ELSEVIER
SAUNDERS

THE DENTAL CLINICS OF NORTH AMERICA

Dent Clin N Am 50 (2006) 69–86

Developmental Occlusion, Orthodontic Interventions, and Orthognathic Surgery for Adolescents

Daniel J. Rinchuse, DMD, MS, MDS, PhD*,
Donald J. Rinchuse, DMD, MS, MDS, PhD

Orthodontics and Dentofacial Orthopedics, School of Dental Medicine, University of Pittsburgh, Pittsburgh, PA, USA

Orthodontic treatment of the adolescent patient presents many unique opportunities that may not be possible for adults. Orthodontics in the mixed dentition may have two putative advantages over treatment of an adult who has permanent dentition: (1) with primary teeth present, leeway space and E-space (primary second molar space), could be used; and (2) growth could ostensibly be modified or redirected. Several recent developments in orthodontics are not age dependent: removable invisible aligners, self-ligating brackets, maxillary molar intra-arch distalization, and implant-assisted orthodontics. Currents trends in orthognathic jaw surgery include rigid internal fixation (RIF) and distraction osteogenesis (DO).

Dental arch development

Because a child is growing in stature, parents and dental practitioners often assume that dental arches will also grow or increase; however, this may not be the case. As early as 1959, Moorrees [1] demonstrated that arch length decreases over time from mixed dentition through the transitional dentition and into early adulthood. It is unfortunate that the arches tend to constrict in the anteroposterior and the transverse dimensions, with added crowding if the dental arch is already inadequate [2]. Therefore, a short arch length only becomes smaller over time. This trend was true for treated and untreated normal subjects [3].

Some orthodontists advocate expansion of the maxillary arch with a rapid palatal expander in the absence of a posterior crossbite. The belief is that the

* Coresponding author. 510 Pellis Road, Greensburg, PA 15601.
E-mail address: drinchuse@aol.com (D.J. Rinchuse).

0011-8532/06/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.cden.2005.09.005

mandibular intercanine width reciprocally expands as the maxillary arch is actively expanded. If this does not happen, then active expansion of the mandibular width, possibly with a Schwarz appliance, is recommended. Gianelly [4] pointed out, however, that any expansion of the mandibular intercanine width is not stable.

Expansion, E-space preservation, and arch length discrepancies

Although virtually all orthodontists use palatal expansion in the presence of a posterior crossbite, there are some who use rapid palatal expansion (RPE) in the absence of a posterior crossbite. Advocates [5,6] of this type of treatment believe that this type of expansion provokes spontaneous expansion of the mandibular arch, particularly the intercanine width, resulting in spontaneous correction of Class II malocclusions. In addition, they proposed that Class II patients who have overjets treated with RPE are inclined to posture the mandible forward and that subsequent mandibular growth will make this initial postural change permanent.

Contrary to this hypothesis are data and evidence provided by Dr. Anthony Gianelly who questioned why anyone would use RPE in the absence of a posterior crossbite [7]. In a recently published article, Gianelly [8] codified the logic, rationale, and literature supporting the principle that RPE in the absence of a posterior crossbite is contraindicated. Similarly, Bowman [5] argued that expansion in the absence of a crossbite to resolve crowding is unscientific and predisposes patients to periodontal problems, pushes teeth out of the envelope of supporting alveolar bone, and is not stable.

A more conservative, nonextraction, approach for resolution of crowding is arch length preservation by the use of leeway space, or E-space [9]. Leeway space is the space available due to the differences in widths of the primary canine, first molar, and second molar compared with the widths of the permanent successors (canine and first and second premolars). Therefore, if leeway space can be preserved, then about 4 mm of space/arch length in upper and lower arches may be gained. The preservation of leeway space is the best way to manage tooth-size-arch-length discrepancies.

Therefore, with proper management of leeway space in the late mixed dentition, approximately 75% of Class I and II malocclusions with good facial balance can be resolved without any extractions [5]. Bowman [9] further pointed out that to avoid premolar extractions with 5 mm of crowding in each quadrant, it would require 12 mm of stable expansion. This amount of stable expansion has not been demonstrated in the known orthodontic literature.

Timing of treatment

According to the American Association of Orthodontists, an orthodontist should examine a child by age 7 years. There are three major approaches to timing of orthodontic treatment. One approach is early phase I treatment, sometimes referred to as growth modification. For difficult cases with skeletal and facial discrepancies, early phase I treatment may reduce the extent of future comprehensive phase II treatment. This treatment may possibly begin at age 7, 8, or 9 years during active growth. Turpin [10], the editor of the American Journal of Orthodontics and Dentofacial Orthopedics, said that 70% of McNamara's mixed dentition patients receive early phase I treatment consisting of maxillary expansion and concomitant mandibular arch expansion for Class II correction. When there is a Class III facial or dental pattern (prominent chin, midface deficiency, or anterior/posterior crossbite), treatment at an age younger than 7 years may be indicated. This protocol is based on better treatment outcomes for which growth augments the orthodontic treatment.

Recent prospective randomized clinical trials at the University of Florida [11], University of Pennsylvania [12], and University of North Carolina [13], and in multicenters in England [14] have failed to demonstrate the advantages of two-phase orthodontic treatments. These prospective studies evaluated correction of Class II malocclusions with headgear and functional appliances such as Frankel, Bionator, and Twin-Block appliances. These studies, however, did not evaluate the use of fixed appliances in phase I treatment such as a maxillary "2 $\times$ 4" (molar bands and incisor brackets with various arch wires) and RPE, among other modalities.

