Seminar 15

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The question of extractions in orthodontics

The most important diagnostic decision one has to make in an orthodontic treatment plan is whether or not to extract teeth; a controversial topic since the emergence of orthodontics as a dental specialty. These days the most outspoken advocates of nonextraction treatment seem to be either self-promoting clinicians outside the mainstream of orthodontics, or general dentists who have attended weekend courses at airport hotels. If you happen to be an orthodontist who has to defend extractions to your patients and/or the press, it is essential to be aware of the historical background, and the arguments for and against. Henry Ford (1863–1947), may have thought "History is bunk," but for George Santayana (1863–1952) … "Those who cannot remember the past are condemned to repeat it."

Historical background

In what is generally recognized as the first modern textbook devoted to the treatment of irregularities of the teeth – *A Treatise on Oral Deformities* (1880), Norman William Kingsley MDS, DDS (1829–1913), discusses at some length the arguments for and against extractions, both for reasons of crowding and aesthetics. The following quotation is a sample of his experience and insight (Slide 3): "It requires a profounder knowledge than most of us possess to decide always upon the wisdom of extraction, and when such a conviction is settled the judgement may be equally at a loss to the choice of teeth to be removed… There are so many considerations to be taken into account that it is hardly possible to lay down any rule of universal application." (p. 43). Kingsley was an inventive contributor to the early development of orthodontics, designed the first soft vulcanized India rubber obturators for patients with cleft palate, introduced the concept of 'jumping the bite' for patients with a retruded mandible, as well as occipital traction to deliver a distalizing force to the upper incisors. He was also a principal founder of the New York College of Dentistry, serving as its first dean from 1865 to 1869 – not a bad CV for someone who left school at fifteen to work as a store clerk and bookkeeper.

The memorably named Victor Hugo Jackson DDS, MD (1850–1929), in another classic textbook *Orthodontia and Orthopaedia of the Face* (1904), expressed the view that the extraction of permanent teeth should be avoided wherever possible "but in some cases a better result is attained by extraction, especially where the child has inherited larger teeth than the jaw will accommodate." The dental course at the University of Michigan of two years' duration was completed by Jackson in 1877; it was also possible for a dentist to acquire a medical degree at Michigan with an additional year of study, which he did in 1888. Dr Jackson's custom in his New York City practice was to set a flat fee for each case, which with few exceptions was more than $1000, collecting $700 during the first year. At the time competent professionals including dentists could expect to make between $2000 and $4000 a year (Peck, 2009), which would explain the source of the remark that "Dr Jackson had accumulated a rather large fortune for a professional man in those days." (Chapin, 1957)

Edward Angle and the 'New School' of orthodontia

Regrettably, reasoned debate regarding the pros and cons of extracting teeth was suppressed with the emergence of Edward Angle as the most dominant and influential figure in orthodontics; leader of the so-called 'New School' of orthodontics and the acknowledged 'Father of orthodontics' (Slide 4). In fact the word 'extraction' does not even appear in the index of the seventh edition of *Treatment of Malocclusion of the Teeth* (1907). Angle was firmly of the opinion: "It is that the best balance, the best harmony, the best proportions of the mouth in its relations to the other features require that there shall be *the full complement of teeth, and that*

each tooth shall be made to occupy its normal position – normal occlusion. (p. 63; the italics are Angle's) Angle also went on to say regarding extraction that … "it is gratifying to note however, that this fallacious teaching and pernicious practice are rapidly passing and will doubtless soon become mere matters of history."

Edward Hartley Angle DDS, MD, DSc (1855–1930) was an unlikely Svengali; a Pennsylvania farm-boy of no obvious scholastic ability, but fond of tinkering with machinery and making things. At the age of 18 his mother arranged for him to become an apprentice with a local dentist, and two years later he enrolled at the Pennsylvania College of Dental Surgery, a proprietary dental school in Philadelphia; in those days, the course was arranged into two 6-month terms spread over two years, and Angle graduated with a DDS in 1878 – an earlier graduate of the school was John Henry 'Doc' Holliday, a famous 'Wild West' gambler and gunslinger from the Class of '72. Angle then set up a general practice in Towander, a small town in the north of the state where he developed an interest in mechanisms for aligning teeth, or 'regulation' as it was known at the time.

However, experiencing declining health (it seems he was suffering from tuberculosis), in 1881 on the advice of his physician, he abandoned his practice and moved to Minnesota in search of better health. With his health improved, Angle then unwisely invested all his savings in a 'get rich quick' scheme with some of his old farming friends from back home – a sheep farming venture in Montana. It was unlikely they knew much about sheep, and the venture was abruptly terminated by the great blizzard of 1882, which killed off the entire flock. Forced back into general practice, Angle enquired of the Dental Department at Minnesota Hospital College in Minneapolis whether they had any vacancies, and in 1886 was appointed a professor of histology and lecturer on comparative anatomy and orthodontia. On the merger of the Hospital College with the University of Minnesota in 1888, he was appointed Professor of Orthodontia (Peck, 2009).

In 1892 Angle announced he would be practicing orthodontia to the exclusion of all other forms of dentistry, in effect becoming the world's first specialist in orthodontics. In 1894 he was appointed Professor of Orthodontia in the new dental school at Marion Sims College of Medicine; a proprietary medical school in St Louis, Missouri who granted him an MD (Asbell, 1990). Proprietary schools were private enterprises owned by their faculty who taught part-time, and with no state support were wholly dependent for their existence on student fees. In 1903 with pressure building from the American Medical Association to force them affiliate with established universities or face closure, Marion Sims Medical and Dental Colleges joined St Louis University. It was a precient move predating the controversial Flexner Report *Medical Education in the United States and Canada* by seven years. Angle became a vocal advocate for the separation of orthodontics from other branches of dentistry declaring … "Not until orthodontia is studied and practiced as a distinct branch of dentistry will it ever obtain success. There should be specialists in orthodontia and the general practitioner should send to the specialist freely." At the time, orthodontics was a neglected part of the prosthetic department in dental schools (Peck, 2009).

To represent the ideal of normal occlusion Angle used a Native American skull with a perfect set of teeth known as 'Old Glory' that had been discovered in Illinois (Slide 5). Interestingly, the skulls used to illustrate normal occlusion in the textbooks of the day, usually showed the morphological characteristics of bimaxillary protrusion – hardly representative of the ethnic background of the majority of the patients of European origin undergoing orthodontic treatment at the time.

Slide 5. Old Glory. This skull with a perfect set of teeth labelled *Secretum Apertum* (the secret revealed) was used by Angle to represent his ideal of normal occlusion. It was owned by Dr Richard Summa a close friend and colleague of Angle. (From Angle (1907), *Treatment of Malocclusion of the Teeth*)

Although all the case histories in the seventh edition were nonextraction, the appendix contains several engravings from previous editions illustrating appliances used to treat cases in which premolars had been extracted (Slide 6). One can only speculate as to the reason Angle

abandoned extractions, but looking at the appliances available at the time it is not hard to guess why. Orthodontists had little choice – closing extraction spaces with such crude mechanics was well-nigh impossible. The alternative, but still technically demanding method, was to expand the arches and pull any displaced teeth into the line of occlusion (Slide 7). Angle also had a personal reason for abandoning extractions. He had removed two upper premolars from his wife Anna in 1905 and couldn't keep the spaces closed (Curtis, 2000). As in many other fields of endeavour, necessity turned out to be the mother of invention.

