the facial parts is the rule, rather than the exception.* **Conclusion**: *Patients view themselves from the frontal perspective, so this carries priority in assessing problems and treatment outcomes. Facial harmony and smile beauty are optimal when facial and dental midlines are aligned. The occlusal plane should be level, or nearly so. The maxillary width should be sufficiently wide to be in harmony with the individual patient facial type and morphology. The chin should be centered, or nearly so. Best facial development and proportionality exist when the transverse skeletal and dental components are optimized and symmetric.* World J Orthod 2003;4:297–316.

In the past, relationships in the sagittal plane have dominated orthodontic thinking to such an extent that the great majority of clinicians did not even bother to procure frontal radiographs (images, headplates). However, several factors have awakened the current clinician to a deeper interest in the transverse dimension[1]: *(1)* maxillary palatal dysjunction expansion (rapid palatal expansion [RPE], rapid maxillary expansion [RME]), with a 100-year history, has become standard teaching in graduate orthodontic programs; *(2)* lighter wires, required as bonded brackets became popular, have been successful for mandibular arch lateral expansion (the writings and demonstrations by Graber,[2] Frankel,[3] and others that functional appliance arch widening occurred with buccal shields, probably stretching the periosteum, further had a profound influence on concepts); *(3)* a full and stunning smile is recognized to emphasize the transverse perspective[4,5]; *(4)* nasal width and piriform aperture asymmetries are factors in frontal esthetics[6] (the entire midfacial complex became associated with the respiratory system, together with mandibular posturing)[7–9]; and (5) mandibular and cranial asymmetries have become significant in planning treatment.[10,11] Surgically assisted palatal dysjunction (rather than dental expansion) was found to be indicated for preservation of the maxillary periodontium[12] and to reduce relapse. Deciduous and early mixed dentition treatment for skeletal and functional corrections involves a 3-dimensional consideration.[13,14] Therefore, it is time for a shift in orthodontic thinking regarding the frontal image and perspective.

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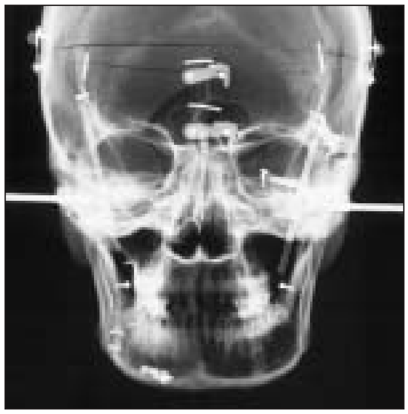


Fig 1 Typical structures traced in the frontal. Tracing points include MSR, midsagittal reference (midline facial plane); Cg, crista galli; ANS, anterior nasal spine; ME, menton; OP, occlusal plane; J,J', lateral maxillae at molars on each side; Ag, gA, antegonial on each side; Ms, mastoid process; Za-aZ, zygomatic process suture on each size; Z,Z', zygomaticofrontal suture; Fr, foramen rotundum; Co, condylion, posterior superior aspect of condylar process; Ra, ramus ascending; SO, superfiscial orbitale; NC, nasal cavity.

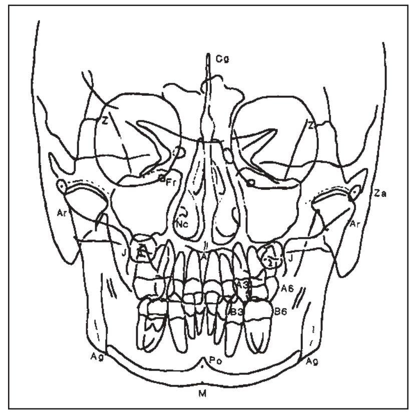


Fig 2 Frontal landmarks are: frontofacial plane (Z-Ag), line from zygomaticofrontal suture (Z) through the antegonial tubercle (Ag); transverse Frankfort plane (Za-aZ), line through centers of zygomatic arches; nasion-point B (Na-B), line from nasion through point B; frontal denture plane, line from Ag to J point; frontal mandibular plane, central sagittal plane from crista galli perpendicular to frontal Frankfort plane; frontal maxillary plane, line through two J points; frontal occlusal plane, bisection of first molar occlusion.

The time has come for frontal cephalometrics to be a routine part of each clinician's practice. By grace of the computer, reference points and planes have been sorted out and time tested. The possibilities with expansion are remarkable, when conducted with current technological knowledge and science, especially for the younger patient. When surgery is needed, a scientific application is offered in indices and differentials. Sensible and useful clinical applications are highlighted in this article.

The cephalometric method has extended orthodontic treatment planning, based on growth expectations and predictions of treatment reactions. This development was based on the data from hundreds of treated patients and control samples studied for growth without treatment.[15] The sequence first used was the behavior of basi-cranial axis (BaN), followed by the mandible, to locate the chin. The midface was then rendered to complete a skeletal framework. The rendering was to set the teeth objectives and the resultant soft tissue profile was predicted. Width changes in the arches were associated in the frontal or transverse dimension.[4,8,16–18]

FACIAL ASYMMETRY: FIVE IMPORTANT QUESTIONS

1. Is the maxillary width equally wide?
2. Is the occlusal plane level?
3. Is the maxillary dentition centered with the facial skeletal midline?
4. Are the maxillary and mandibular midlines aligned?
5. Is the chin location centered, or nearly so?

Common facial and/or dental asymmetries have midlines off center. Their genesis may be any of the following: tooth-size discrepancy; missing or migration of teeth; extra teeth; crowding; eruption sequence variation; crossbites; mandibular functional shift or deflective contacts; habits influencing facial morphology; skeletal dysplasia of jaw or facial structures; corpus length/mandibular body length variations; condylar hyperplasia, or hypoplasia; condylar process remodeling or degeneration (condylysis); TMJ disc dislocation/dyscrasia or fossae changes; craniofacial sutures prematurely fused; paralysis, especially in young; neoplasia/tumors; airway compromise, typically greater on one side; and cervical dysfunction, scoliosis, and degenerative conditions.

FRONTAL POINTS OF REFERENCE

By 1969, detailed research with the computer was reported.[19] New and useful frontal reference points on the skull were examined (Figs 1 and 2). Three new points were found to be significant for basic orientation: the medial margin of the zygomaticofrontal suture (Zf), a point on the curve of the jugal process at the crossing of the outline of the tuberosity (J or Mx), and a point at the lower border of the trihedral eminence or the antegonial tubercle (Ag). Careful inspection of the frontal film will reveal the tips of the canine crowns. For measuring dimensions of the posterior teeth, the widest point on the buccal surfaces of crowns is employed. Three meaningful frontal guidelines are utilized today in the Ricketts and Grummons frontal image analysis and application: centrals to midline, occlusal plane, and chin location.

Computer protocols

For the computer research, untreated "controls" were assembled for serial study. Data for age, sex, racial types, and morphologic characteristics were derived. The mean data provided standards for a starting reference. "Clinical deviations" supplied standards for variation assessments.

The computer studies revealed four significant contributions: *(1)* determination of the most cogent reference points and lateral orientation for frontal; *(2)* new growth information in 3 dimensions; *(3)* new parameters as a basis for separation of growth from treatment changes; and *(4)* development of a laboratory service for the procurement and processing of data for individual patients.

Consequently, the computer developments satisfied several needs in the specialty. The findings were applied for a new analysis. Developments moved on to be used for establishing treatment objectives. The process then served as a basis for designing treatment strategies in 3 planes of space.[20,21] At this time, the applications of cephalometrics have become remarkably enhanced by scanning and electronic technology. Clinicians can now have extensive 3-dimensional prognostic information at their fingertips in seconds, not days or weeks.[8,22,23]

Frontal summary analysis

Eleven measurements, three being bilateral, were added to the "abridged plan" making a total of 15. The comprehensive analysis (computer) is beyond the scope of the present paper. Just as practiced for the lateral comprehensive analysis, the frontal analysis was organized into fields, or families, of measurements by Rocky Mountain Data Systems (Los Angeles, California, USA). The summary analysis includes the frontal skeletal relations: Field I, the teeth alone; Field II, skeletal maxillomandibular conditions; Field III, denture to skeletal relations; Field IV, esthetics was not evaluated in the frontal; Field V, craniofacial relation; Field VI, the deep structural factors.

Expansion or arch extension

Width increases have been practiced since the beginning of the specialty. Despite the claims of many traditional clinicians, transverse enlargement does indeed contribute to the correction of arch length problems. The differences in belief probably lie in the method employed for mandibular arch treatment. Clinicians using the functional approach employ lateral expansion liberally. Those with rigid fixed appliance modalities, who also wait until permanent teeth erupted, have become disenchanted with expansion. Most came to reject it altogether. Expansion with a straight-wire approach automatically meant forward displacement of mandibular incisors or arch extension. For this and other reasons, interest in transverse changes became almost nonexistent.