A second approach, advocated by Gianelly [15], is preservation of arch length, leeway space, and E-space in the late mixed dentition at approximately age 10.5 years. This age is variable, however, and the patient should be evaluated before age 10.5 years, probably around age 7 years. At that time, the orthodontist can decide whether nonextraction or extraction is preferred. The treatment can be completed in one phase within a reasonable time frame. Currently, this protocol probably has the most evidence to support its use [2,15a].

According to Gianelly [15], approximately 10% of orthodontic cases are truly phase I. Serial extractions and lingual arches are passive treatments and, therefore, are not active mechanotherapy. For that reason, they are not included in the following phase I treatments:

- Incisor crossbites or crossbites complicated by functional shift of the mandible
- Class III malocclusions, particularly those involving maxillary retrognathism
- Excessively protrusive and proclined maxillary incisors (accident prone profile)
- Habits such as finger sucking

Antithetical to the first approach that involves two-phase treatments, a third approach is to delay treatment until the primary teeth are exfoliated (even later than Gianelly proposed), and to do one treatment. There is evidence that patients who had two-phase treatments were indistinguishable from those who had only one treatment, except that it cost more for two-phase treatments and the treatment time was longer [16,17]. Nonetheless, there is still much controversy in the literature regarding timing of treatment.

Turpin [18] stated that evidence regarding many questions relevant to the correction of Class II malocclusions is lacking. Therefore, the Council of Scientific Affairs of the American Association of Orthodontists is searching for systematic reviews to answer the following questions:

1. Is there evidence that functional appliances result in greater mandibular growth than would normally occur?
2. Is there evidence that two-phase treatment has better outcomes than one-phase treatment for Class II patients?
3. Is there evidence that increased overjet is associated with increased trauma to the incisors?
4. Is there evidence that functional appliances result in alterations to the temporomandibular joint?
5. Is there evidence that maxillary molars can be distalized in a stable position?
6. Is there evidence that a particular method of Class II correction is more effective, efficient, or stable?

Extractions

Currently, some orthodontists attempt to treat all orthodontic patients without extractions. In a growing child with good facial balance and E-space preservation, it has been reported that under the best conditions, approximately 75% of orthodontic cases can be resolved by nonextraction [9,15]. Motivation for this nonextraction approach is high because orthodontic practitioners, parents, and patients like to avoid extractions and view this treatment as conservative. In addition, some orthodontists are not evidence-based in their thinking. The trends in orthodontics that employ alternatives to extractions of premolars lack scientific support. Case scenarios and anecdotal reports in non–peer-reviewed journals have incorrectly projected a belief that extractions cause unesthetic results such as "dished-in" faces and "dark spaces" at the corners of the mouth called the buccal corridor [8]. Proffit and Fields [19] presented the following guidelines for extractions in Class I crowded patients with good facial balance and no significant protrusion:

- Arch length discrepancy less than 4 mm: should be nonextraction
- Arch length discrepancy between 5 and 9 mm: some clinicians would extract and some would not
- Arch length discrepancy greater than 10 mm: extractions are almost always required

As another guide for extraction patterns, Gianelly [8] advocated mandibular arch-based diagnosis and treatment planning in patients who have

Class I and II malocclusions. With this strategy, if extractions are required in the mandibular arch, then extractions are also needed in the maxillary arch. Regarding maxillary arch-based diagnosis, however, the converse would not necessarily be true.

In response to the contention that extractions result in narrower dental arches compared with nonextraction therapy, Gianelly [20] recently demonstrated that this is not the case, and therefore, extractions do not produce dark spaces as some orthodontists claim.

In summary, the following is a quotation from Bowman [9] regarding extraction therapy:

> A review of the refereed literature provides little support for the view that premolar extraction has a routinely negative impact on facial esthetics and the functional health of the muscles and joints….If one believes that the elimination of extraction treatment is a goal more important than that of addressing the patient's chief complaints concerning protrusion, and if one is unconcerned with the possibility of pushing roots through cortical plates or of poor long-term stability, one can elect to treat all patients without using extraction. However, those who believe in avoiding extraction at all costs should give thought to the possibility that their only ethical option in many patients with crowding and protrusion would be either to refer or to render no treatment at all.

Serial extractions

From a 30-year retrospective time frame, Boley [21] discussed the indications and advantages of serial extractions in the mixed dentition followed by multibanded/bonded treatment in the permanent dentition. Some of the comments in that article were that premolar extractions do not produce poor facial balance, that Tweed believed that serial extraction would allow the mandibular incisors to tip lingually into a position of functional balance, and that shorter appliance treatment times in the orthodontic phase II treatment typically last 15 months [21].

Little and colleagues [2,22,23], however, concluded that first premolar serial extractions that were followed by orthodontic treatment had no value over conventional premolar extractions in the permanent dentition because both treatments produced similar results.

Class III orthodontic treatment

A Class III malocclusion is one with a strong, protruding chin; a deficient, small, upper jaw; or combinations or permutations of these conditions. Typically, the treatment protocol in addition to RPE is the use of a chincap or facemask. Recently, Ngan and colleagues [24,25] described treatment outcomes of Class III patients who had maxillary deficiency treated with facemask therapy in conjunction with maxillary expansion. The effects included positive overjet-forward movement of the maxilla, backward and downward movement of the mandible, proclination of the maxillary incisors, and retroclination of the mandibular incisors.

Mitani [26] responded to two questions regarding orthopedic changes from chincap therapy. When asked whether it was possible to inhibit or retard growth of the mandible with chincap force, he replied, "Presumably, chincap force can retard the mandibular form and condylar growth; these changes occur mainly during the first 2 years of chincap use." When asked whether chincap therapy could permanently correct a prognathic skeletal pattern, he stated, "Mandibular chin position will be greatly improved anteroposteriorly during the initial stage (approximately 2 years) of chincap therapy, the changes do not take place continuously after that, and the initial changes will not be maintained if chincap use is discontinued before facial growth is complete. Some vertical development of the maxilla might be inhibited."