Slide 6. Left: Use of traction screws to move canines distally following the extraction of two first premolars. (From Angle (1892), Third edition.) Right: Combination of traction screws and an expansion arch (B arch) to treat a first premolar extraction case; the ball attached to the front of the expansion arch is an attachment for occipital anchorage (From Angle (1900), Sixth edition.). These illustrations are Figs. 632 and 650 respectively from Angle (1907), *Treatment of Malocclusion of the Teeth*.

Slide 7. Appliances designed to correct crowding in a non-extraction case. Left: Upper arch. Right: Lower arch. Expansion of the arches was provided by the ribbed expansion arch (E arch) held in position by clamp bands on the first molars. Notches were cut in the arches to prevent slipping of the ligature wires applying traction to the displaced teeth. (From Angle (1907), *Treatment of Malocclusion of the Teeth*.)

To underpin his nonextraction treatment philosophy, Angle came up with the 'full complement' theory; many of his students became teachers, and the doctrine of the full complement of teeth was widely taught. The Angle School ridiculed claims that heredity was one of the causes of malocclusion. They considered malocclusion to be the consequence of inadequate bone growth that could be stimulated by alignment of the teeth – a rather liberal interpretation of Wolff's law. In other words, the stimulating effects of orthodontic tooth movement, and the establishment of normal occlusion if started young enough would cause the jaws to grow. The mantra became malocclusion could be treated without extracting teeth by growing bone (Slide 9).

Some of Angle's contemporaries, however, maintained that this concept was a fiction and unrealistic in practice. Calvin Suveril Case (1847–1923) representing the 'Rational School' was another influential figure at the time, and the leading critic of Angle's rigid proclamation that no teeth should ever be extracted (Slide 10). A graduate of Ohio College of Dental Surgery, Cincinnati (DDS, 1871) and the University of Michigan Medical School, Ann Arbor (MD, 1884), he adopted a more reasoned view and concluded from the statistics of his own practice … "there was only about one case in twelve to fifteen in which the question of extraction should ever arise" (Case, 1911). These powerful personalities had their disciples, and the topic of extraction became the subject of acrimonious debate at orthodontic society meetings.

Case, a pioneer in the treatment of cleft lip and palate was originally an admirer and supporter of Angle, and had given up general practice because of his influence. Their falling out arose over the seemingly trivial issue of priority over who first used intermaxillary elastics. Angle attributed it to Henry Albert Baker (1848–1934), whereas Case claimed to have used them in 1890, and had reported it to the Chicago Dental Society, and Columbian Dental Congress of 1893.

The Extraction Debate of 1911

Martin Dewey DDS, MD (1881–1933) son of a pioneer dentist in Kansas, in 1899 enrolled in the Keokuk (Iowa) Dental College, founded in 1897 and merged with the University of Iowa in 1907. In 1902 he enrolled in the second class of ten students at the Angle School of Orthodontia in St Louis, taught on the course in subsequent sessions, as well as enrollling for an MD in St Louis, which at the time had several proprietary medical schools. With Angle's encouragement, Dewey challenged Case to defend his position on extractions. Case's response, together with the subsequent discussion became known as the extraction debate of 1911 (Slide 11). Originally published in the *Journal of the National Dental Association* of that year, Case's article and the lively discussion that followed was reprinted serially in the *American Journal of Orthodontics* in 1964.

Calvin Case: The question of extraction in orthodontia

To Case the question of extraction was intimately bound up with the question of causation. Is malocclusion, for example, due to local causes operating after birth as maintained by the 'New School', or does it arise, at least in part, from the laws of heredity and other laws that govern the development of plants and animals? Case was a confirmed Darwinian (Slide 12): "There is no doubt in the minds of advanced anthropologists that the form, structure, and relation of the bones of the human skull, like those of other bones of the body, were evolved from a being very much lower in the animal scale, through the unwavering laws of heredity, variation, natural selection and influences of environment." (Case, 1911; pp. 682). Racial variation in *Homo sapiens* arose from segregation in markedly different environments and malocclusion resulted from the union of dissimilar types. In Case's opinion, the bones of the jaws and especially the mandible assumed the forms and sizes determined by the laws of heredity. And while their early growth may be accelerated, there was no proof that orthodontically induced mechanical stimulation could make them grow larger than their inherent normal size.

Case was a very conservative extractionist by present day standards, and was clearly offended by disinformation implying he practiced extraction on a large number and variety of cases. As far as he was concerned, the main indication for extraction was to harmonize facial relations (Slide 13), particularly in cases of bimaxillary protrusion, or where the upper canines had been impacted in cases with a Class II buccal segment relationship (Slide 14). His guiding principle was never to extract teeth for the purpose of making correction easier, and no dental malposition should be regarded as a basis for extraction, since the teeth with few exceptions can be placed in normal alignment. (Although Case was a prominent opponent of the full complement of teeth and bone growing, there is a certain ambiguity in these principles, which suggests that in practice his philosophy of treatment differed little from that of the Angle School.)

Slide 13. Records of a patient aged 14, initially treated non-extraction and the teeth placed in normal occlusion. A, Before treatment, B, After treatment, C, After extraction of four first premolars to facilitate correction of the bimaxillary protrusion. D, Facial cast prior to extraction treatment. E, Facial cast and F, profile photograph following extraction treatment. (From Case (1921), *Dental Orthopedia*.)

Slide 14. A. Study models of a patient aged 12 with severe crowding in the upper arch and a heavily decayed lower right first molar treated by Dr. Case. B. Two upper first premolars and the first molar were extracted. C. The canines were moved distally and intermaxillary elastics used to move the molars mesially. (From Case (1921), *Dental Orthopedia*.)

Cryer's contribution

Mathew Cryer a noted anatomist and breeder of prize livestock led the discussion. He therefore had firsthand experience of artificial selection, and was well versed in the works of Darwin, Mendel, de Vries and the laws relating to heredity and breeding. He firmly supported Case in criticizing those who claimed that malocclusion was invariably the result of factors operating after birth. The only point on which he disagreed was on the policy of never extracting a tooth to make treatment easier.

Dewey's response

Dewey in the tradition of the Angle School, firmly believed that malocclusion of the teeth was the cause of malformation of the jaws, not the result (Slide 15). The aim therefore was to restore normal occlusion and function and normal growth would follow. In his book *Practical Orthodontia* (1914), he divided the aetiology of malocclusion into general or constitutional causes: scarlet fever, measles, rickets, tuberculosis; and local causes: cleft lip and palate, missing teeth, habits, plus adenoids and mouth-breathing (Slide 16). Dewey dismissed inheritance as an aetiological factor and believed the occurrence of malocclusion in parents and siblings was because each had experienced exactly the same environment. So-called family traits therefore were … "not the result of transmission of the malocclusion, but the result of acquired conditions which are the same in each individual" (Dewey, 1912; pp. 89).

If that statement seems surprising today, one has to remember that opposition to Darwin's theory of natural selection to explain evolutionary change was widespread. Lamarckian concepts of the direct action of the environment on organisms to produce inherited changes in structure (the inheritance of acquired characteristics) continued to exist well into the 20th century. Even Darwin believed in a certain amount of soft inheritance. That is to say the belief in a gradual change of the genetic material itself, either by use or disuse, or by some internal progressive tendency through the direct effect of the environment; this modified genotype was then transmitted to the next generation (Mayr, 1998).