Factors were needed to associate the frontal image data with the dimensions on the cast. Normal occlusions were collected. Mean measurements were established together with standard deviations from the most buccal points on the crown. Moorrees studied normal arch width and arch length dimensional changes.[24] But, ironically, the transverse emplacement of the mandibular molars in the face, or between the jaws, has received a dearth of scientific attention. Frontal cephalometric headfilms were used for growth studies in Broadbent's original work. However, many of the transverse parameters he employed were not fruitful (such as bizygomatic and bigonial measurements). Consequently, most clinicians did not use frontal headfilms because of a belief that there existed no concrete value for the frontal headplate. Yet, 90% of patients receiving orthodontic care show changes in the transverse dimension during treatment. Studies from Goldstein's sample, 20 to 30 years following extraction treatment, showed the dental arch was always further constricted at the first molars. [25]

Frontal cephalograms, photographs, and occlusal and basilar radiographs contain valuable information, unique from that perspective, that should be incorporated into any comprehensive facial analysis. It is the foundation for treating the entire face 3-dimensionally, not just the dentition. Asymmetries, in particular, are best detected from the frontal perspective as per Zachrisson,[26] at the diagnostic phase, with the clinician directly in front of the patient. It is not unusual for the clinician and the patient to pay less attention to asymmetry in a crowded or misaligned malocclusion. In fact, it may often be masked at that stage, only to become obvious after leveling and alignment. Then, it may be more challenging to explain and address. It is better

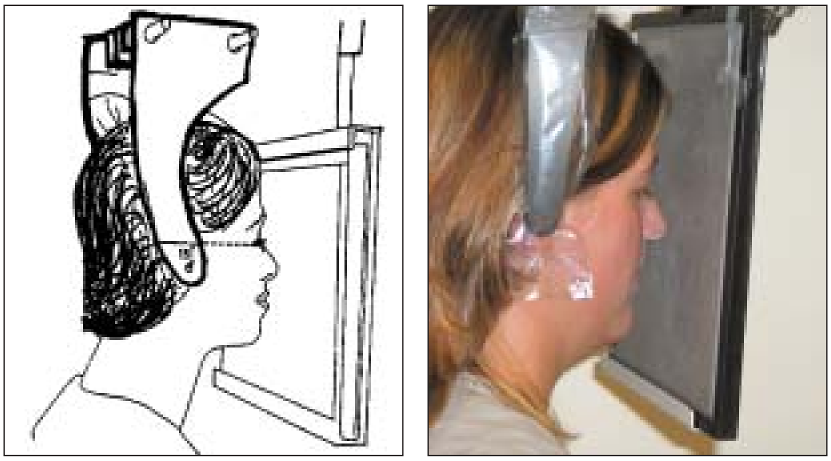


Fig 3 Head positioning for posteroanterior image.

to detect asymmetry during diagnosis, factor it into treatment planning options, and set appropriate expectations for different treatment options. This is superior to a rationale for discovering it later in treatment, and managing this as the case progresses.

TRANSVERSE AND FRONTAL PERSPECTIVES

The transverse perspective, as viewed from the front, deserves priority from initial assesment through the therapeutic process. In smile design, Langlade[17] and Grummons[4,11] have described and emphasized facial/dental asymmetry and frontal analysis key factors. The simplified frontal analysis emphasizes the following: *(1)* the maxillary dental midline should coincide with the skeletal midsgittal reference (MSR) line; *(2)* the occlusal plane should be level, or nearly so; *(3)* the chin location should be centered or disguised to appear neutral, or options for this correction should be offered to the patient. These key aspects of the frontal dimension need to be effectively managed and communicated to patients.

Patients often seek re-treatment not because of their dentition, but rather because they are not pleased with the overall facial and esthetic outcome. If a patient's teeth are straight, with the occlusion functional, yet the smile line is tipped or the maxillary incisors are off-center from the facial midline, the patient probably will not be pleased with the result.

Head positioning, exposure, and anatomic display

For the frontal image, inconsistency in head positioning with the head tipped downward at one setting and upward in another makes analysis or comparisons difficult. Therefore, posturing the patient in the cephalometer is critical for the frontal exposure. For improvement in images, Bench[27] modified the technique as follows: A line is scribed on the ear rod assembly at a point 15 mm above the ear rod (Fig 3). The height of the orbit is about 3 cm, and the lateral canthus is essentially at the center of the orbit, or 15 mm. The patient should be seated snugly against the top of the ear rods with the head positioned so that the lateral canthus of the eye is located on a level with that line. The jaw is held in the habitual occlusion. The exposure is up to 3 times that used for the lateral headplate. Experience has shown that a properly oriented frontal headfilm will show the top of the petrous portion of the temporal bone to lie near the center of the orbit. Also, the J points and Ag points can be identified, and nasal cavity morphology will be visible. The zygomatic arches will be revealed in cross section.

Frontal film and interpretations: Ricketts method

This method requires a better discipline for tracing the frontal, as compared to the lateral image. There is greater superimposition of skeletal and dental structures. With study of the structural images, a depiction can include even the mandibular condyles and articular eminence. Literally, all the teeth can be identified in the mixed and permanent dentitions (Fig 4). A review of skulls is helpful in the learning process.

The Ricketts tracing template (Dome) includes tooth outlines in the frontal dimension and is of great help. Locating the buccal surfaces of posterior teeth and positioning the template over them can allow the clinician to trace a good representation. Incisal edges of anteriors likewise can be located with the template. Not all the complete structures need be traced, but the issue is their visibility. In particular, the first molars and central incisors should

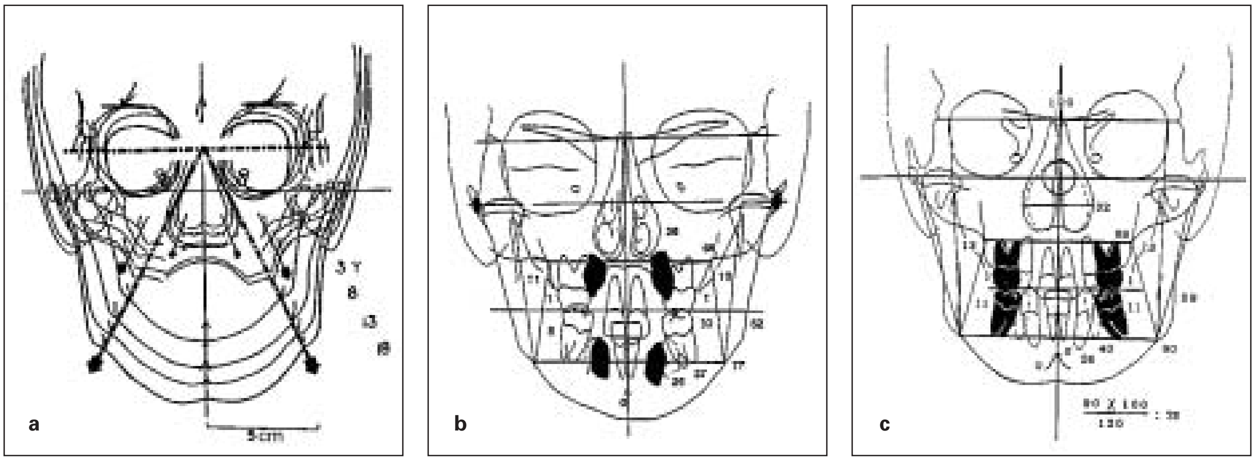


Fig 4 Frontal tracings of symmetric examples. **(a)** Gnomic growth. **(b)** Child, mixed dentition. **(c)** Adult.

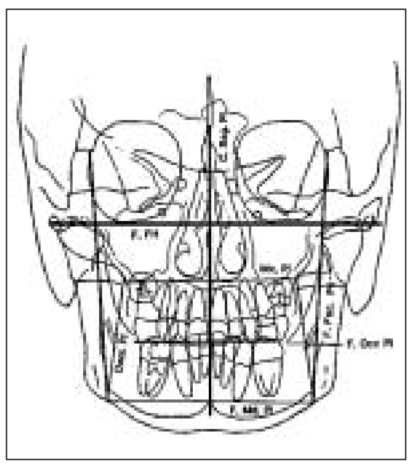


Fig 5 Frontal planes of reference.

Table 1 Maxillary width (J-J') in males

Age (y)	Width (mm)
3	55
4	56
5	57
6	58
7	59
8	60
9	61
10	62
11	63
12	64
13	65
14	66
15	67
16	68
17	69
18	70
19	71
20	72
21	73

be identified as accurately as possible. The center of the cross section of the zygomatic arch is selected, as points Za and aZ, for drawing the frontal Frankfort plane when the two are connected. A second check reference is the connection of Zf points as a basic frontal reference. From the Frankfort plane, a perpendicular line is dropped from the crest on the frontal or top of the nasal septum. This will form a basic coordinate as a starting frame of reference.[11,14,23,28] This is depicted on a composite of N = 82 normal adults gathered by the Foundation for Orthodontic Research (FOR) and Education (FORE). The next step toward frontal diagnosis is the connection of corresponding points bilaterally. These are points Nf (nasal floor), J, Ag, and the bisection of the first molar occlusion (or second deciduous molars). At the deciduous level, when the lines of connection are parallel, a vertical symmetry is presented. Vertical lines established are Zf-Ag and J-Ag (Fig 5).

Maxillary width

One of the alerts to a Divine Proportion or Fibonacci phenomena was that maxillary width at the J point (which represents also width at the tuberosity) was double that of nasal width increase. The growth value conveniently was 1.0 mm per year starting with 55 mm at 3 years of age, in males (Table 1).