In conclusion, Turpin [27] cautioned that in the long-run, total success should not be expected in a high percentage of patients. When Class III is severe, orthodontic treatment should be delayed until pubertal growth has terminated and the patient can be re-evaluated for orthognathic surgery.

Open bites

Although many treatment modalities are used in an attempt to correct an open bite (particularly an anterior open bite), the success rate of achieving correction with proper overlap of the incisors has been reported to be 80% [27]. In other words, 20% of patients do not attain correction of their open bite. The orthodontic treatments for open bite, used singly or in combination, include oblique headgear, clenching exercises, vertical elastics, posterior bite blocks, and orthognathic surgery [27].

There are many possible explanations for the instability of open bite corrections; however, the most critical is the nonadaptability of the tongue [28]. Most open bites are associated with a tongue-thrusting or reverse-swallowing pattern. Therefore, even after initial removal of orthodontic appliances with the open bite being corrected, the open bite may relapse due to the tongue-thrusting pattern.

Orthodontics and temporomandibular disorders

In the early 1970s, gnathologists believed that because orthodontists treated patients' occlusions to merely optimal static occlusion (morphologic) goals, possibly ignoring functional occlusion, they were producing iatrogenic "functional occlusions" predisposing to temporomandibular disorder (TMD) [29,30]. Sample studies [31], TMD national conferences [32–34], and systematic reviews [35,36] on this topic, however, overwhelmingly support the view that conventional orthodontic treatment and appliances do not cause TMD. Furthermore, orthodontic treatment does not generally cure or mitigate TMD [37]. Hence, orthodontic treatment is generally considered TMD "neutral" [31–37]. In addition, malocclusion per se does not predispose one to TMD [38]. The recommendation of orthodontic treatment for adolescents who have varying types of malocclusion for the sole purpose of mitigating future TMD is not evidence based [31–38].

Current trends

Invisible aligners

Removable orthodontic appliances (versus fixed appliances) have been used for tooth movement for more than a century. Notably, minor tooth movement has successfully been accomplished with such removable appliances as Hawley appliances, modified Hawley appliances, spring aligners, and positioners. A recent trend is the use of invisible removable aligners for minor tooth movement, with the most popular being Invisalign (Align Technology, Inc., Santa Clara, California) [39]. Although marketed for adults, there is no reason why adolescent orthodontic patients could not benefit from this technology. For the Invisalign technique, the dentist merely takes an impression and sends it to Align Technology, which fabricates multiple esthetic, transparent aligners. The patient is instructed to wear each aligner for approximately 22 hours per day for 2 weeks and to switch to a new aligner. Tooth movement is minimal (perhaps 0.25 mm per aligner) and is progressive from one aligner to the next. Several dozen aligners or more are needed for each case.

After an impression is received at Align Technology, a three-dimensional rendering of a dental model is made. From this original model, the Invisalign virtual orthodontic technician uses software to "cut" the virtual model and separate the teeth, allowing them to be electronically moved. The computer images are then converted to physical models using a process called stereolithography. Next, the physical models are used to fabricate aligners using a Biostar machine (Great Lakes Orthodontics, Ltd., Tonawanda, New York) [39]. As envisioned by Ackerman and Proffit [40], in the future, this technology could incorporate laser-scanned images of the mouth so that no impression is needed. These three-dimensional images of the teeth could be seamlessly integrated with three-dimensional photographs and radiographs and transmitted by way of the Internet.

The Invisalign technology was derived from work using Essix-type invisible aligners made in-house by orthodontists [41–45]. For the Essix aligners (Raintree Essix, New Orleans, Louisiana), an impression and dental cast are made first. Next, the model is altered to align to the teeth or to be repositioned. Repositioning the dental model for the desired orthodontic correction can be achieved in one of two ways. One is to make a wax setup in which the dental model teeth are cut and ideally repositioned. Another way to modify the dental model is to artistically "shave" (modify) the side of the tooth model that needs the force application and then block out (void) the opposite side where the tooth is to be moved. Documented in the literature [41,42] are a number of ways to accomplish these methods. Lastly, an Essix aligner is made over the model (Fig. 1). If the malocclusion is severe, then multiple impressions are needed to fabricate models and setups to progressively "move" teeth. One company has developed a system for fabricating noncomputerized, laboratory-made, Essix-like aligners. The dentist is sent approximately three aligners per impression/dental cast. If the correction is not achieved with the initial three aligners, then the dentist sends new models for additional aligners.