Dewey adopted a somewhat sarcastic tone in his response, particularly in relation to the question of inheritance and Cryer's examples of selective breeding. He also claimed that Case was trying to prove malocclusions that were the result of inheritance could only be treated successfully with extractions – something that Case had clearly not done. Nor did Case or Cryer make the simplistic statement that inherited malocclusions were due to the … "small jaws of one parent and the large teeth of the other", or … "the mandible of one parent and the maxilla of the other." One gets the impression that Dewey chose to deliberately misinterpret what Case and Cryer had said in order to ridicule them. After his response when asked what he would do in a patient with bimaxillary protrusion, Dewey replied …"as I said before, certain features of this paper have appeared to me as a joke. Bimaxillary protrusions are a joke." To the question would he extract? Dewey's response was … "no I would not." Reading between the lines one gets the impression that Dewey lost his composure, got trapped, and made something of a fool of himself. (He later became a leading political figure in dentistry and was elected President of both the American Dental Association and the American Association of Orthodontists.)

Post-treatment relapse

While few experienced orthodontists did not at some stage resort to the extraction of teeth, not many were prepared to acknowledge the fact publicly. One of the first to comment that the results of orthodontic treatment were frequently disappointing was the Swedish orthodontist Axel Lundström (Slide 17). Following the discussion of a paper he had presented in the USA, Lundström was complimented by a member of the audience for his courage in exhibiting his failures.

Axel Lundström and the apical base

In a landmark paper read before the British Society for the Study of Orthodontics (BSSO) in 1927 and extensively illustrated with treated cases several years out of retention, Lundström challenged many of the prevailing dogmas of the day, including the universality of non-extraction treatment irrespective of the malocclusion (Lundström, 1928 a,b). He concluded from the clinical evidence that the effects of orthodontic treatment were confined to tooth movement, thereby pre-dating the findings of the first cephalometric study of orthodontic treatment by Brodie *et al.* (1938) by some ten years (Slide 17).

Lundström regarded malocclusion of the teeth as a problem associated with the apical base (that part of the upper or lower jaw that remains following tooth loss and resorption of the alveolar process), and stressed the importance of distinguishing the apical base or basal bone from the alveolar bone (Lundström, 1923). The size and form of the apical base is independent of the position of the teeth and in the horizontal plane the interface between basal and alveolar bone will coincide with the location of the root apices. Lundström believed the incorporation of bodily moving appliances into the Angle system to bring about apical development was therefore biologically unsound. Malocclusions caused by dentoalveolar disproportion could be corrected by orthodontic methods, but disturbed development of the apical base (a skeletal discrepancy), required an orthopaedic or surgical approach (Slide 18).

Edward Angle and evolution of the Edgewise Appliance

When Angle published *Treatment of Malocclusion of the Teeth*. *Angle's System* in 1907 he was using the Expansion or E-Arch, a crude appliance system limited to expanding the dental arches by tipping the teeth (Slide 7). What was required was an appliance to move the roots bodily "by a force so gentle and so well distributed that it would stimulate cellular activity and the growth

of bone." (p 855). In 1912 he came up with the Pin and Tube, which he called a bone growing appliance. However, it was technically difficult to use, and replaced in 1916 by the Ribbon Arch, itself superseded by rotating the rectangular archwire through 90° to engage a horizontal rectangular bracket slot to produce "the latest and best" Edgewise Appliance (Slide 19).

Post-retention relapse and Charles Tweed

Charles Tweed DDS (1895–1970), attended Stanford University as a predental student, and in 1919 completed his DDS at the University of California, San Francisco. He practiced dentistry in Phoenix, Arizona until 1927, and then due to join the Angle School of Orthodontia in Pasadena, California. However, when it was time for the course of five students to start, they were informed it would close, perhaps permanently. Since a condition of joining the course was to dispose of their general practices this was a serious blow; as a compromise they were offered an alternative course of instruction in Berkeley lasting eight months. Tweed helped field-test the Edgewise Appliance, and also helped Angle complete the article that had languished in draft form since 1925 (Philippe, 2008). 'The Latest and Best in Orthodontic Mechanism' was finally published in four parts in *The Dental Cosmos* in 1928–29.

Tweed's first paper illustrating the treatment of four nonextraction cases with the edgewise appliance appeared in the October issue of *The Angle Orthodontist* (Tweed, 1932). The June issue of the journal the same year, had included in the Report of the Eighth Annual Meeting of the Edward H Angle Society of Orthodontia, 7–12 March, (pp 187–195); the rapporteur records "On Saturday morning we were given a real thrill. Dr Charles H Tweed of Phoenix, Arizona, at Mrs Angle's request (she had a DDS from the University of Iowa by the way), went to the trouble and expense of bringing twelve of his patients to Pasadena, a task that involved an overnight trip on the train for the group … The writer has never seen such a collection of beautiful dentures evolved through orthodontic treatment as were shown by these boys and girls. One cannot praise Dr Tweed too highly for this work. He is a master of the edgewise arch mechanism."

In his practice in Tuscon, Arizona, Tweed followed the Angle philosophy of the full complement of teeth diligently for several years. He then recalled 70 percent of the patients he had treated, and divided them into successes and failures (Slide 20). To his amazement he found that of those patients who had been out of retention for 2–5 years, his success rate was less than 20 percent. His colleagues were also amazed and convinced they were doing much better, but when asked, were unable to produce the records to prove it. (Some things never change.) After analysing his cases, he found a correlation between facial balance, and the position of the mandibular incisors with respect to basal bone (Slide 21).

Tweed concluded that successful treatment depended on positioning the mandibular incisor teeth over basal bone, and to achieve this had begun to extract first premolars. This did not go down well with his colleagues. Strang (1974) recalls that at a meeting of the Angle Society in Chicago during the 1930s, prior to presenting a paper, Tweed had displayed the records of one hundred consecutively treated patients. The results were all excellent and in many of the cases he had extracted first premolars. Following his presentation that was greeted in silence, Tweed was severely condemned for violating the sacred principle of Dr. Angle – never extract teeth. It is difficult to avoid the conclusion that by this time the Angle Society had acquired the hallmarks of a cult. It is therefore ironic that by inventing the Edgewise appliance, Angle had unwittingly provided the mechanism for Charles Tweed, and eventually all orthodontists to treat extraction cases to a high standard.

The Extraction Panel of 1944

Tweed's iconoclastic extraction philosophy coupled with his demonstrable clinical ability, eventually made an impact gaining many supporters, to such an extent that in April 1944, a debate was held in Chicago during the annual meeting of the American Association of Orthodontics. Essayists who participated were Charles Tweed, Milo Hellman, George Grieve and Allan Brodie with George Hahn acting as moderator (Hahn, 1944). Their contributions were published in the *American Journal of Orthodontics and Oral Surgery* of the same year (Slide 22).

Tweed: Indications for the extraction of teeth

In his opening remarks Tweed modestly pointed out that his educational background was quite ordinary, without the advantage of research connected with a University (Hellman and Brodie were academic heavyweights). However, he goes on to remark that his opinions and conclusions are based not on hearsay, but on factual clinical evidence gathered during seventeen years orthodontic practice. During this period he had followed the philosophy of the full complement of teeth for six and a half years, and for eleven years otherwise (Tweed, 1944). Tweed had come to the conclusion that the key to a stable occlusion was the incisor–mandibular plane angle (Slides 23, 24), which had been shown by Margolis (1943) to be on average 90±5 degrees; a measurement later incorporated into the Tweed diagnostic triangle (Tweed, 1954). As a result extraction became an integral part of his treatment philosophy in which he maintained: "When a discrepancy between tooth pattern and basal bone does exist, it is far better to remove dental units to bring about balance between tooth anatomy and bone; and that if this correction is made, our patients will be benefited by a nearer approach to the normal than is possible if we retain all the dental units and in so doing are compelled to displace all the teeth off the dental ridge and into protrusion."