Table 2 Mandibular width (Ag-gA) in males

Age (y)	Width (mm)
3	68.0
4	69.5
5	70.0
6	71.5
7	73.0
8	74.5
9	76.0
10	77.5
11	79.0
12	80.5
13	82.0
14	83.5
15	85.0
16	86.5
17	88.0
18	89.5
19	91.0
20	92.5
21	94.0

Table 3 Maxillomandibular differential and index values in males

Age (y)	Maxillary (mm)	Mandibular (mm)	M-M differential (mm)	Ratio (%)
3	55	68.0	13.0	80.0
8	60	74.5	14.5	80.5
13	65	82.0	17.0	79.27
18	70	87.5	19.5	80.0
Adult	72	92.5	20.5	78.0

Table 4 Nasal cavity and maxillary differential and index values in males

Age (y)	Nasal cavity (mm)	Maxilla (mm)	differential (mm)	Ratio (%)
3	22.0	55.0	33.0	40.0
8	24.5	60.0	65.5	41.0
13	27.0	65.0	38.0	41.5
18	29.5	70.0	40.5	42.0

Mandibular width

As stated before, the selection of Ag point was fortuitous. It was investigated because it was in a reasonable plane with the J point and could be related with the mandibular molar teeth. Starting at 68.00 mm at 3 years of age, it grows in width essentially 1.5 mm each year, to have a mean at age 21, in males, of around 94 mm. The clinical deviation is around 2.5 mm (Table 2).

Maxillomandibular differential and index values

This value was found to be significant by Vanarsdall,[12] for determining width to be established by treatment with palatal width increases for adults. There is a 20-mm width difference between the Mx points and the Ag points. Vanarsdall studied the application of surgically assisted palatal expansion in adults. He found that a differential in total width of about 20 mm was satisfactory.[29] These measurements were the maxillae at the J points (or Mx) compared to the Ag points on the mandible. A group of 82 adults with normal occlusions revealed a differential of 22 mm (Ag-gA, 90 mm; J-J', 68 mm). This is reasonably consistent with his objective. The Facial Index was 75, as derived from a facial height of 120 mm, divided into a width of 90 × 100. The computer findings are shown in Table 3.

If the proportion is calculated at different ages, a surprising regularity is observed. The value or ratio of maxilla to mandible is about 80%, and the ratio of nasal cavity to maxilla ranges from 40% to 42% (Table 4).

Comparative widths and symmetry

The maxillomandibular width relationship in the face, as expressed by distance from the J point laterally to the frontofacial plane (midsagittal plane), also is age linked. This is a good value for symmetry, as well as actual size (Table 5). A 10-mm value at 8 years of age increased to 12 mm by adulthood, and the mature adult samples were nearly 13 mm.

The mandibular bimolar width tends to stabilize after molars erupt to occlusal function. To assess width relative to the reference plane J-Ag, the values were calculated as shown in Table 6. The mandibular first molar at 6 years of age was 4.4 mm, but, in males, by 18 years of age it had increased about 10 mm, due to posterior growth of the jaws.

Differences in intermolar width between the maxillary first molars were statistically significant in individuals with and without tooth crowding. There was about a 6-mm difference in both males and females, with the average transpalatal width in males of 37.4 mm (SD, 1.7 mm). Crowded individuals had only 31.22 mm, with a higher SD of 4.1 mm. A clinical guideline assumes maxillary intermolar size to be, on

Table 5 Proportional maxillary width (J to Z-Ag) in males

Age (y)	Width (mm)
3	9.0
4	9.2
5	9.4
6	9.6
7	9.8
8	10.0
9	10.2
10	10.4
11	10.6
12	10.8
13	11.0
14	11.2
15	11.4
16	11.6
17	11.8
18	12.0
19	12.2
20	12.4

Table 6 Mandibular molar (B6) to J-Ag in males

Age (y)	Width (mm)
6	4.4
7	5.2
8	6.0
9	6.8
10	7.6
11	8.4
12	9.2
13	10.0
14	10.8
15	11.6
16	12.4
17	13.6
18	14.2
19	15.0

average, 36 to 38.8 mm (SD, 1 mm). Pursue arch expansion using rapid maxillary expansion, since it addresses the skeletal deficiency, which contributes to arch length or arch perimeter deficiency more frequently than excessive tooth size. Measurement of transpalatal width between the maxillary first molars is one indicator of transverse dimension. Transpalatal width must be evaluated in conjunction with other relevant hard and soft tissue parameters, facial form, facial pattern, etc. Just as the mandibular incisor to mandibular plane is measured, the use of a transpalatal measurement as a routine part of orthodontic diagnosis and treatment planning is important. For an idea of arch dimension, measure palatal width between the mesiolingual cusps of the maxillary first molars.

Maxillary expansion

Numerous retrospective studies[30–34] have examined the effects and stability of maxillary expansion (ME) with a variety of appliances. However, few investigations have considered orthopedic expansion in the mixed dentition with active decompensation and transverse uprighting of the mandibular arch, or concurrent changes in mandibular arch dimensions with RME. Mandibular arch dimensional changes concurrent with expansion in the mixed dentition have been studied.[29,35] Other studies[29,35,36] indicated that maxillary RME with mandibular Schwarz therapy retained larger increases in arch width than those achieved with RME only for the maxillae. The maxillary arch experienced more stable increases in arch width compared to the mandible. Typical maxillary pretreatment widths were observed to be 67% deficient,[37] or up to 80% deficient.[2,12] Eighty percent of Class II problems have a transverse deficiency in the maxillary or midfacial component.[4,8,38] It has been found that for every millimeter of maxillary expansion width measured at the maxillary premolars, there was a 0.7-mm increase in available arch perimeter.[31,32,39]

MAXILLARY ORTHOPEDICS AND ORTHODONTICS

Expansion utilizing RME provides enhanced maxillary development. Broadening the smile helps reduce negative space (the dark space or shadow in buccal corridor) at the sides of the smile.[8] Perhaps the most common reason for using RME is to increase arch length.[4,8,14,35,40] Maxillary orthopedic expansion applies to Class I, for nonextraction approach; Class II, to unlock the mandible; and Class III, to protract the maxillae with facemask influence. Upon studying dental widths, relapse of transverse development and expansion is 20% in young patients, and there is a 30% relapse occurrence in adults. Plan for this in treatment objectives, design, and follow-up by applying overcorrection aspects and principles.[4,8,14,37] RME appliances fulfill an important therapeutic priority; apply one turn daily or every other day, with a gradual decrease in turns when close to the overcorrected skeletal width. With a

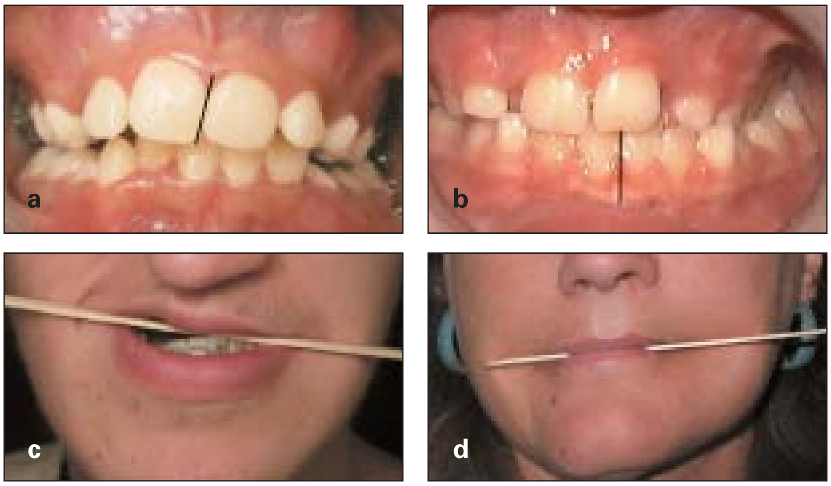


Fig 6 Midline **(a,b)** and occlusal plane **(c,d)** variations.

Midsagital reference key indicators

- Maxillary width
- Occlusal plane
- Maxillary dental to skeletal midline
- Dental midlines
- Chin location

facemask, one turn every 4 to 7 days allows protraction gain while keeping the maxillary sutures in dysjunction for a more extended time, to achieve greater midfacial protraction orthopedic response.

RME and RPE orthopedics enhance maxillary sutural and alveolar development with facial reshaping. It should be considered a form of distraction osteogenesis. Broadening the smile optimizes the display of teeth, providing that it is in harmony with the overall facial pattern. Greater width reduces the negative space at the commissures (buccal corridors) for a pleasing smile. RME is widely applied for width issues and increased arch space.[41] Relapse is minimized by keeping the buccal segment teeth upright and related to basal structures.

Ricketts[21] stated that the ultimate objectives of the Bioprogressive orthodontic philosophy are to work in harmony with growth, to achieve permanent orthopedic changes, and to set the stage for lifelong enjoyment of the natural dentition. The oral soft tissues, including the periodontal ligament (PDL), determine the stability of orthodontic results. The importance of the PDL as a root rating system was developed to provide clinicians with the correct force levels for different tooth movements, and to obtain cortical anchorage. Gugino[42] stated that functional unlocking encompasses cognitive awareness training that involves patients in the treatment of their dysfunction. The early resolution of oral dysfunctions is not only an essential part of orthodontic treatment, but it is also a vital component of the stability of the treatment results. Mechanical unlocking removes occlusal interferences that could affect the development and function of the entire stomatognathic system. This directly and significantly affects facial width and proportionality.