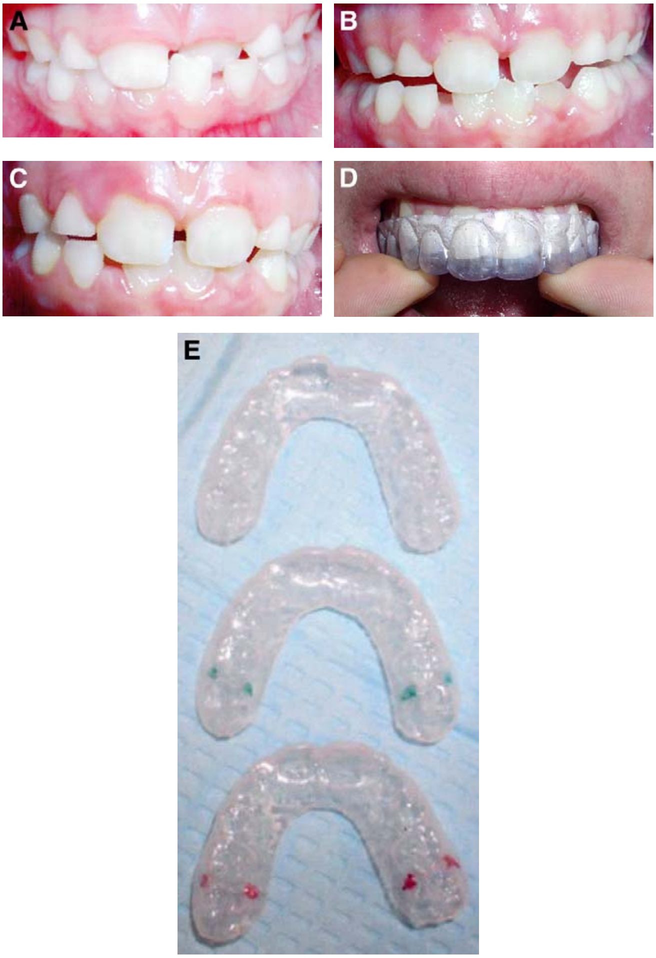

Fig. 1. Anterior crossbite of maxillary left central incisor corrected with the use of several Essix aligners. Treatment time was approximately 6 weeks.

There has been some criticism of invisible aligners [46]. The following are several of the antithetical arguments against their use:

- They are a very inefficient and costly way to move teeth. The invisible "trays" (aligners) are too rigid and not flexible enough for a "spring-type" force. This is one reason so many aligners are needed to treat cases with minimal tooth irregularities.
- Limited types of cases can be treated.
- The cases treated with them are the most difficult type to treat from the standpoint of patient satisfaction. That is, when the case does not appear to look that "bad" to start with, the expectation of the patient for a total correction and complete stability is much greater than for a case perceived from the beginning to be more difficult and "handicapping." Furthermore, if the patient is paying a significant amount of money for only minor orthodontic treatment, then he or she may be more particular about the result and its stability.
- They have some liabilities regarding patient comfort, particularly when they must be worn 22 to 24 hours per day.
- The corrections attained with these appliances are the most difficult to retain, and patients must wear retainers for perhaps a lifetime. Dentists treating cases with invisible aligners may therefore have to manage these patients for many years, possibly a lifetime.

Furthermore, traditional types of removable appliances such as modified Hawley retainers and spring aligners may be better and more economically suited for many of the cases now being treated with invisible aligners. In addition, the best outcome of treatment may involve any combination of invisible aligner, "clear" ceramic fixed appliances, and possibly a spring aligner. Turpin [47] added a caveat for the general dentist using invisible aligners: "The education and breadth of experience of an orthodontist are needed to successfully manage this unique approach to correcting malocclusions." He further stated that when his patients had a choice of treatment options (fixed appliances versus Invisalign), they assumed that the result would be the same [47].

Maxillary molar distalizing appliances

It is estimated that Class II malocclusions account for one third of all orthodontic treatments [48,49]. Headgears (night brace) and functional appliances alone or in combination with full fixed appliances (braces) have been the most popular appliances for class II treatment in children. The headgear can distalize maxillary first molars that are in a Class II relationship, resulting in a correction to Class I. In addition, the headgear may have an orthopedic effect in which it may affect maxillary-to-mandiblular growth relationships in adolescent patients. The net effect might be a retardation of maxillary growth with a relative increase in mandibular growth. It should be made clear that Angle's Class II malocclusions can be associated with various skeletal components such as retruded mandible, protruded maxilla, or a combination of each. Therefore, the appropriate choice of appliance for Class II corrections must include a consideration of the patient's skeletal pattern and dental classification.

Some contemporary thinking in orthodontics suggests that modern-day American children are less motivated and compliant regarding the wear of extraoral appliances (and any appliances in general). Hence, some orthodontists believe that headgear and functional appliances are no longer viable and realistic options for the children of the new millennium. In this regard, the search continues for nonextraction, noncompliant orthodontic appliances and techniques to treat Class II patients without the need of headgear or functional appliances. As a result, maxillary intra-arch molar distalizing appliances are currently popular and new types are appearing [50].

The basic idea for most maxillary intra-arch molar distalizing appliances is to secure anchorage intraorally without much (if any) involvement of the dentition. The most popular anchorage source is from the palate and the most popular appliance makes use of a fixed Nance button arch [50]. The Nance arch includes an acrylic button (approximately 1 cm in diameter) that lies against the palate and has incorporated wires that extend to both halves of the upper arch by way of a soldered connection to banded maxillary first bicuspids, or perhaps the second bicuspids. A force mechanism is then used against this anchorage system to distalize the first maxillary molars. Most systems rely on nickel titanium springs for their action. (The Pendulum appliance is an exception.) Typically, a nickel titanium open coil is compressed and then trapped between the bicuspids and first molars [50]. After the maxillary first molars are distalized, they are held in place with a "stopped" arch wire. The bicuspids drift naturally or they are orthodontically moved distally. Finally, the anterior teeth are retracted into the space gained through the use of the distalizer.

There are a number of intra-arch maxillary molar distalizing appliances. These include Distal Jet (American Orthodontics, Inc., Sheboygan, Wisconsin) (Fig. 2), Pendulum, Jones Jig, and a combined Jones Jig and Jasper Jumper. Maxillary intra-arch molar distalizing appliances generate approximately 70 to 100*g* on the maxillary molars [50]. The Distal Jet appliance is marketed as delivering 180 to 240*g* depending on whether or not the maxillary second molars are erupted. Studies for the Pendulum appliance have found that maxillary molars distalized approximately 5.8 mm, tipped 10°, and intruded between 0.7 and 1.7 mm and maxillary incisors flared 2.8° [49,51]. Even though the Herbst appliance is used for Class II treatments, it is not an intra-arch appliance but is an interarch appliance. Furthermore, the Herbst appliance effects are more directed at mandibular dentoalveolar protrusion.