Slide 23. This patient with mild mandibular retrognathia, but not much of an overjet, was one of several used by Tweed to illustrate the creation of a bimaxillary protrusion with non-extraction treatment. (From Tweed (1944), *American Journal of Orthodontics and Oral Surgery.*)

Slide 24. The extraction of all four first premolars and the correct positioning of the mandibular incisors was indicated in this patient because of the discrepancy between tooth pattern and basal bone. (From Tweed (1944), *American Journal of Orthodontics and Oral Surgery*.)

Milo Hellman's contribution

Milo Hellman DDS (1872–1947) was born in Romania; a talented musician, at the age of 16 he had emigrated to the United States becoming a member of the Pittsburgh Symphony Orchestra. He did not choose to remain a professional musician, however, and after completing high school became a dental student at the Pennsylvania College of Dental Surgery. He graduated DDS in 1905, and started teaching at New York College of Dentistry (Founded in 1865 by Norman Kingsley and others; in 1925 merged with NYU to become New York University College of Dentistry). Hellman also became a research associate in physical anthropology at the American Museum of Natural History, New York.

In 1908 he was one of twelve men who spent three months on the Angle course held that year in New York (Noyes, 1947). A distinguished academic and clinician, he also served as a Professor and Chairman of Orthodontics at Columbia University, who in 1916 had established their own School of Dentistry, now known as the College of Dental Medicine. (In 1917, to further confuse the history of New York's two dental schools, Columbia merged the school with the newly acquired New York Post-graduate School of Dentistry, and the New York School of Dental Hygiene.) Hellman seems to have been a rather patrician figure, held in some awe by his clinical colleagues – the highest honour of the American Association of Orthodontists for research being the Milo Hellman Research Award.

While emphasizing he had no quarrel with Dr Tweed, Hellman adopted a rather patronizing attitude, branding him a clinician holding unsound, unscientific views…"when he ventures to demonstrate as much wisdom with the support of so little exact knowledge" (Slide 25). Hellman goes on further to state that…"resorting to compromises, such as extraction of teeth in children without due regard for the consequences, is an arrogant assumption of cocksureness and a barrier to further progress, not to mention the injustice to the patient" (Hellman, 1944). Given the tone of these comments, it makes one wonder what they might have been, had Hellman really wanted to pick a quarrel with Tweed. Interestingly, Hellman's clinical experience had been no different to that of Tweed. He even mentions an anecdote in which he asked Angle what had become of the case shown in Figs. 501 to 508 (Slide 26) on pages 494–498 of *Treatment of Malocclusion of the Teeth* (1907), to which Angle was said to have replied "It went back."

Slide 26. Class II division 1 malocclusion treated non-extraction by Angle. Precisely how the antero-posterior correction was achieved in this case is not explained, but Angle describes the used of bite-jumping devices and elastics in the treatment of such patients. Angle points out that the method of treating such a case by the extraction of the upper first premolars and retracting the incisors and canines is now regarded as obsolete by all orthodontists of the new school. (From Angle (1907), *Treatment of Malocclusion of the Teeth*.)

By this time Hellman was seventy-two years of age, and his contribution to the debate is something of a disappointment. His paper contains no illustrations and precious little factual information; it is largely a discussion of the contribution of palaeontology, comparative anatomy and embryology to understanding the evolution of the human dentition, followed by a restatement of Angle's treatment philosophy and the debt owed to him by orthodontics, and finally, the importance of making the Jesuitical distinction between failures and relapses. After this intellectual detour, he did conclude that since perfect occlusion rarely existed in nature, some compromise should be accepted and there was no justification for extracting four first premolars to achieve perfect alignment of the incisor teeth.

The third essayist was Grieve, a prominent Canadian orthodontist in private practice from Toronto of some thirty years standing. His experiences had mirrored those of Tweed, and he had resorted to the extraction of four teeth in more extreme cases. His views essentially coincided with Tweed (Grieve, 1944).

Brodie: scientific investigations in support of the extraction of teeth

Alan Gibson Brodie DDS, MS, PhD (1897–1976), after a DDS from the University of Pennsylvania School of Dental Medicine in 1919, began practice in Newwark, New Jersey in 1920. In 1925–1926 he studied at the Angle School of Orthodontia in Pasadena, California, where he was the first to treat a patient with the new Edgewise appliance. He then returned to practice in Newark until 1929, when he was invited by the Dean of the College of Dentistry, Frederick Bogue Noyes (1872–1961), a 1908 alumnus of the Angle School, to organize an orthodontic residency programme at the University of Illinois, Chicago. It was the first in the United States, fulfilling Angle's dream of an orthodontic training programme in a university; under Brodie's leadership and 'defender of the faith,' the department prospered, becoming the most prestigious in the country.

Brodie addressed the rhetorical question: 'Does scientific investigation support the extraction of teeth in orthodontic therapy?' He discussed each of the variables he considered to be relevant to the problem; these included axial inclination of the lower incisors, anchorage, aesthetics, adequacy of supporting bone and the stability of the final result (Slide 27). Brodie was critical of Tweed's concept of uprighting teeth over basal bone with emphasis on the lower incisors since their axial inclination varies greatly (Slide 28). Not a particularly elegant illustration, but effective nonetheless, designed to show that with such a large range in the incisor–mandibular plane angle, employing a mean value of 90 degrees as a criterion for the treatment of an individual had no scientific justification.

Slide 28. Diagrammatic representation of the wide variation in lower incisor inclination for 36 Class I cases, 43 Class II division 1 cases, and 15 Class II division 2 cases. Although the angulation between the lower incisors and mandibular plane averaged 90.9, 89.3 and 86.6 degrees respectively, the ranges were 28 degrees for Class I (control in the diagram), 35 degrees for Class II division 1, and 42 degrees for Class II division 2. (From Brodie (1944), *American Journal of Orthodontics and Oral Surgery.*)

Brodie was also critical of anchorage preparation (in which the posterior teeth are tipped back or uprighted), a major stage in the Tweed technique, and felt that an undisturbed tooth was the best source of anchorage. In Brodie's opinion, orthodontic treatment had a limited effect on facial aesthetics, and the extraction problem reduced itself to a single consideration. 'Is there enough bone to hold the teeth in a normal and stable position following treatment?' He also echoed Hellman's sentiment… "Are we justified in extracting two premolars…whose combined diameters measure 13–14 mm in order to gain 1–2 mm of space?" It is an argument with which it is difficult to disagree.

P Raymond Begg and Stone Age man's dentition

Another student of Angle who abandoned nonextraction treatment was Percy Raymond Begg AO, BDSc, DDSc (1898–1983) from Adelaide in South Australia (Slide 29). Born in a tent on the goldfields of Coolgardie, Western Australia, he studied dentistry at the University of Melbourne (BDSc, 1923), and in 1924 enrolled in the Angle School of Orthodontia in Pasadena, returning to Adelaide in 1925. A Doctor of Dental Science from the University of Adelaide was conferred on him in 1935, and in 1981 he was made an Officer of the Order of Australia. Begg had made an extensive study of Australian aboriginal skulls including tooth wear, and adopted Stone Age man's attritional occlusion as the basis of his philosophy of orthodontic treatment, regarding it as the anatomically and functionally correct occlusion (Begg, 1954, 1965). The food of Stone Age man was hard, coarse, fibrous and gritty leading to extensive and rapid occlusal and interproximal wear throughout life (Slide 30).

Slide 30. Adult Australian aboriginal skull with an anatomically correct attritional occlusion, including an edge-to-edge bite of the incisors. The occlusal views of the teeth show that the enamel has been worn away from some teeth and that wear has extended into the dentine. There has been considerable post-mortem loss of tooth enamel and alveolar bone. Enamel chipping does not occur during life. (From Begg (1965), *Begg Orthodontic Theory and Technique*.)