FRONTAL PERSPECTIVES

Patients see themselves from the frontal dimension and may be aware of the following treatment results: facial proportionality; smile and facial harmony; teeth supporting the lips in a full smile; buccal corridors filled in a wide smile; midlines centered in the smile; smile and occlusal plane level; smile beautified, enhanced, and optimized; and facial symmetry.

Esthetic enhancement alternatives for additional facial and transverse benefits include chin augmentation, mentoplasty, mandibular border graft/implant, malar implant, styling (hair, make-up, clothing), liposuction or fat grafting, lipid or collagen injection, alloplastic implantation, and additional approaches.

The facial frontal image and related analysis is a most valuable tool in the study of right and left facial structures, since they are located at relatively equal distances from the film and radiographic source. As a result, the effects of unequal enlargement by the diverging rays are minimized and the distortion is reduced. Comparison between sides is more accurate, since the midlines of the face and dentition can be recorded and evaluated (Fig 6).

DISCUSSION REGARDING FRONTAL

A background of problems with the frontal application and the possible solutions should be understood for appreciation of the transverse dimension. The frontal headfilm came into realistic use with the development of points jugale (J) and the antegonial tubercle (tri-hedral eminence) (Ag). It made the assessment of transverse maxillomandibular relationships possible at a skeletal depth more related to the molar teeth. Dental arch dimensions also were coordinated with the transverse skeletal morphology.

The parameters of the mandibular denture, measured from buccal surfaces, were employed to establish standards for diagnostic and planning purposes. The great majority of contemporary orthodontists engage in palatal alteration, either slow or rapid. Also, the practice of orthognathic surgery in adults has grown, but often is diagnosed and planned only from casts. With expansion treatment, changes in the J point regions are produced. All this prompts the need for better science and application of the frontal image and appreciation for its analysis and clinical value.

Extraction rates have dropped significantly, and maxillary width increase with expanders, extraoral traction, quad-helix, and buccal or labial shielding have been shown to be healthy and stable. These bring the frontal headfilm and the transverse dimension into prominence. The scientific parameters had to await studies with the application of the computer, and growth forecasting in the frontal has been worked out. Values for arch dimensions were standardized as a starting point for diagnosis and planning for the permanent, mixed, and primary dentition. Treatment for all major malocclusions requires consideration in the transverse dimension at any age. The application of the information available takes one more step toward application of a scientific approach to clinical work.

The following analyses are intended to provide a practical, functional method for determining the locations and amounts of facial asymmetry. Even greater clinical value occurs when integrated with data from lateral and submental vertex radiographs. The analyses are in many computerized cephalometric tracing programs for orthodontic and/or surgical practices (Fig 7).

POSTEROANTERIOR FRONTAL ANALYSIS SIMPLIFIED

Grummons method

This useful analysis permits the clinician to readily observe the midsagittal reference (MSR) line, to compare right and left sides for transverse and vertical variations, disproportional relationships, and asymmetry (Fig 8). The analysis is now in many computerized cephalometric tracing programs. It is quite simple and visual: Look down the tracing (MSR line) at the midline. If the horizontal lines do not match or intersect at MSR, one side is different than the other by the millimeter difference observed at the midline. Locate the chin and measure the number of millimeters it is away from the midline at MSR. This frontal view: *(1)* helps decide how much width is needed in the maxillae; *(2)* locates the maxillary incisors to the skeletal midline; *(3)* shows the occlusal plane cant; *(4)* shows the mandibular morphology; and *(5)* indicates what must be done for each clinical problem (Fig 9).

Today, more adult patients than ever before are receiving orthodontic treatment, with more sophisticated treatment goals and expectations. Identification of transverse and skeletal asymmetries from the frontal radiograph can be integrated with submental vertex and occlusal radiographic data to plan a multidisciplinary approach to adult treatment. Such frontal and asymmetry information is vitally important. For the degree of parallelism and symmetry of the facial structures, a plane is connected to the medial aspects of the zygomatic frontal sutures (Z-Z'). MSR normally runs vertically from Cg through ANS to the chin area, and will typically be nearly perpendicular to the Z plane. MSR has been selected as a key reference line because it closely follows the visual plane formed by subnasale and the midpoints between the eyes and eyebrows.

Frontal tracing steps

It is important to first locate christa galli and construct a midfacial line vertically through ANS to establish the MSR. With this reference line in place, other key points will be observed. With significant asymmetries, an option is to properly position the patient for the frontal radiograph as described earlier; orient the head to film and then use just one ear-rod. In this way, the patient does not have to turn or tip the head (which creates image distortion) to fit into the cephalostat. Position the patient, keep one ear rod in, instruct the patient to swallow so a natural posture is assumed, then take the radiograph or digital image. A plum line wire can be used for a true vertical reference line on the image. View the image to check landmarks to visualize foramen rotundum in the lower medial region of orbit, and to see that the distance from lateral orbital rim to the temporal region is about the same bilaterally. Once you confirm that head position and resultant image are acceptable, turn the posteroanterior (PA) radiograph backward to trace the image as an anteroposterior (AP) view, as if you are looking directly at the patient. The clinician is thus able to view photographs, mounted casts, frontal tracings, and the actual patient in the same way. So it is a PA image, but turned the other way, as an AP image, when it is traced and analyzed.

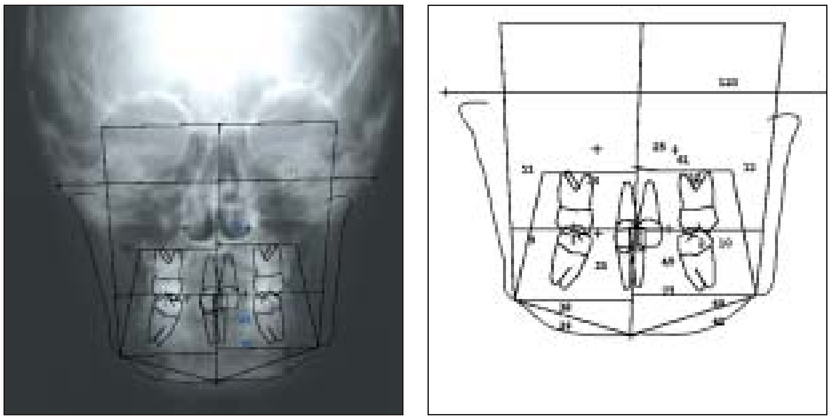


Fig 7a Computerized Ricketts and Grummons frontral tracings from three sources. Quick Ceph (San Diego, CA, USA). Combined Ricketts and Grummons frontal are shown.

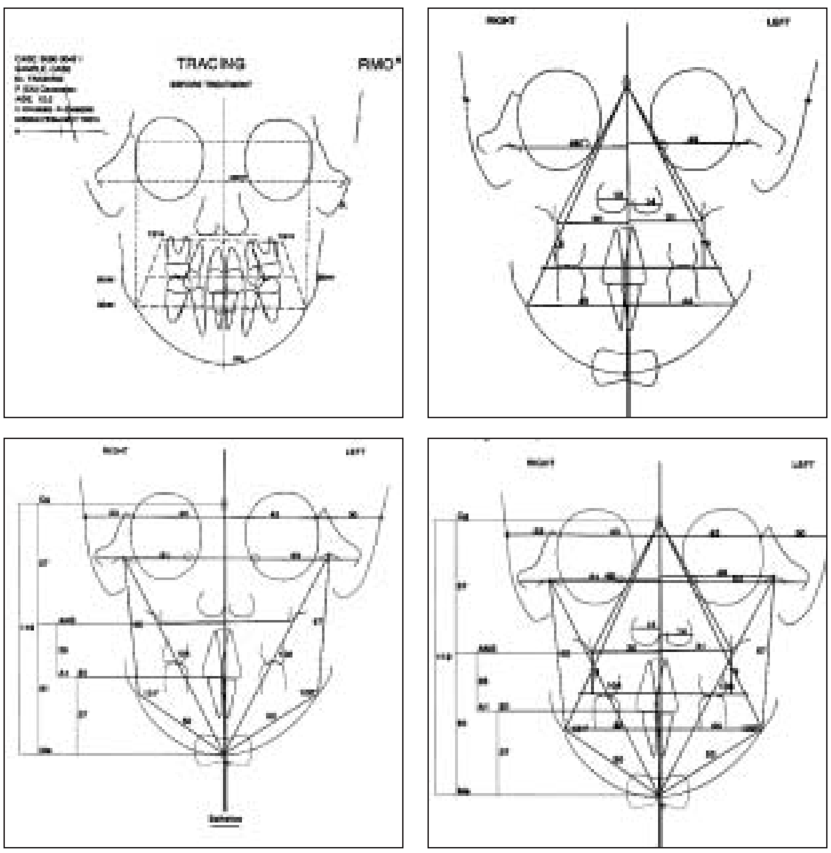


Fig 7b Rocky Mountain Data Systems (Los Angeles, CA, USA). Shown are Ricketts frontal, Grummons frontal/partial (2), and Grummons frontal/complete.