Maxillary molar distalizing appliances are contraindicated in patients who have skeletal and dental open bites, high mandibular plane angles, excessive lower facial height, or proclined maxillary incisors [50]. Criticism of

Fig. 2. Distal Jet appliance. (Courtesy of Dr. Eric Wu, San Francisco, CA.)

these appliances is that they tip the maxillary molars distally rather than translating them through bodily movement. It is further argued that these appliances have the tendency to flare (procline) the maxillary incisors [50]. These appliances have no orthopedic effect, which is often needed for the successful treatment of many adolescence orthodontic patients. The data on the beneficial effects of these appliances are equivocal.

Anchorage: implant-assisted orthodontics

With the improved survival rate for dental implants, their use has been adapted for orthodontics anchorage support (Fig. 3). In place of traditional dental implants, specific orthodontic implants such as onplants, miniplates, miniscrews, and palatal implants have been developed. Miniplates have been advocated for molar intrusion, whereas palatal implants are used for space closure and maxillary molar distalization [52]. Most of the orthodontic implants, including miniscrews, are made of titanium (medical grade 4 or 5) and come in various sizes. Early data for implant-assisted orthodontics (sometimes termed "skeletal anchorage") have been encouraging [53,54]. There are a wide variety of applications for implant assisted orthodontics, including Class II correction (molar distalization), closure of extraction spaces, molar intrusion, molar extrusion, leveling a canted occlusal plane, alignment of dental midlines, extrusion of impacted canines, canine retraction, molar uprighting, and so forth [52]. The greatest advantage for using implant-assisted orthodontics is that it avoids the need for patient compliance [52]. Several other advantages of orthodontic implants are that multiple teeth can be moved without loss of anchorage and can be placed in areas where natural anchorage or conventional orthodontic appliances are impractical, including the edentulous spaces in the alveolus in either arch, the palate, the zygomatic process, the retromolar regions, and the ramus. In the maxillary arch, implants are typically placed in the midpalatal area or in the inter-radicular space between the roots of the first and second

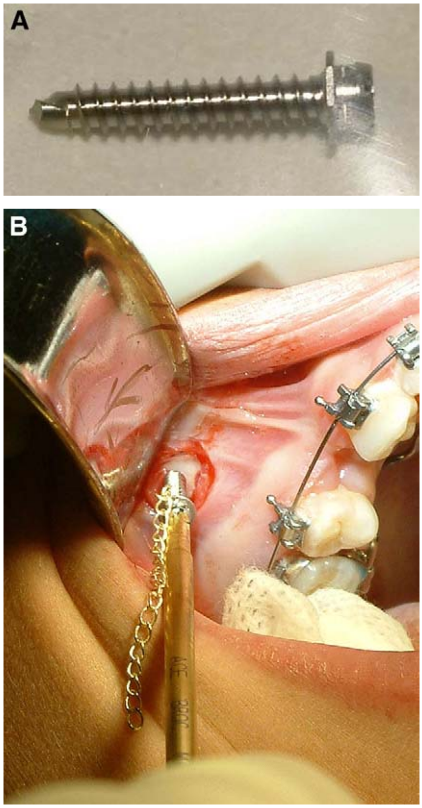

Fig. 3. Implant-assisted orthodontics. (Courtesy of Dr. Jeff Meckfessel.)

bicuspids depending on the specific type of tooth movement [52]. Limiting factors for the use of implants in orthodontics include (1) added cost; (2) some inconvenience to the patient with regard to their placement and maintenance; (3) inflammation around the implant; (4) possible implant failure due to fibrous encapsulation; (5) damage to anatomic structures such as nerves, vessels, and roots; (6) a healing period of approximately 3 to 6 months before orthodontic forces can be applied; and (7) no possible orthopedic use/effect (horizontal/sagittal dimension) [52–58]. The 2-year survival rate for mandibular implants is 100%, whereas for maxillary implants, the steadily increasing success rate is approximately 87.1% [55].

Patients who have congenital anomalies and developmental defects that have anchorage limitations can greatly benefit from implant-assisted orthodontics [59]. For adolescent orthodontic patients in whom growth/orthopedic effects are deemed unnecessary or anchorage considerations are maximal, the possibility exists for the use of implant-assisted orthodontics [53,54,57,58]. This benefit has been demonstrated for Class II extraction patients in whom overjets as great as 8 mm were reduced in 9 months with no loss of anchorage [54]. Some investigators, however, caution against the use of orthodontic implants for girls younger than 16 years and boys younger than 18 years [52].

Because midpalatal implants are located away from maxillary posterior anchor teeth, some connections must be made from the implant to these teeth. In this regard, there are two types of connections for midpalatal implants: direct and indirect. In the direct system, also called the Orthosystem, a transmucosal fixture with a clamping cap is fixed to the implant by an occlusal screw [54]. With the indirect system, the midpalatal endosseous implant provides anchorage indirectly by virtue of a connection to a transpalatal arch [57]. When orthodontic treatment using the palatal implant is completed, the implant is explanted (removed) with no residual defect after several weeks of healing. Bioresorbable implants made of polylactide with a metal superstructure are available [60].

Self-ligating brackets

Recently there has been resurgence in the use of self-ligating brackets. Self-ligating brackets incorporate a clip as a fourth wall instead of using stainless steel ligatures or elastomeres to engage the arch wire (Fig. 4). As early as the mid-1930s, the Russell attachment was developed to reduce ligating time and improve operator efficiency [61]. Currently, numerous self-ligating brackets have been engineered. The two main types are (1) those that have a spring clip that can press against the arch wire (In-Ovation [GAC International, Inc., Islandia, New York], SPEED [Strite Industries, Ontario, Canada], and Time brackets [American Orthodontics, Inc.]) and (2) those that have a clip, like a buccal tube, that does not press against the arch wire (Damon [Ormco/"A" Company, Orange, California] and Activa ["A" Company]) [61].