He concluded that interproximal wear was in large part responsible for the relatively low incidence of malocclusion in Stone Age man. When Australian aboriginal children were reared on a Westernised soft diet, tooth attrition did not occur, and the incidence of malocclusion increased. Begg argued that since the lengths of Stone Age man's dental arches were continually reduced throughout life by tooth wear, orthodontists had a well-founded scientific precedent for reducing arch length by extracting teeth (Begg, 1965). Begg had abandoned the Edgewise appliance in 1928 and adapted the ribbon arch bracket to create what became known as the Begg light wire technique (Begg, 1956, 1961, 1965). The extraction of four first premolars became an integral part of the philosophy of Begg treatment during its early years.

Extractions and treatment stability

The problem with the non-extraction–extraction controversy was that the arguments were largely personality driven and anecdotal, and to some extent still are. Both sides lacked the objective documentation of post-retention results necessary to prove their case. What was the evidence base for their respective points of view? The aim of premolar extractions was to effectively treat patients with arch length discrepancies and bimaxillary protrusion, the rationale being to ensure post-treatment stability and improve facial aesthetics. However, while Tweed, Begg and others were key figures in establishing extraction therapy as a respectable clinical practice during the 1950s, they failed to address the next logical question (Little *et al*., 1981). Were premolar extraction cases more stable after retention had been discontinued, or were they also subject to relapse? As it turned out, the assumption that the extraction of four premolars resulted in a more stable occlusion, particularly of the lower incisors, proved to be false (Slide 31).

Frequency of extraction

If one examines the reported extraction frequencies from 13 sources in the literature assembled by Peck and Peck (1979) during the period 1913–1979, the frequency ranged from 6.5 percent (Case, 1913) to 80–83.5 percent (Tweed, 1966; Hooper, 1967; see Peck and Peck for references). They concluded that two spheres of influence control the extraction question: (1) biological influences (where extractions are used to gain arch space and relieve crowding); these depend on the frequency of crowding within a population, which will lead to parallel increases in extraction frequency; and (2) socio-economic influences (treatment need and treatment methods) which are open to varying interpretations and demands from governments, orthodontists and patients. In their sample of 537 patients from an orthodontic practice in the northeastern USA (presumably their own), the frequency of extraction was 42.1 percent.

In a study by Weintraub *et al*. (1989) who surveyed 238 orthodontists by telephone in the state of Michigan, estimated extraction rates ranged from 5 percent to 87.5 percent. Of the two variables considered – school and year of graduation from orthodontic training – no association

with extraction rates was found. Three practices from the high end, and two from the low end, were then chosen for examination of patient records. The actual extraction rates differed from the clinician's estimate from an overestimate of about 20 percent to a 15 percent underestimate. In other words, large discrepancies exist between perceived and actual extraction rates; this is not surprising given the subjective nature of the data, and the perception of many orthodontists that they do not extract as many teeth as their colleagues. Although the evidence is anecdotal, one gets the impression we have entered a more conservative period as far as extractions are concerned.

Relapse following premolar extractions

Numerous follow-up studies of changes in dental arch relationships and crowding, after the completion of retention in both non-extraction and extraction cases have been reported in the literature (Litowitz, 1948; Walter, 1953; Lombardi, 1972; Bishara *et al*., 1973; Gardner and Chaconas, 1976; Johnson, 1977; Sadowsky and Sakolis, 1982; Uhde *et al.*, 1983). However, probably the most widely known long-term study of post-retention stability comes from the University of Washington in Seattle. Largely the result of an initiative by Richard Riedel, an acknowledged expert on the subject of retention (Riedel, 1960, 1969, 1976), the post-retention assessment of orthodontic treatment formed an important part of the clinical research undertaken in the Department of Orthodontics for more than forty years (Slide 32). Starting with MSD theses by Dona (1952), Kelley (1959), Arnold (1963) and Welch (1965), a large treatment database has been established including cases more than 10–20 years out of retention. When I was a Resident (Registrar) in the department (1967–69), we were required to locate and collect records of a patient who was at least 10 years out of retention. Not an easy task given the mobile society of the West Coast. Much of this work has been published and makes for interesting, if sometimes depressing reading (Slide 32).

The University of Washington experience

In a study of 65 first premolar extraction cases (27 Class I, 26 Class II division 1 and 8 Class II division 2) a minimum of 10 years out of retention Little *et al.* (1981) made the following measurements on each set of casts; the irregularity index (Little, 1975), mandibular intercanine width, mandibular arch length, overbite and overjet. (Slide 33). They found that the long-term response of mandibular incisors to orthodontic alignment was unpredictable. Marked variation in response characterized the sample (Slide 34). Initial crowding was a poor indicator of long-term crowding and there was no significant relationship between length of retention and the post-retention irregularity index; 60 out of the 65 cases showed intercanine width reduction regardless of lower arch expansion or constriction, with most constricting more than 2 mm.

Slide 33. Pretreatment, post-treatment and postretention study models of two first premolar extraction cases. Age, years-months; Ext, first premolars; AL, arch length; II, irregularity index; 3/3, intercanine dimension; OB, overbite. In Fig.8 there has been a return of crowding and in a pattern almost identical to the pre-treatment arrangement of the teeth. In Fig. 9 the incisors have remained well aligned. (From Little *et al.* (1981), *American Journal of Orthodontics*.)

Slide 34. Fig.2 is a scattergram showing the weak association between pre- and post-retention irregularity of the lower incisors. Initial crowding was a very poor predictor of long-term irregularity, the Pearson correlation coefficient being only 0.20. Fig. 4 shows that with only 5 exceptions, intercanine width decreased post-retention, with most constricting more than 2 mm. The degree of constriction was only weakly associated with post-retention irregularity (R=0.38). (From Little *et al.* (1981), *American Journal of Orthodontics*.)

These observations confirmed Johnson's (1977) report of eleven cases 6 years out of retention, and the findings of Gardner and Chaconas (1976) involving twenty-nine cases averaging more than 5 years out of retention. The reduction in intercanine width did not support the perfectly logical idea that the distal movement of canines into premolar extraction spaces allowed for stability of expansion (Strang, 1949). In a subsequent paper, Little *et al.* (1988) found that crowding continued to increase during the 10–20–year post-retention phase but to a lesser degree.

In a follow-up study of 54 cases from the above sample, Shields *et al.* (1985) looked for clinically significant predictors of lower labial segment stability from study model and cephalometric data. No cephalometric parameters such as (1) maxillary or mandibular incisor proclination, (2) horizontal or vertical growth magnitude, or (3) inclination of the mandibular plane, were found to be useful in establishing a prognosis. Furthermore, there were few associations of predictive value between cephalometric parameters and study cast measurements such as overbite, arch length, intercanine width or overjet.

The University of Illinois study

In an investigation from the University of Illinois in Chicago, the long-term stability of orthodontic treatment was evaluated in a group of ninety-six patients who had received orthodontic treatment 12–35 years previously (Sadowsky and Sakols, 1982; Uhde *et al*., 1983). In contrast to the Washington data, the sample consisted of a mixture of non-extraction and extraction cases; all had been treated with a fully banded edgewise appliance prior to adulthood. A Hawley-type removable retainer had been used in the maxillary arch and a fixed lingual retainer in the lower. Average time out of retention was 20 years.

Changes in selected occlusal parameters are shown in Slide 35 Remarkably, the mean changes in both the non-extraction and extraction cases were almost identical with a tendency to revert to pre-treatment values, although there was a large individual variation. The authors were less pessimistic about the results than Washington, but this is probably a reflection of the less stringent criteria used to decide what constituted a successful outcome. The ideal range chosen for mandibular incisor crowding, for example, was 0.0 to 3.0 mm. As the authors pointed out, the range of ideal used in the study will to some extent vary with the eye of the beholder, and the results need to be interpreted in that light.