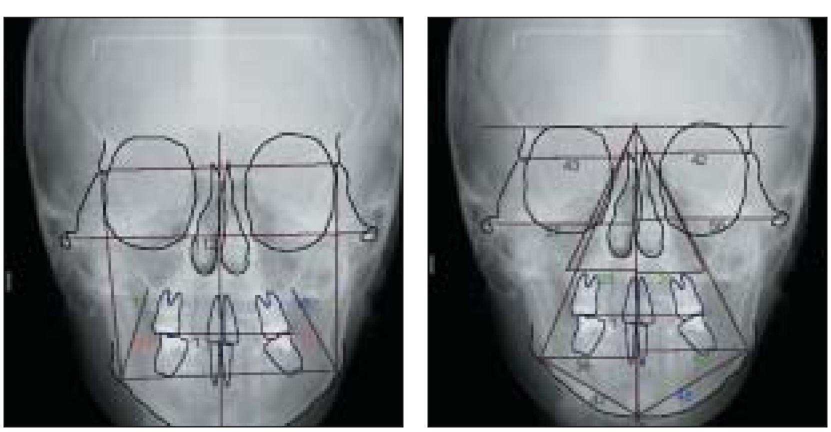
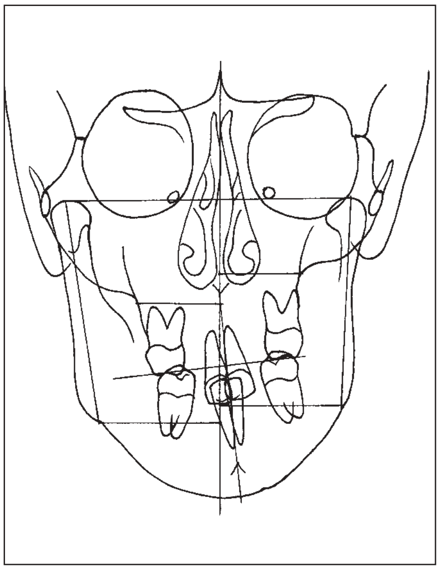


Fig 7c Dolphin Imaging (Los Angeles, CA, USA). Shown are Ricketts *(left)* and Grummons *(right)* frontals.



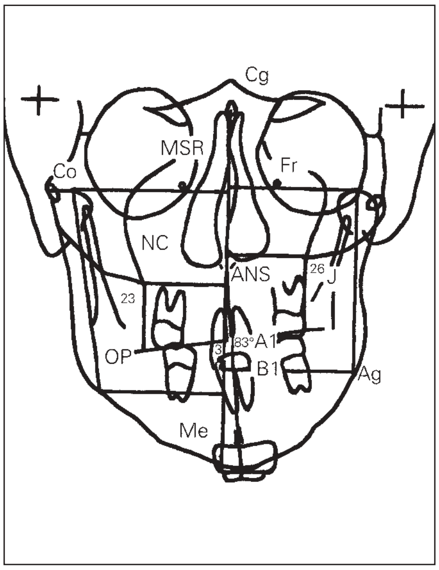
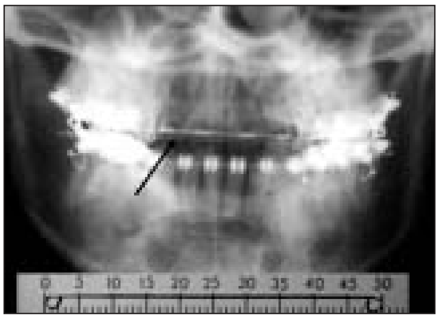


Fig 8 Grummons frontal analysis. The right and left side differences are visually evident by observing the intersections at the midline reference.

Fig 9 Grummons frontal analysis. Perpendiculars from bilateral structures are constructed to this vertical midsagittal reference (MSR) line. The differences between the projections from the two sides are then measured and compared to quantify discrepancies in height, as well as in the distances between the bilateral structures and the midline. In addition, the maxillary and mandibular dental midlines are compared to the skeletal midline.



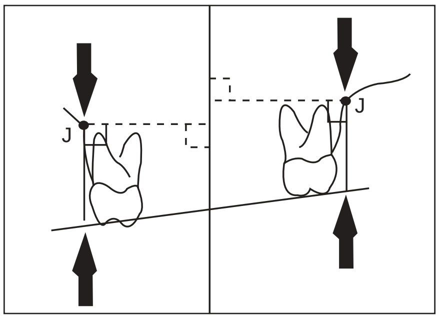


Fig 10 Wire (50 mm) on the occlusal surface at maxillary first molars depicts the true occlusal plane.

Fig 11 Occlusal plane tipped, due to underlying maxillary skeletal vertical asymmetry.

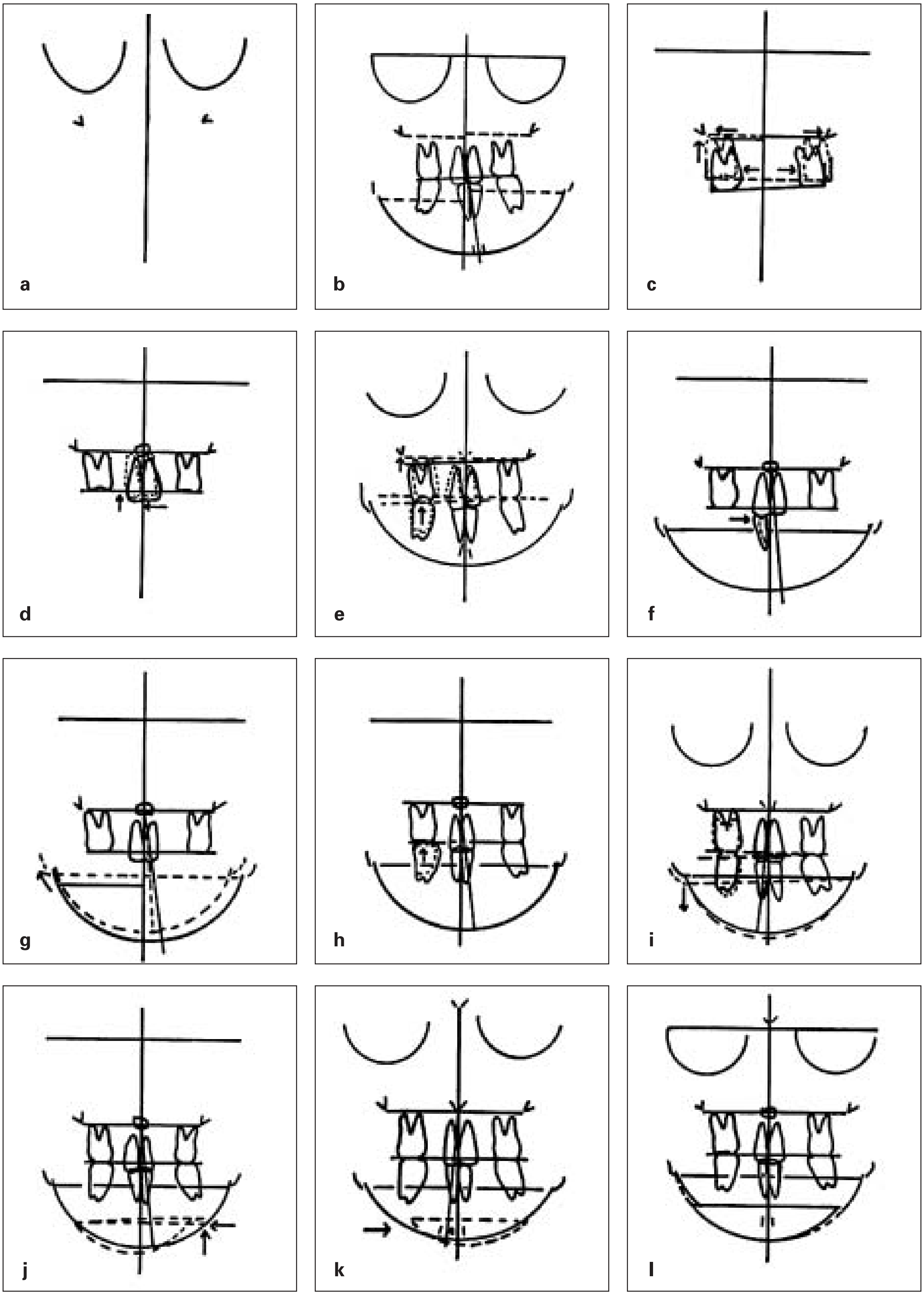
Midsagittal reference

The skeletal midline reference is constructed from christa galli vertically through anterior nasal spine (ANS) and extended inferiorly beneath the chin. From this line, the clinician can view laterally (transversely) to assess relationships of skeletal/dental references. It is simple and useful to follow down this midsagittal line and compare the intersection of the right and left lines at the point where they intersect MSR. This permits the clinician to readily see differences and make comparisons of right and left landmarks. For example, if the line from right-side antegonion (Ag) is 3 mm above the intersect of the left Ag line, then the clinician readily knows that these points and anatomic regions are different by 3 mm vertically.

From the MSR reference line, extend a perpendicular line to maxillary lateral J points, each condylion, and each Ag. Look down the midline; if the lines do not match or intersect at MSR, one side is higher than the other by the difference observed at the midline. Locate the chin and measure the number of millimeters it is off the midline at MSR. To visualize and trace the true occlusal plane is difficult. It is helpful to keep three 0.014-inch size wires (50, 55, and 60 mm long) in the office imaging area. Place one of these wires mesial to the maxillary first molars and let it extend buccally beyond the molars, so the wire can be easily located bilaterally on the radiograph to trace the true occlusal plane (Fig 10). Construct the occlusal plane using the occlusal wire as a guide. This frontal view helps decide how much width is needed in the maxilla, determine the occlusal plane cant and what must be done for it to become level, and consider midline issues.