Compared with conventional brackets, self-ligating brackets demonstrate exceptional performance with regard to lower frictional values, reduced treatment times/chair time, and increased patient comfort [62]; however, there are many factors that affect frictional forces, such as wire dimension

Fig. 4. Traditional brackets (*A*) compared with self-ligating brackets (*B*). Notice red rubber ligatures on traditional bracket system that are not necessary in the self-ligating system.

(size), bracket (width, slot), wire material, angulation, ligation forces, and interbracket distance [61]. Patients claim that self-ligating brackets are generally smoother, more comfortable, and more hygienic because elastic or steel ligatures are not used [61].

Orthognathic surgery

Timing

Orthognathic surgery to reposition the maxilla, mandible, or chin is a viable treatment option for dentofacial deformities too severe for orthodontics to camouflage alone. Generally, surgeons prefer to wait to perform orthognathic surgery until growth has ceased. According to Profitt and Phillips [63], however, early surgery is indicated primarily in two instances: (1) in extreme conditions such as in patients who have craniofacial syndromes or facial distortions for whom quality of life is significantly affected; and (2) in patients who have progressive deformity in which the condition steadily worsens (eg, the affected area grows less than the adjacent normal areas such as in mandibular ankylosis). The object of surgical treatment in these cases is to create an environment in which subsequent growth is possible rather than an attempt to correct the discrepancy.

Rigid fixation versus wire fixation

A rather recent trend in orthognathic surgery is the use of RIF versus traditional interarch dental wire fixation. Traditional wire fixation involves the use of interarch wires as the major component of fixation, and for certain situations, it is still indicated. With wire fixation, the patient's teeth are ‘‘locked’’ (‘‘wired’’) together for as long as 6 to 10 weeks and the patient ‘‘feeds’’ through a straw. RIF involves direct and rigid fixation of bony segments through the use of small plates and screws at the line of surgery. With RIF, the period of maxillomandibular fixation and jaw immobilization can be greatly reduced, and in most cases eliminated, after surgery. The patient who is treated with RIF is able to open the mouth immediately and eat normally. The obvious advantage for patients who have rigid fixation is improved comfort and convenience. There also are the added advantages of increased stability in the immediate postoperative period and more rapid bone healing [64].

Stability

With reduced reimbursements for orthognathic surgery and concerns for stability, one-jaw procedures are preferred over double-jaw procedures (ie, both maxilla and mandible). In addition, rigid fixation procedures generally are more stable than traditional wire fixation procedures. Surgical interventions are best performed at completion of growth. Proffit and Phillips [63] established a hierarchy of stability for particular surgical procedures, assuming normal facial height for the perspective orthognathic patient:

- Category 1 (very stable)
  - Maxilla up
  - Mandible forward
  - Chin any direction
- Category 2 (stable)
  - Maxilla forward
  - Maxilla—asymmetry
- Category 3 (stable, rigid fixation only)
  - Maxilla up plus mandible forward
  - Maxilla forward plus mandible back
  - Mandible—asymmetry
- Category 4 (problematic)
  - Mandible back
  - Maxilla down
  - Maxilla widen

Maxillofacial distraction osteogenesis

During the 1950s, the Russian orthopedic surgeon Ilizarov [65] began experimenting with methods to increase the length of long bones (eg, femur) to correct congenital and traumatic deformities. Ilizarov [65] discovered a number of biologic and mechanical principles and factors that play a role in the process of new bone formation. His pioneer work gave rise to the modern era of DO. DO is the surgical technique in which new bone formation is induced by the gradual separation of osteotomized bone segments. The soft callus of bone healing in DO is stretched, delaying the creation of new bone and causing regenerated bone. In 1992, McCarty and coworkers [66] were the first to report (in the English language) the use of DO in a human maxillofacial application: a congenitally hypoplastic mandible. DO is particularly applicable for syndromic patients who have severe dentofacial deformities. In addition to lengthening hypoplastic mandibles (ie, mandibular distraction), DO can be used to lengthen hypoplastic maxillas (in patients who have Crouzon and Apert syndromes). Although DO was initially introduced as an extraoral procedure, it can now be applied intraorally. With the promise of DO, it is imperative that maxillofacial DO not be a technique in search of applications [67]. Alveolar distraction involves using the DO concept and principles to augment alveolar ridges for prosthodontics and, therefore, is not considered an orthognathic DO procedure.

Summary

As highlighted in this article, many controversies regarding orthodontic treatment still exist. These include the timing of treatment and expansion in the absence of a posterior crossbite to correct Class II relationships, among others. When additional data from evidence-based systematic reviews become available, more predictable and standardized orthodontic treatments may develop. Thus, with the collective data derived from evaluating all studies concerning a particular topic, the most unbiased and best-validated knowledge should have a major impact on the future provision of orthodontic care for adolescent patients [68].

Current trends in orthodontics include invisible tooth aligners, self-ligating brackets, maxillary intra-arch molar distalizing appliances, and implant-assisted anchorage. Orthognathic surgical procedures are best applied after growth has ceased. Stability and patient comfort have improved with RIF versus traditional wire fixation. DO used in medicine to increase the length of long bones has been adapted for certain orthognathic surgical procedures.

References

[1] Moorrees C. The dentition of the growing child. A longitudinal study of dental development between 3 and 18 years of age. Cambridge (MA): Harvard University Press; 1959.

[2] Little RM. Stability and relapse: early treatment of arch length deficiency. Am J Orthod Dentofacial Orthop 2002;121:578–81.