Slide 35. A. Mean values for mandibular intercanine width, overbite, overjet and mandibular crowding for 45 non-extraction cases before treatment and short and long-term post-treatment. B. Mean values for 27 extraction cases. The standard deviations for all values in both groups were higher than the mean changes. (From Uhde *et al*. (1983), *The Angle Orthodontist*.)

The A-Pog line and stability

Many recommendations have been made regarding the use of cephalometric planes of reference that can be used as a guide to the position of the lower labial, the aim being to enhance stability. Based on observations of patients with a pleasing facial profile, Downs (1956) and Ricketts (1957) both recommended that the incisal edges of the lower incisors should be placed on the A-Pog line. The A-Pog or diagnostic line was strongly endorsed by Williams (1969) and became widely used in the treatment of patients with the Begg technique.

To test the validity of this recommendation, Houston and Edler (1990) examined the records of 47 cases treated with the Begg technique, in which one of the objectives of treatment had been to place the lower incisal edges within 2 mm of the A-Pog line; the cases were treated by a single operator, and on average were over 10 years out of retention. The A-Pog line was not found to be a reliable guide to lower incisor stability. In 62 percent of the cases examined, the lower incisors tended to return towards their original positions while in the remaining cases the changes were extremely variable (Slide 36).

Slide 36. Not the easiest figures to interpret but designed to show that in the majority of cases, following retention the lower incisors moved back toward their original position, although the extent to which this occurred was highly variable. Even when there was very little change during treatment there could be substantial alteration subsequently. (From Houston and Edler (1990), *European Journal of Orthodontics*.)

Factors influencing the extraction decision

Life was much simpler when crowding equalled extraction. Unfortunately, in patients with mild crowding there are no clear diagnostic criteria currently available to show whether extraction is the correct choice or *vice versa*. Certainty has now been replaced by doubt. The decisions that orthodontists use clinically on a daily basis are determined by their training and personal experience acquired from many years of practice. As a consequence, orthodontists have

different policies on extraction. In an orthodontic training programme with several clinical instructors this can present difficulties for trainees in assessing borderline extraction cases. Which brings us to the question. Given that extraction therapy does not guarantee post-treatment stability, under what circumstances should teeth be extracted? (Slide 37)

Lower incisor position

As a general rule the treatment plan should be designed around the existing position of the lower incisor teeth and is based on the findings of Litowitz (1948), and a series of papers by Mills (1964, 1967, 1968), that any great amount of labial or lingual movement was likely to relapse; the lower incisors appear to lie within a very narrow zone of stability. Many patients, particularly those with Class I crowding can be treated without significantly altering the labio-lingual position of the lower incisors. There are, however, some exceptions to this rule which include (Slide 38):

- Class II Division 2 malocclusions. There is some evidence to suggest in cases with a deep anterior overbite, arch expansion and lower incisor proclination exhibit a significantly greater ability to be maintained (Shapiro, 1974).
- Where there has been a thumb or finger-sucking habit in which the lower labial segment may have been retruded and/or intruded.
- Retraction of maxillary and mandibular labial segments will be necessary in the treatment of bimaxillary proclination.
- Class II Division 1 malocclusions in which the lower lip has been trapped behind the upper incisor thereby retroclining the lower labial segment – there is frequently an increased curve of Spee in these cases, the levelling of which will produce lower incisor proclination.
- Pre-surgical Class III cases in which the incisors are decompensated prior to orthognathic surgery.

Lower arch crowding

A number of arch length analyses based on measurements of study models and periapical radiographs have been proposed (Nance 1947; Hixon and Oldfather 1958). However, probably the most practical way to estimate crowding is to use the irregularity index described by Little (1975). While not without criticism (by measuring tooth displacement it tends to overestimate the amount of crowding) its great merit is simplicity; visual observation and some mental arithmetic are usually sufficient (Slide 39).

- Mild crowding (0–4mm). Since the available data shows that the extraction of premolars does not obviate post-retention relapse, where the crowding is mild, interproximal stripping may be the treatment of choice. Some clinicians recommend that second, not first premolars should be extracted in such cases.
- Moderate crowding (4–6mm). First premolars are the teeth of choice, although over the past few years there seems to have been a trend towards the extraction of second premolars. This does not, however, lead to greater post-retention stability (Reynolds and Little, 1991).
- Crowding in the mixed dentition. Advantage can be taken of the leeway space.

Anchorage

The one law of physics that orthodontists can remember is Newton's Third Law, which states that for every action there is an equal and opposite reaction. In orthodontic terminology anchorage is used to mean resistance to displacement or unwanted tooth movement. Each orthodontic appliance can be regarded as consisting of two parts; the active parts concerned with tooth movement and the resistance elements that provide the anchorage. In treatment planning one must consider not only the teeth whose movement is desirable, but also the reciprocal effects likely to be produced throughout the arch. These must be evaluated and controlled and may influence the choice of extractions.

Facial aesthetics

It was recognized from the beginning that one of the aims of orthodontic treatment was to improve the patient's appearance. A good deal has been written about the effects of orthodontic treatment and especially extractions on the facial profile, much of it mischievous – one appears to be the profile of a patient with their dentures out! In the circumstances it seems appropriate to look at the relationship between the facial profile, and orthodontic treatment with and without extractions.

Determination of the ideal profile

Many attempts have been made to determine what constitutes the ideal profile from the Apollo Belvedere of Angle (1907) to the early cephalometric studies of Downs (1948) and Riedel (1950), who used hard tissue measurements to describe it. Downs originated the facial angle and angle of convexity which relate incisors, point A and pogonion to the Frankfort horizontal plane to quantitate profile changes. Riedel concluded that an ANB of 2.5° and an angle of convexity of less than 4° provided an ideal combination.

Analyses incorporating the soft tissue outline have also been widely used and since the introduction of computerized cephalometry can be quite complicated. However, three eponymous planes or lines have been commonly used to investigate soft tissue profile changes. Ricketts (1968) in addition to using the facial angle and the angle of convexity introduced what he called the esthetic plane represented by a line extending from the most anterior point of the nose and soft tissue pogonion (Slide 40). He found that in childhood the lips lie just ahead of the aesthetic line and progressively retrude until in adulthood they lie 4 mm behind it.

Slide 40. Use of the esthetic plane to assess the facial profile. (From Ricketts (1968), *American Journal of Orthodontics*.)

Holdaway (1983) described the use of a plane from the upper lip to the chin point. The angle formed between this line and the line NB he termed the H angle The lip analysis of Steiner is based on a line bisecting the S-shaped curve between the tip of the nose and subnasale and extended to soft tissue pogonion; ideally the lips should lie on this line (Slide 41). Comparison of Rickett's E line, Holdaway's H line and Steiner's S line suggest that the H and E lines are heavily influenced by growth. The S line was found to be useful for profile analysis as it more closely reflects dentoalveolar structures (Angelle, 1973).

Slide 41. Left. Holdaway's H line; Right. Steiner's S line and Ricketts' E plane. (From Angelle (1973), *Transactions of the European Orthodontic Society*.)

The bottom line of course is that facial aesthetics is a very subjective phenomenon determined amongst other things by ethnic and cultural considerations – beauty is in the eye of the beholder. Apart from the static 2-dimensional pre- and post-treatment clinical photographs beloved by orthodontists, we rarely look at someone's face in profile. The face has an animated 3-dimensional character; an equally important determinant of facial attractiveness not available from photographs is the personality of the individual.