Frontal visual treatment objectives and superimpositions

Frontal visual treatment objectives (VTO) construction is beneficial. The clinician can focus upon maxillary skeletal and dental relationships, midline, and occlusal plane measures. A new maxillary plane can be constructed to show the feasible treatment changes and objectives. Superimpositions readily show the pretreatment, progress, and/or posttreatment comparisons to identify the specific treatment changes and benefits that are desired or have occurred (Figs 11 and 12).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Posteroanterior tracing (VTO) using Grummons simplified frontal analysis[8]

1. When tracing the PA cephalogram, reverse the radiograph, observing it as an AP view. Anatomic points/areas are located on this PA radiograph/image. Label the radiograph for left and right sides. The tracing will then correspond with the patient in casts, photographs, and as the patient appears to himself. This will minimize confusion during analysis, as well as in conversations with the patient and/or other clinicians.
2. Check the clinical midline of the maxillary central incisors and compare to the MSR skeletal midline. The headfilm and clinical observations should coincide. Locate christa galli (Cg) or nasion (Na), the center of anterior nasal spine (ANS), draw MSR, and extend this line inferiorly beyond the chin (Me) reference point.
3. Draw the occlusal plane (OP). Use a wire transversely across the palate at the maxillary first molars to depict the true maxillary occlusal plane. When taking the frontal radiograph, position a 50- to 60-mm length of 0.014-inch wire (extending wider than the molars) at the mesio-occlusal of the maxillary first molars and have the patient bite together. The wire will be visible in the image when tracing the true maxillary molar occlusal plane.
4. Locate the maxillary incisors and maxillary dental midline in relation to MSR.
5. Locate midsymphysis of the mandible. Determine how many millimeters the chin reference (ME) is located laterally from the MSR.
6. Relocate the maxilla: Is the transverse sufficiently wide? Should posterior segments be moved up or down? Are the incisors aligned to MSR midline?
7. Relocate the maxillary incisors: vertically, confirm midlines by clinical input and direct visual observation; at MSR, move frontal tracing laterally; upright the axial inclination; as occlusal plane levels, incisors re-angulate.
8. Relocate the mandible: chin to MSR—position of best tooth fit influences this decision. Possible observations include *(1)* symmetric and acceptable; *(2)* asymmetric and subtle; *(3)* accept as is; or *(4)* plan for a secondary chin procedure. Occlusal plane findings: *(1)* molars level as is; *(2)* asymmetric, accept as is; *(3)* erupt molars to become level
9. Chin may be: *(1)* symmetric as is; *(2)* asymmetric, accept as is; *(3)* asymmetric, and may be moved laterally to MSR, vertically to 45%/55% (1/3:2/3 proportions), a mentoplasty wedge for chin balance and symmetry may be an option; excise or shape bone versus graft to add support, or plan for implant enhancement.

Mandibular border may need enhancement or recontouring.

Other options to enhance facial harmony and esthetics, as desired and indicated.

POSTEROANTERIOR (FRONTAL) ASYMMETRY

Optimal transverse dimension yields esthetic advantages, compared to less appealing narrow arches and smiles. Midlines should be centered, with pleasing facial and dental features. The patient should triumph with good self-esteem and a radiant smile after treatment. Facial width inadequacies are best influenced by orthopedic intervention. Nonextraction approaches provide the best functional occlusion, structural stability, with full esthetic smile transverse harmony, and lip support (Fig 13).

Symmetry objectives should be a priority at the beginning of treatment, rather than waiting to overcome midline challenges later, or having to remove a premolar to compensate. Several authors have detailed

Fig 12 *(Facing page)* Frontal tracing and surgical-orthodontic VTO/VTG planning steps: **(a)** locate midsagittal reference plan (MSG); **(b)** locate lateral maxillary and lateral mandibular anatomic points/planes, occlusal plane; mandibular midline (menton); **(c)** overlay tracing with leveled occlusal plane reveals extent of osteotomy required to create symmetric maxillary component; **(d)** locate incisors to treatment objective and center on facial midline (MSR); **(e)** trace key landmarks and lines on overlay tracing; **(f)** position mandibular overlay optimally to level horizontally Ag-gA plane with chin at midline (decision about possible separate chin osteotomy may be needed to reach best-fit occlusion and a centered chin in the final result); **(g)** when occlusal plane is set level, mandibular Ag-gA plane and chin are still asymmetric; **(h)** symmetry of lower facial two-thirds exists, as does molars best-fit occlusion; **(i)** if mandible is positioned to best symmetry, then molars are not reaching on the short side (these can be erupted and leveled postoperatively); **(j)** if chin is more than 3 mm off facial midline (MSR), then consider chin relocation for centering and lower facial third proportionality (side overlay tracing so Me region is on MSR and the contour of chin border is balanced); **(k)** measure/record chin reference point changes to predict millimeters of movement laterally, rotationally, and vertically; **(l)** symmetric outcome predicted and summary of treatment changes and extent/location of surgical moves are known and calculated.

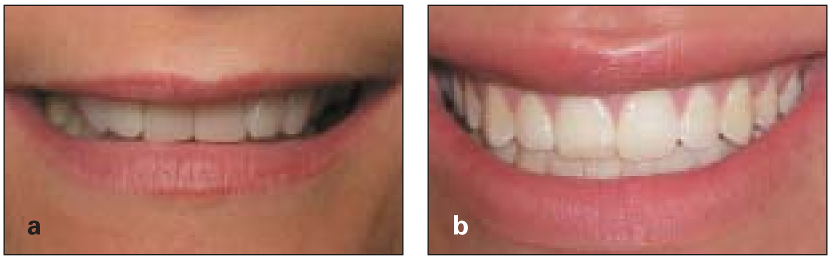


Fig 13 Maxillary arch width harmony and pleasing display of teeth are treatment priorities. **(a)** Narrow arch. Buccal corridors may have negative space, vacant commissures, black space at corner of smile, and edentulous appearance. **(b)** Broad arch.

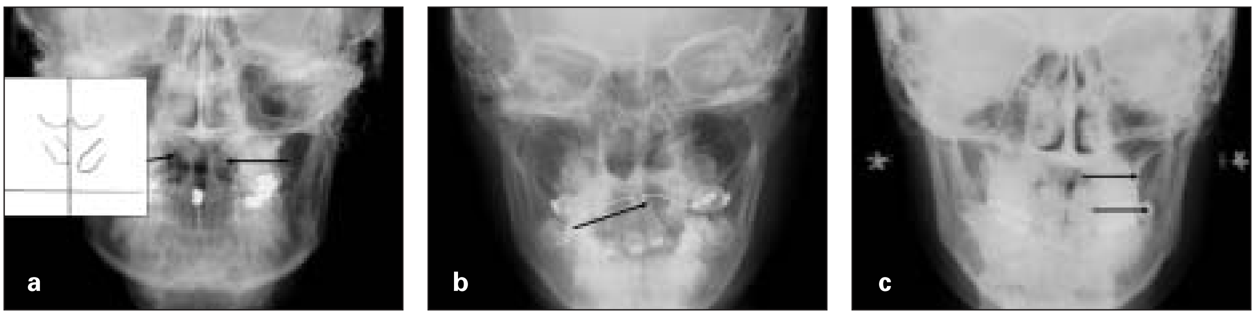


Fig 14 Clinical applications of frontal imaging: locate impactions; assess craniofacial condition; and assess skeletal dysplasia conditions. **(a)** Impacted maxillary canines, frontal (PA) image. **(b)** Unilateral cleft palate visualized. **(c)** Maxillomandibular (skeletal) width deficiency of maxilla results in crossbite.

frontal goals to include the upper dental-to-skeletal midline, vertical and horizontal placement of maxillary incisors to the smile line; leveling the occlusal plane; and opening space for any missing maxillary incisor for symmetry and best smile harmonies.[4,8,11,14,17]

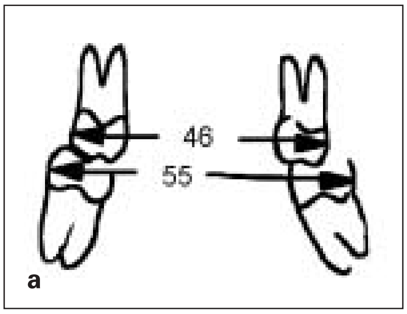
HARD TISSUE ANALYSIS PINPOINTS DENTAL AND SKELETAL ASYMMETRIES

The simplified Grummons frontal analysis provides a practical method to determine conditions, locations, and extent of facial asymmetry using hard tissue analysis (Fig 14). It is useful for orthodontic, facial orthopedic, and/or orthognathic surgery applications and is of greatest clinical value when integrated with frontal cephalometics, submentovertex and/or occlusal radiographs, and photographs. It allows the clinician to pinpoint the MSR line to compare the right and left sides for transverse asymmetry, disproportional relationships, and overall facial harmony or imbalances. Most computerized cephalometric programs now feature this analysis.