[3] Sinclair P, Little R. Maturation of untreated normal occlusions. Am J Orthod Dentofacial Orthop 1983;83:114–23.

[4] Gianelly A. Bidimensional technique: theory and practice. Islandia (NY): GAC International, Inc; 2000.

[5] McNamara JA Jr. Early intervention in the transverse dimension: is it worth the effort? Am J Orthod Dentofacial Orthop 2002;121:572–4.

[6] McNamara JA Jr, Brudon WL. Orthodontics and dentofacial orthopedics. Ann Arbor (MI): Needhan Press; 2001.

[7] White L. JCO interviews Dr. Anthony Gianelly on current issues in orthodontics. J Clin Orthod 1996;30(8):439–45.

[8] Gianelly A. Rapid palatal expansion in the absence of crossbites: added value? Am J Orthod Dentofacial Orthop 2003;124(4):362–5.

[9] Bowman SJ. More than lip service: facial esthetics in orthodontics. J Am Dent Assoc 1999; 130:1173–81.

[10] Turpin DL. Eary treatment conference alters clinical focus. Am J Orthod Dentofacial Orthop 2002;121(4):335–6.

[11] Keeling SD, Wheeler TT, King GJ, et al. Anteroposterior skeletal and dental changes after early Class II treatment with bionators and headgear. Am J Orthod Dentofacial Orthop 1998;113(1):40–50.

[12] Ghafari J, Shofer FS, Jacobsson-Hunt U, et al. Headgear versus functional regulator in the early treatment of Class II, division 1 malocclusion: a randomized clinical trial. Am J Orthod Dentofacial Orthop 1998;113(1):51–61.

[13] Tulloch JF, Phillips C, Profit WR. Benefits of early Class II treatment: progress report of a two-phase randomized clinical trial. Am J Orthod Dentofacial Orthop 1998;113(1):62–72.

[14] O'Brien K, Wright J, Conboy F, et al. Effectiveness of early orthodontic treatment with the Twin-block appliance: a multicenter, randomized, controlled trial. Part 1: dental and skeletal effects. Am J Orthod Dentofacial Orthop 2003;124:234–43.

[15] Gianelly A. Timing of treatment. Pract Rev Orthod 1996;8(3) [audio tape].

[15a] Dugoni S, Lee J, Varela J, et al. Early mixed dentition treatment: post retention evaluation of stability and relapse. Angle Orthod 1995;65:311–20.

[16] Livieratos FA, Johnston LE Jr. A comparison of one-stage and two-stage nonextraction alternatives in matched Class II samples. Am J Orthod Dentofacial Orthop 1995;108:118–31.

[17] Johnston LE Jr. Functional appliances: a mortgage on mandibular position. Aust Orthod J 1996;14:154–7.

[18] Turpin DL. The year in review. Am J Orthod Dentofacial Orthop 2004;126(6):649.
[19] Proffit WR, Fields HF Jr. Contemporary orthodontics. 3rd edition. Boston: Mosby; 2000.
[20] Gianelly A. Arch width after extraction and nonextraction treatment. Am J Orthod Dentofacial Orthop 2003;123:25–8.
[21] Boley JC. Serial extraction revisited: 30 years in retrospect. Am J Orthod Dentofacial Orthop 2002;121:575–7.
[22] Little R, Reidel R, Engst E. Serial extraction of premolars—postretention evaluation of stability and relapse. Angel Orthod 1990;60:255–62.
[23] Little R. The effects of eruption guidance and serial extraction on the developing dentition. Pediatr Dent 1987;9:65–70.
[24] Ngan P. Biomechanics of maxillary expansion and protraction in Class III patients. Am J Orthod Dentofacial Orthop 2002;121:582–3.
[25] Ngan PW, Haag U, Yiu C, et al. Treatment response and long-term dentofacial adaptations to maxillary expansion and protraction. Sem Orthod 1997;3:255–64.
[26] Mitani H. Early application of chincap therapy to skeletal Class III malocclusion. Am J Orthod Dentofacial Orthop 2002;121:584–5.
[27] Turpin DL. Early treatment conference alters clinical focus. Am J Orthod Dentofacial Orthop 2002;121(4):335–6.
[28] Shapiro PA. Stability of open bite treatment. Am J Orthod Dentofacial Orthop 2002;121(6): 566–8.
[29] Roth RH. Temporomandibular pain—dysfunction and occlusal relationship. Angle Orthod 1973;43:136–53.
[30] Roth RH. Functional occlusion for the orthodontist II. J Clin Orthod 1981;25:100–23.
[31] Reynders RM. Orthodontics and temporomandibular disorders: a review of the literature (1966–1988). Am J Orthod Dentofacial Orthop 1990;97:463–71.
[32] Griffiths RH. Report of the president's conference on the examination, diagnosis, and management of temporomandibular disorders. J Am Dent Assoc 1983;106:75–7.
[33] McNeil C, Mohl ND, Rugh JD, et al. Temporomandibular disorders: diagnosis, management, education, and research. J Am Dent Assoc 1990;120:253–60.
[34] National Institutes of Health Technology Assessment Conference Statement. Management of temporomandibular disorders. J Am Dent Assoc 1996;127:595–606.
[35] Kim MR, Graber TM, Viana MA. Orthodontics and tempormandibular disorders: a meta-analysis. Am J Orthod Dentofacial Orthop 2002;121:438–46.
[36] McNamara JA Jr, Seligman DA, Okeson JP. Occlusion, orthodontic treatment, and temporomandibuar disorders: a review. J Orofacial Pain 1995;9(1):73–89.
[37] Gianelly AA. Orthodontics, condylar position and TMJ status. Am J Orthod Dentofacial Orthop 1989;75(6):521–3.
[38] American Academy of Pediatric Dentistry, University of Texas Health Science Center at San Antonio. Treatment of temporomandibular disorders in children: summary statement and recommendation. J Am Dent Assoc 1990;120:265–9.
[39] Wong BH. Invisalign A to Z. Am J Orthod Dentofacial Orthop 2002;121:540–1.
[40] Ackerman JL, Proffit WR. What price progress? Am J Orthod Dentofacial Orthop 2002;121: 243.
[41] Sheridan JJ, LeDoux W, McMinn R. Essix retainers: fabrication and supervision for permanent retention. J Clin Orthod 1991;27:37–45.
[42] Rinchuse DJ, Rinchuse DJ. Active tooth movement with Essix-based appliances. J Clin Orthod 1997;31:109–12.
[43] Nahoum HI. The vacuum formed dental contour appliance. N Y State Dent J 1964;9: 385–90.
[44] Pontiz RJ. Invisible retainers. Am J Orthod Dentofacial Orthop 1971;59:266–71.
[45] McNamara JA Jr, Kramer KL, Juenker JP. Invisible retainers. J Clin Orthod 1985;19:570–8.
[46] Rinchuse DJ, Rinchuse DJ. Orthodontics and the general practitioner [letter]. J Am Dent Assoc 2002;133:1160–4.