Changes in facial profile during orthodontic treatment

The most common criticism of extraction treatment is that it causes flattening of the facial profile, with the term 'dishing' used by the anti-extraction lobby to describe the effects of premolar extractions, followed by excessive retraction of the upper and lower labial segments. Several retrospective studies have looked into the relationship between orthodontic treatment and the facial profile in both extraction and non-extraction cases to determine whether this criticism is justified. No doubt these will continue to appear *ad nauseam* in the literature.

In an evaluation of 30 Class II division 1 cases treated by the extraction of four premolars and the Begg technique, Looi and Mills (1986) found that the average change in the nasolabial angle was 5.9° and for the labiomental angle 5.3°. In another group of 30 Class II division 1 cases treated with the extraction of four first premolars and the edgewise appliance (Finnoy *et al*.,

1987), the mean change in the nasolabial angle was found to be 6.5°, suggesting there is no significant difference between the two appliance techniques.

In another study, Drobocky and Smith (1989) examined the soft-tissue profile in 160 orthodontic patients treated with the removal of four first premolars (Slide 42). The records came from five sources; (1) patients treated by Charles Tweed on file at the Tweed Foundation, (2) patients treated with the Begg technique by the Kesling-Rocke group, (3) patients from two practices treated with straight-wire edgewise and (4) patients who had premolars enucleated at an early age. The mean changes for the total sample included an increase of 5.2° in the nasolabial angle, and retraction of the upper and lower lips 3.4 mm and 3.6 mm respectively to the E line (Slide 39). In comparisons amongst groups the Tweed patients generally exhibited the greatest lower lip retraction. When profile changes were compared to values representing normal or "ideal" facial aesthetics, it was evident that extraction of four first premolars generally did not result in a dished-in profile. 80–90 percent of patients had soft-tissue measurements that suggested the profile was improved by treatment or remained satisfactory.

Slide 42. Measurements used by Drobocky and Smith (1989) to assess the effects of the extraction of four first premolars and orthodontic treatment on the facial profile. (From Drobocky and Smith (1989), *American Journal of Orthodontics and Dentofacial Orthopedics*.)

A comparison of the long-term effects of orthodontic treatment in 33 extraction and 30 non-extraction patients with Class II division 1 malocclusions identified by discriminant analysis as being equally susceptible to the two strategies was undertaken by Paquette *et al*. (1992). They found that the two groups showed an essentially identical pattern of post-treatment relapse that was related more to differential growth of the jaws, than to the post-treatment position and orientation of the denture (Slide 43). Interestingly, the non-extraction patients did not rate their appearance any more highly than the extraction patients and they concluded that the data provided little support for the oft quoted claims that premolar extractions — as opposed to expansion — must of necessity produce distal mandibular displacement, and in the process, flatten the profile enough to ruin the face.

Slide 43. Three superimpositions showing: (Left) Average pre-treatment cephalometric tracings (red, extraction; blue, non-extraction) showing that the two groups were essentially identical both dentally and skeletally; (Middle) Average post-treatment cephalometric tracings. The lips and incisors of the non-extraction patients are on average about 2 mm more procumbent; (Right) Average post-retention (recall) tracings. The differences present at the end of treatment are still obvious over a decade later. (From Paquette *et al*., (1992), *American Journal of Orthodontics and Dentofacial Orthopedics*.)

Retention strategies for minimizing relapse

It is easy to become disheartened by the findings of the many long-term studies of post-retention stability, showing that no predictors or associations can be found to determine the long-term prognosis for orthodontic treatment. However, knowing the bad news enables one to devise strategies for improving post-treatment stability beyond the obvious one of permanent fixed retention.

Rotational relapse

Rotational movements of teeth are guaranteed to relapse; fortunately, it is the one feature of relapse for which we have an adequate biological explanation. In experiments carried out on dogs, Reitan (1959) found that while the principal collagen fibres of the periodontal ligament (PDL) were rearranged or remodelled within 28 days (50–80 days in humans; Edwards, 1970), even after a retention period of 232 days some of the free gingival fibres remained displaced and stretched. He concluded that rotational relapse was caused primarily by a contraction of the supra-alveolar gingival fibres (which were later shown to contain elastic or oxytalin fibres) and advised the over-rotation and/or pericision of these fibres during retention to ensure tooth stability. Although often talked about, over-rotation is not a valid method for the simple reason it is impossible to predict whether the over-rotated tooth will relapse by the desired amount.

Direct evidence for the attachment of the supra-alveolar gingival elastic fibres of the tissues to the root has been graphically demonstrated by Edwards (1970) with a simple tattoo technique (Slide 44). Under local anaesthetic, Edwards recommended inserting the point of a No. 11 Bard-Parker blade into the gingival sulcus down to the crest of the alveolar bone and severing all fibrous attachments surrounding the tooth, a technique also known as circumferential supracrestal fiberotomy. He found that tissue repair was complete in 5–7 days and the zone of attached gingiva was unaffected. He further observed that during a 3-month postoperative period in which no mechanical retention device was used, negligible rotational relapse occurred.

Slide 44. Vertical tattoo line on the gingival tissues adjacent to a rotated canine prior to derotation (Fig. 8). Following alignment the tattoo has deviated in the direction of tooth movement (Fig. 10). In Figs. 11 and 12 the canine has been allowed to relapse; the tattoo has also relapsed. (From Edwards (1970), *American Journal of Orthodontics*.)

The value of pericision in reducing rotational relapse, with or without retention has been supported by several investigations (Pinson and Strahan, 1973; Walsh, 1975; Boese, 1980a,b). In a study of twenty-one rotated teeth in fifteen teenage patients, Pinson and Strahan (1973) found that pericision combined with 16–28 weeks retention reduced relapse to a mean of 4.6°, approximately 20% of the original rotation. They concluded that the technique was successful in reducing the amount of relapse to a degree that in most cases was not clinically significant. Interestingly, in my experience many orthodontic trainees these days seem reluctant to carry out the procedure (even if they could find a scalpel in some departments) despite its simplicity, proven efficacy and the fact that without it rotated teeth can be guaranteed to relapse; they seem to have forgotten their first degree was in dental surgery.

Fiberotomy and interproximal stripping

Pericision is indicated for any case in which the supragingival tissues have been distorted by tooth movement; this includes not only rotated teeth but also severely crowded, displaced (eg. palatally positioned lateral incisors) and tipped teeth (Boese, 1980a). Concerned about the frequency and unpredictability of lower incisor relapse, instead of ignoring the problem or using fixed cuspid-to-cuspid retainers Boese (1980a,b) combined interproximal stripping (reproximation) with supracrestal fiberotomy, and evaluated their effectiveness in maintaining post-treatment stability. In addition to Edwards' published research, Boese had first-hand knowledge of the biological mechanisms responsible for rotational relapse from the MSD research that he had carried out on monkeys at the University of Washington (Boese, 1969).

The practice of stripping teeth, particularly lower incisors has a long history, but about that time, Peck and Peck (1972) reported that well-aligned mandibular incisors possessed distinct dimensional characteristics and had introduced the MD/FL (mesio-distal/facio-lingual) index. They concluded that well-aligned mandibular incisors had significantly lower MD/FL indices (a more rectangular form) than crowded ones and recommended interproximal stripping to improve tooth shape. In addition to providing space in borderline extraction cases (removal of 0.5 mm from each of the ten surfaces from canine-to-canine can reduce arch length by 5 mm), stripping provides broader contact point areas and (in theory at least) greater contact stability.