ASYMMETRY IN THREE PLANES OF SPACE WITH A GROWING PATIENT

In the growing patient, growth redirection (inhibition or expression of growth anteroposteriorly, transversely, and vertically) and maxillary orthopedic and/or dental expansion are additional treatment considerations. One of the priorities with the patient in Figs 15 to 17 was to correct the maxillary arch issues simultaneously in all three planes of space: widen the palate, distalize the molars, and control the vertical dimension at the molars. To deal with such cases, an innovative appliance called the Grumrax (Leone, Florence, Italy) expands and differentially distalizes molars. In addition to these functions, it also controls the vertical dimension (3-D) and the maxillary molar positions. In this case, the maxillary left molar needed to be intruded as it was moved distally, for the occlusal plane to become level and for the midline to move toward the center. The appliance can also be used to extrude or hold molars against their usual eruption down the facial growth axis. Thus, it can alter the occlusal plane, create more arch length on one side compared to the other at the molars, and it assist in relocating the dental midline to the midfacial skeletal midline (MSR).

Many innovative RME appliance designs are available. The Grumrax 3-dimensional maxillary expander effectively corrects transverse deficiency in the growing patient. It achieves maxillary molar derotation and distalization, with differential vertical control of the molars and functional occlusal plane. Asymmetric distal, vertical, and lateral molar movements can be produced by varying molar spring adjustments (see Figs 16 and 17). Preformed Grumrax expanders (Leone) with molar distalizer springs permit the clinician or technician to fabricate and place the appliance in one



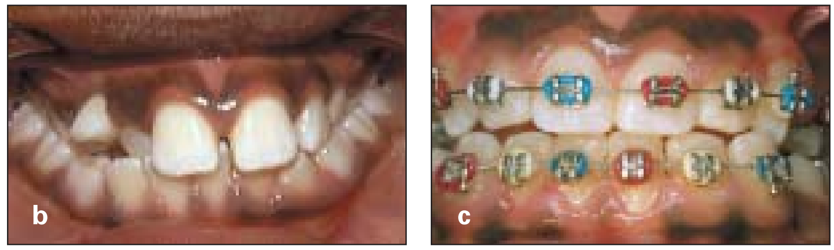


Fig 15 Transverse dimension treated first with asymmetric RME facial orthopedics (intermolar width increased and midlines are better).

Fig 16 Asymmetric space gainers achieve greater space gain on deficient side. This space was used for Class I and midline corrections.

Fig 17 Asymmetric expansion concepts include **(a)** unilateral spring + sheath to molar as per Grumrax expander series; **(b)** RME screw placed at an angle.**(c,d)** The Grumrax space gainer permits differential and asymmetric space gain at molars. This permits the dental midline to become corrected to match the facial midline. Molars can be unilaterally extruded or intruded, which levels the occlusal plane. Thereafter, orthodontic therapy can be more routine, with the finished result becoming symmetric.

step. Such efficiency and convenience have significant advantages.

Molar teeth can upright (greater inter-root distance mesial to maxillary first molars) as they distalize, and radiographs confirm that arch-length gain is significant. Utilize and leave the 3-dimensional appliance in a few months longer for molars to upright (inter-root distance) and skeletal/dental changes to stabilize. Significant arch length is gained in a short time. Asymmetric gains at molars and midline are able to be achieved. These appliances are tolerated well and are effective for differential space gain with little cooperation or compliance required. This helps achieve the treatment goal with a smile that fills the lips (buccal corridor) transversely, and with symmetric midlines and a

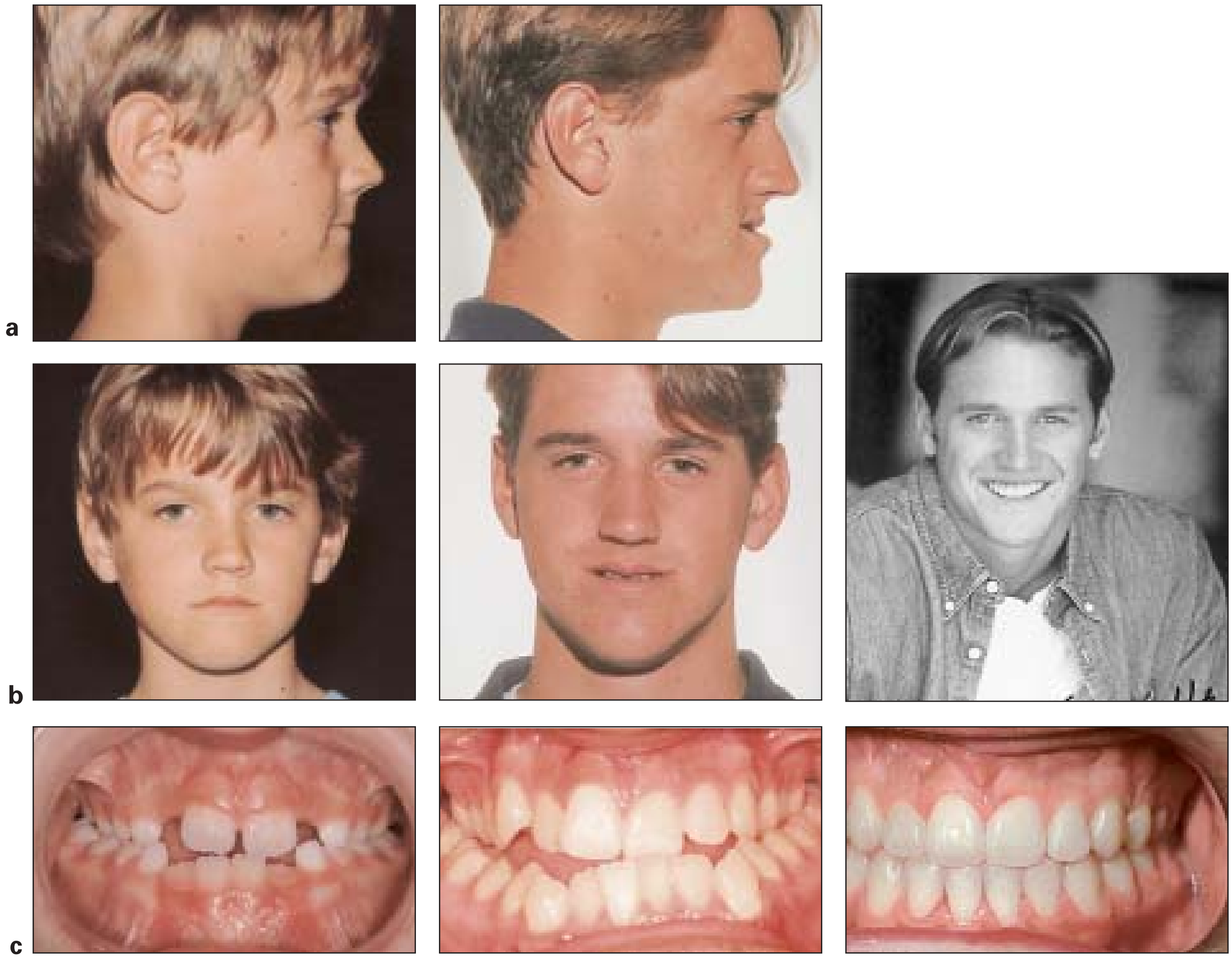
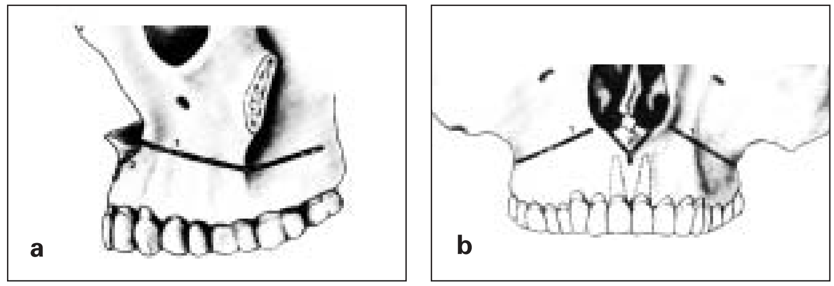


Fig 18 Patient with maxillary asymmetric transverse hypoplasia, mandibular asymmetric hyperplasia, crossbites, Class III traumatic occlusion, and facial imbalances with disharmonies. Shown at ages 8, 18, and 20 years. **(a)** Profile. **(b)** Frontal. **(c,d)** Intraoral views. Optimal arch uprighting and alignment were achieved.

Fig 19 Two-stage orthognathic surgery was performed on patient in Fig 18 at age of 19 years. Asymmetric SARPE with parasagittal and delayed piriform osteotomy was performed first, combination of maxillary advancement and mandibular setback osteotomies. (Drawings courtesy of Timms DJ, Rapid Maxillary Expansion. Chicago: Quintessence, 1981).