[47] Turpin DL. Orthodontists rely on education, experience and research. Am J Orthod Dentofacial Orthop 2002;121:551.
[48] Bolla E, Muratore F, Carano A, et al. Evaluation of maxillary molar distalization with the Distal Jet: a comparison with other contemporary methods. Angle Orthod 2002;72:481–94.
[49] Burkardt DR, McNamara JA Jr, Bacetti T. Maxillary molar distalization or mandibular enhancement: a cephalometric comparison of comprehensive orthodontic treatment including the Pendulum and the Herbst appliance. Am J Orthod Dentofacial Orthop 2003;123:108–16.
[50] Keim RG, Berkman C. Intra-arch maxillary molar distalization appliances for class II correction. J Clin Orthod 2004;38(9):505–11.
[51] Bussick TJ, McNamara JA Jr. Dentoavleolar and skeletal changes associated with the Pendulum appliance. Am J Orthod Dentofacial Orthop 2000;117:333–43.
[52] Carano A, Velo S, Leone P, et al. Clinical applications of the miniscrew anchorage system. J Clin Orthod 2005;39(1):9–24.
[53] Wehrbein H, Merz BR. Aspects of the use of endosseous palatal implants in orthodontic therapy. J Esthetic Dent 1998;10(6):315–24.
[54] Wehbrbein H, Merz BR, Diedrich P, et al. The use of palatal implants for orthodontic anchorage. Design and clinical application of the orthosystem. Clin Oral Implants Res 1996; 7(4):410–6.
[55] Wehrbein H, Merz BR, Hammerie CH, et al. Bone-to-implant contact of orthodontic implants in humans subjected to horizontal loading. Clin Oral Implant Res 1998;9(5):348–53.
[56] Molly L, Willems G, Van Steenberghe D, et al. Periodontal parameters around implants anchoring orthodontic appliances: a series of case reports. J Periodontol 2004;75(1):176–81.
[57] Celenza F. Implant-enhanced tooth movement: indirect absolute anchorage. Int J Periodont Restor Dent 2003;23(6):533–41.
[58] Schlegel KA, Kinner F, Schlegel KD. The anatomic basis for palatal implants in orthodontics. Int J Adult Orthod Orthognath Surg 2002;17(2):133–9.
[59] Henry PJ, Singer S. Implant anchorage for the occlusal management of developmental defects in children: a preliminary report. Pract Periodontol Aesthetic Dent 1999;11(6):699–706.
[60] Glatzmaier J, Wehrbein H, Diedrich P. Biodegradable implants for orthodontic anchorage. A preliminary biomechanical study. Eur J Orthod 1996;18(5):465–9.
[61] Cacciafesta V, Sfondrini MF, Ricciardi A, et al. Evaluation of friction of stainless steel and esthetic self-ligating brackets in various bracket-archwire combinations. Am J Orthod Dentofacial Orthop 2003;124:395–402.
[62] Henao SP, Kusy RP. Evaluation of the frictional resistance of conventional and self-ligating bracket design using standardized archwires and dental typodonts. Angle Orthod 2004;74: 202–11.
[63] Proffit WR, Phillips C. Physiologic responses to treatment and postsurgical stability. In: Proffit WR, White RP Jr, Sarver DM, editors. Contemporary treatment of dentofacial deformity. St. Louis (MO): Mosby; 2003. p. 656–8.
[64] Tucker MR, Schardt-Sacco DS, White RP Jr. Prinicples of surgical management of dentofacial deformity. In: Profitt WR, White RP Jr, Sarver DM, editors. Contemporary treatment of dentofacial deformity. St. Louis (MO): Mosby; 2003. p. 277–84.
[65] Ilizarov GA. The tension-stress effect on the genesis and growth of tissues: part II. The influence of the rate and frequency of distraction. Clin Orthop 1989;239:263–85.
[66] McCarty JG, Schreiber J, Karp N, et al. Lengthening the human mandible by gradual distraction. Plast Reconstr Surg 1992;89:1–8.
[67] Crago CA, Proffit WR, Ruiz RL. Maxillofacial distraction osteogenesis. In: Profitt WR, White RP Jr, Sarver DM, editors. Contemporary treatment of dentofacial deformity. St. Louis (MO): Mosby; 2003. p. 357–93.
[68] Ismail AI, Bader JD. Practical science: evidence-based dentistry in clinical practice. J Am Dent Assoc 2004;135:78–83.