In an important study, Boese (1980b) evaluated a sample of 40 patients from his practice that had been treated with premolar extractions, 4–9 years after treatment. Crowding was assessed by the irregularity index (Little, 1975) and the lower incisors showed remarkable stability, even allowing for the fact that it was a retrospective study (Slide 45). None had been retained, but all the lower incisors had received interproximal stripping to varying degrees plus interproximal fiberotomy. The term interproximal fiberotomy is used deliberately; with the narrow gingival attachment on the labial and lingual aspect of lower incisors and canines, surgical interference with these surfaces must be avoided. The aim of interproximal stripping was to reduce the MD/FL ratios of the incisors. However, as discussed in Section 4.3 below, stripping alone does not guarantee tooth stability.

Slide 45. Some of the cases used to illustrate the effects of interproximal fiberotomy and stripping on the stability of the lower labial segment. The mean MD/FL index at the start of treatment for the lateral incisors was 99.1 ± 6.78%, reduced by stripping to 92.7 ± 6.64%. The corresponding figures for the central incisors were 96.4 ± 13.5% and 91.0 ± 6.7%. (From Boese (1980b), *The Angle Orthodontist*.)

The MD/FL index, lower incisor crowding and relapse

While common sense would suggest that rectangular mandibular incisor teeth with broad contacts and low MD/FL ratios would be more stable than those with high MD/FL ratios, if one compares incisor shape and crowding both before treatment and post-retention, the association is weak (Smith *et al*., 1982; Gilmore and Little, 1984).

Smith *et al*. studied two groups. The first comprised 100 pre-treatment orthodontic patients from the University of Maryland. Although not random, the sample was considered relevant to the practicing orthodontist by addressing the question whether tooth shape ratios are useful in explaining crowding. The second group consisted of 100 sets of study models from an isolated Hutterite population living in Canada. This group served mainly to test whether or not the findings from the orthodontic patients were consistent with another population of different ethnicity, age distribution and occlusal status. They found that in each population incisor crowding was correlated with tooth shape ratios, thus confirming the general observations of Peck and Peck. None of correlations, however, exceeded 0.30.

Gilmore and Little (1982) examined 164 cases from the records of the University of Washington; 134 had received orthodontic treatment and were a minimum of 10 years out of retention. Statistical tests showed there was a weak correlation between incisor widths ($r = 0.56$) and alignment in the long term. There was a weak tendency for narrower incisors to be associated with better alignment in some cases (Slide 46), but narrower mesiodistal widths by themselves did not guarantee long-term stability (Slide 47).

Slide 46. These two scattergrams demonstrate the weak association between the MD/FL index and irregularity in 164 treated orthodontic cases from the records of the University of Washington, Department of Orthodontics more than 10 years out of retention. (From Gilmore and Little (1984), *American Journal of Orthodontics*.)

Slide 47. Two cases designed to illustrate that the MD/FL ratio does not necessarily guarantee stable tooth alignment. (From Gilmore and Little (1984), *American Journal of Orthodontics*.)

Age changes in the dental arches

Age changes in the size and form of the maxillary and mandibular dental arches have been widely investigated, with several studies based on longitudinal material (Cohen, 1940; Speck, 1950; Woods 1950; Clinch 1951; Barrow and White, 1952; Meredith and Hopp, 1956; Knott, 1961; Moyers *et al*., 1976). Many different definitions and techniques have been used to measure dental arch width and arch length, so that while the mean trends in the various investigations are similar, quantitatively the measurements are significantly different. The most widely known work on the subject is *The Dentition of the Growing Child* by Moorrees (1959). The findings of this investigation were based on two groups of children; (1) the Stuart series from the Harvard Growth Study of 59 boys and 73 girls measured from birth to 18 years, and (2) the Stucklen series from Wilmington, Delaware which comprised 25 boys and 27 girls studied from 5–6 to 16–18 years of age (Slide 48).

Coenraad FA Moorrees DDS (1916–2003), Professor of Orthodontics, Harvard School of Dental Medicine, and Chief of Orthodontics at the Forsyth Dental Center, Boston, had a more interesting back story than most. Born in Den Haag, The Netherlands, he received his dental degree (Tandheelkunde) from the University of Utrecht in 1939, and in 1941 a DDS from the University of Pennsylvania Dental School. Ordered by the Dutch government in exile to report to London, he was soon on his way to Java with his wife where he joined the Royal Netherlands East Indies Army. In March 1942 Japanese troops occupied Java; Moorrees and his wife were separated and sent to concentration camps. Both survived the ordeal of being POWs in the tropics, and after the Japanese surrender in 1945, returned to America, where he completed his orthodontic studies at

the Forsyth Dental Infirmary as it was then called in 1947; he was then asked to stay on as Acting Chief of the Orthodontic Department.

Changes in arch length

The average dental arch length was found by Moorrees (1959) to be smaller at 18 years than at age 3 in both males and females. The reduction was greater in the mandibular than maxillary arch (Slide 49), and occurred mainly between 4 and 6 years of age and between 10 and 14 years (Arch length increased temporarily in the maxilla and the mandible with eruption of the incisor teeth.) The first decrease can be explained by the disappearance of the spaces between the deciduous teeth; the second follows replacement of the deciduous molars by the smaller premolars and closure of the leeway space. The later implant studies of Björk (1963), showed that uprighting of the lower incisors also contributed to the decrease in arch length in many individuals, particularly those with marked horizontal mandibular growth. The obvious clinical manifestation of these changes is lower incisor crowding.

There was considerable variation around the mean or average values for arch length. Some children showed an increase and others a decrease, irrespective of the direction or amount of the mean change at each age level. Moorrees suggested that it was therefore hazardous to accept the average annual change as a guide to predict individual growth patterns in arch length. For example, the length of the mandibular dental arch decreased on average by about 0.5 mm between 5 and 6 years of age, but an increase of 1.2 mm or a decrease of 2.0 mm was observed in some subjects.

Changes in arch width

In the mandible the average distance between the canines increased continuously after 5 years of age to a maximum at 10 years in males and 9 years in females, followed by small decreases with eruption of the permanent canines (Slide 50). Little change occurred after 12 years of age. The distance between the mandibular first permanent molars increased gradually, apart from an appreciable increase at 13 years in boys and at 11 years in girls. In the maxillary arch the increase in width took place during three phases, each followed by a period of little change.

Conclusions

- Reading the literature relating to the extraction debate one is reminded of the remark attributed to Wallace Sayre (1905–1972), a political scientist at Columbia University, New York, who asserted the intensity of academic squabbles was a function of the triviality of the issue under discussion: “In any dispute the intensity of feeling is inversely proportional to the value of the issues at stake.” Other variants include “Academic politics is much more vicious than real politics because the stakes are so low.”

- There is more than a hint of hubris about the early practitioners of orthodontics, and a sense of superiority amongst the graduates of the Angle School, being members of an exclusive club, and custodians of the true faith. And woe betide any apostates.

- One is tempted to suggest the reason Angle became a firm advocate of nonextraction treatment, was the absence of an orthodontic appliance that could do more than just tip teeth; one was left with those embarrassingly ugly black spaces that couldn’t be closed. Not to put to fine a point on it, the mechanics available made nonextraction treatment a necessity. And if Curtis (2000) is correct, extracting two premolars from his wife Anna and failing to keep the spaces closed, was an everyday reminder, and a powerful motive for Angle to invent a fixed appliance that could.

- The result after many years of trial and error was Angle’s gift to the World – the Edgewise arch mechanism of the late 1920s. The irony can’t have been lost on Angle, that by inventing an orthodontic appliance that could be used to treat extraction cases to a high standard, he had unwittingly undermined his nonextraction philosophy, as Charles Tweed was soon to demonstrate.

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