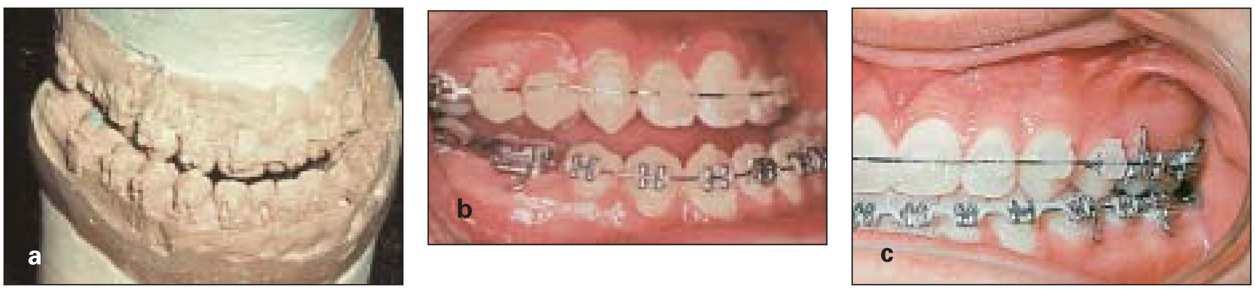


Fig 20 Maxillary asymmetric expansion was achieved with SARPE and mandibular osteotomy at age 19 years. **(a)** Presurgical articulated models. **(b)** Presurgical decompensated alignment. **(c)** Postsurgical transverse bite correction.

leveled occlusal plane. Then, transition into a quadhelix or transpalatal bar, or permit naturalized growth to maintain the transverse gain.

Surgically assisted maxillary/palatal expansion

Nongrowing patients with maxillary transverse hypoplasia benefit from surgically assisted rapid palatal/maxillary expansion (SARPE), in conjunction with an expansion device. This widens the dentoalveolar portion to create arch space for tooth alignment and smile width, while improving stability of results and lessening the need for extraction orthodontics. Sarver described vestibular incisions similar to the LeFort I osteotomy, with a midline vertical incision between the maxillary central incisors.[18] A parasagittal or paramedial palatal incision can be included for more palatal expansion. Grummons suggested that the lateral nasal piriform rim can be left partly intact unilaterally after SARPE surgery, so that expansion initially begins on the more deficient maxillary side.[8] As the initial unilateral expansion progresses, minor surgical re-entry to incise/release the contralateral piriform area then permits expansion bilaterally and symmetrically to the desired treatment objective (Figs 18 to 21).

In the patient shown in Figs 18 to 21, maxillary asymmetric expansion was achieved with SARPE (surgically assisted rapid palatal expansion) and parasagittal palatal incision at age 19 years. The piriform aperture region (lateral nasal region) was not separated initially, so that the expander appliance could produce greater expansion on he opposite side for the first turns (4 mm gained on most hypoplastic side) over 1-week timeframe. At this stage, the piriform area was accessed with minor surgical entry and dissection of bone. Thereafter, the remainder of expansion was essentially equal on each side (another 20 turns yielded 5-mm gain and this was sustained until removal of expander 3 months after last turns were done). Net results were a gain of 9 mm of maxillary intermolar width, with 6 mm on one side and 3 mm on the other side. As the maxillary expander turns were being done, the maxillary anterior teeth were being consolidated toward the midline. In the author's experience, if an excessive diastema is permitted to develop between the maxillary central incisors, the interseptal papilla tends to overstretch and remodel, resulting in less than complete gingival fill at the midline, with dark

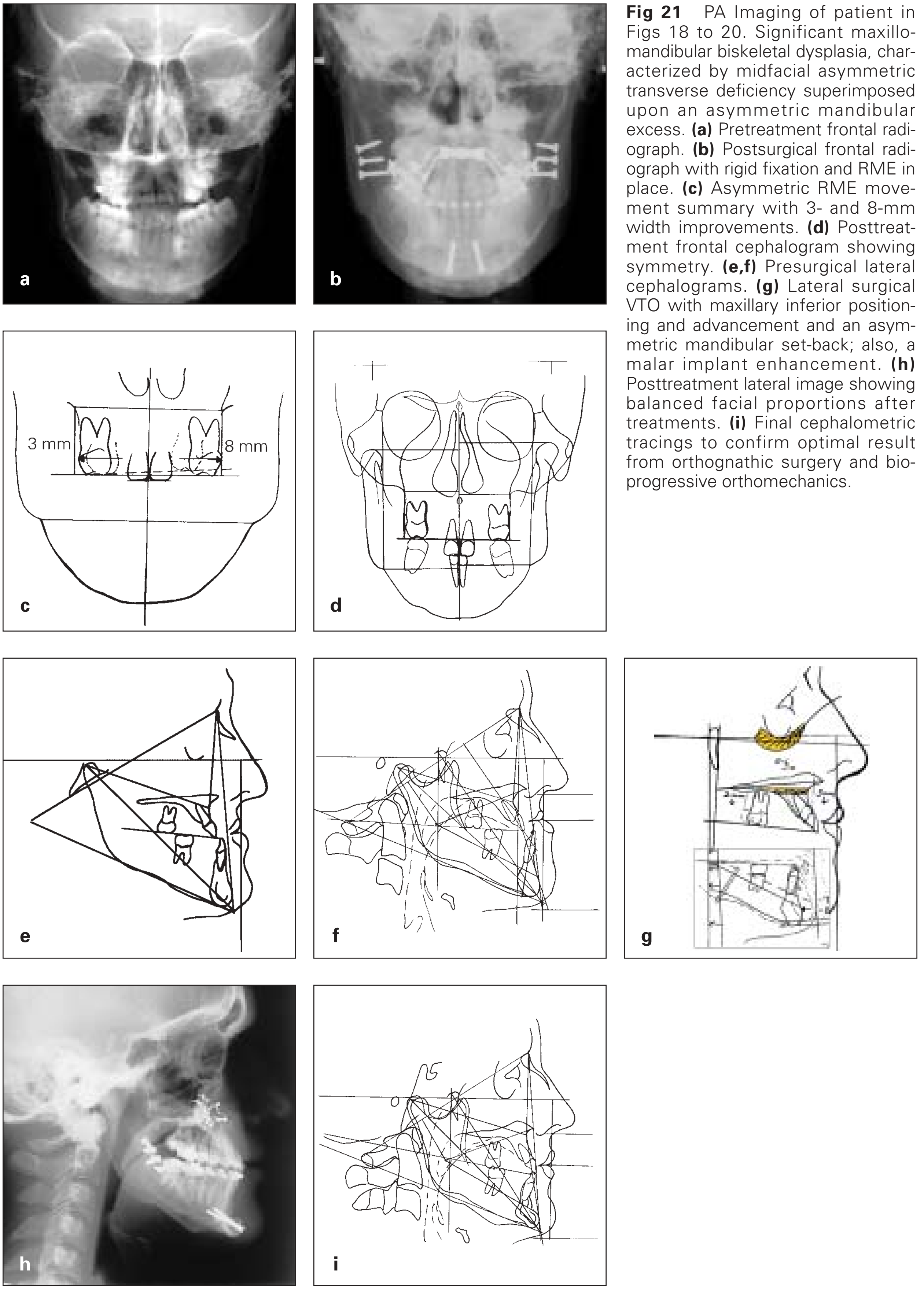


Fig 21 PA Imaging of patient in Figs 18 to 20. Significant maxillomandibular biskeletal dysplasia, characterized by midfacial asymmetric transverse deficiency superimposed upon an asymmetric mandibular excess. **(a)** Pretreatment frontal radiograph. **(b)** Postsurgical frontal radiograph with rigid fixation and RME in place. **(c)** Asymmetric RME movement summary with 3- and 8-mm width improvements. **(d)** Posttreatment frontal cephalogram showing symmetry. **(e,f)** Presurgical lateral cephalograms. **(g)** Lateral surgical VTO with maxillary inferior positioning and advancement and an asymmetric mandibular set-back; also, a malar implant enhancement. **(h)** Posttreatment lateral image showing balanced facial proportions after treatments. **(i)** Final cephalometric tracings to confirm optimal result from orthognathic surgery and bioprogressive orthomechanics.

unesthetic triangular embrasure space. The final alignment proves the midline papilla was protected and preserved. So long as periodontal ligaments are intact, the incisors can be moved and bone will follow to fill the osteotomy site at maxillary midline between these teeth.

After the second piriform incision, both sides expand now to the symmetric clinical objective, with greater width correction on the deficient side. Asymmetric crowding in the mandibular arch mirrors the asymmetric skeletal problem in the maxillary arch. If the mandibular arch has one side constricted more, that side will be more crowded. As the maxillary arch expands more, the mandibular arch can become aligned. Unilateral surgical expansion of the adult maxilla is a sophisticated challenge. A surgical release incision above the maxillary teeth apices and at the pterygoid plates relieves and permits skeletal widening transversely. The lateral nasal piriform area intentionally remains connected on the side of least maxillary constriction. Once some transverse correction occurs, the other piriform area is set free surgically (in-office procedure) so that symmetric, bilateral expansion can continue to the desired treatment requirement.

CONCLUSION

The transverse perspective deserves great appreciation and attention with today's 3-dimensional treatment and esthetic emphasis. Best facial development, shaping, and proportionality with harmonious smile development occurs when the transverse, skeletal, and dental dimensions are optimized.

Dental asymmetries and a variety of functional deviations can be treated orthodontically. Structural facial asymmetries are not addressed by, nor amenable to, orthodontic treatment alone. Excessive dental compensations and unfavorable, unesthetic conditions should be prevented. These problems require orthopedic correction during the growth period, and/or surgical management at a later stage of development. Ordinary cases may be routine, while unusual asymmetry problems challenge the understanding and expertise of the therapeutic team. The capability to differentially handle such patients has advanced immeasurably through better patient management and predictable treatment responses, with therapy based upon fundamentals of basic science and with clinical sensibility in comprehensive and definitive approaches.

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