REVIEW ARTICLE

Retention and stability: A review of the literature

Marielle Blake, BDent Sc, FDS(Orth), DOrth, MOrth, MRCDC,[a] and Kathryn Bibby, BDS, MSc, FDS, DOrth, MRCDC[b]
Dublin, Ireland, and South Slocan, British Columbia, Canada

Long-term posttreatment stability is an issue of great concern to all orthodontists. This article highlights the factors reported to play a role in posttreatment crowding and reviews the long-term retention studies evaluating the stability of various treatment modalities. Recommendations, based on well-documented basic principles, are made to try to insure greater posttreatment stability of our orthodontically treated cases. (Am J Orthod Dentofacial Orthop 1998;114:299-306)

Retention after orthodontic treatment has been defined by Moyers[1] as "the holding of teeth following orthodontic treatment in the treated position for the period of time necessary for the maintenance of the result" or by Riedel[2] as "the holding of teeth in ideal aesthetic and functional position." The proposed basis for holding the teeth in their treated position is to: allow for periodontal and gingival reorganization; to minimize changes from growth; to permit neuromuscular adaptation to the corrected tooth position; and to maintain unstable tooth position, if such positioning is required for reasons of compromise or esthetics.

NORMAL DEVELOPMENT

Posttreatment changes in the dentition may be affected by physiologic dentoalveolar adaptation. During normal development a moderate increase in arch width is seen until permanent cuspid eruption,[3,4] followed by a reduction of intercanine width.[5-7] The intermolar width remains stable from 13 to 20 years,[1,3,4,6,7] and there is a reduction in the AP dimension of the mandibular arch with time.[3,6-11] Incisor irregularity increases during the teenage years and is more pronounced in females.[6,7] The mandibular anterior segment is thought to be displaced lingually relative to the body of the mandible during normal growth.[12,13] This however, is not a universal finding as Bjork[14] has documented certain cases showing an increase in dentoalveolar prognathism.

[a]Lecturer Consultant, Department of Child Dental Health, Dublin Dental Hospital.
[b]In private practice.
Reprint requests to: Marielle Blake, BDent Sc, FDS(Orth), MOrth, MRCDC, Lecturer Consultant, Department of Child Dental Health, Dublin Dental Hospital, Lincoln Place, Dublin 2, Ireland.

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FACTORS THAT AFFECT POSTTREATMENT STABILITY

Although numerous factors have been reported to play a role in posttreatment crowding, no definite conclusions regarding the relative contribution of these factors have been reached. Some areas of investigation are discussed in the following section.

Alteration of arch form

With some notable exceptions, it is generally agreed that arch form and width should be maintained during orthodontic treatment.[15,16] In certain cases, where arch development has occurred under adverse environmental conditions, arch expansion as a treatment goal may be tolerated. Mills[17] found stability after proclination in cases with skeletal deep bites and retroclined incisors in conjunction with a digit or lip entrapment habit.[17] Årtun[18] stated that proclination may be successful provided that the lower incisors are initially retroclined, a reason for the retroclination determined, and the cause eliminated during treatment.

There is evidence to show that intercanine and intermolar widths decrease during the postretention period, especially if expanded during treatment.[19-22] For this reason, the maintenance of arch form rather than arch development is generally recommended. Expansion is thought to be better tolerated in Class II Division 2 cases that show a significantly greater ability to maintain intercanine expansion than Class I and Class II Division 1 cases.[23,24] This statement, however, was based on a sample of six patients and was not accepted by Little et al.[25] who maintained that intercanine and intermolar width will relapse if expanded in Class II Division 2 cases as much as in other Angle classifications.

Another exception to the maintenance of arch width may be found in cases of mandibular expansion concurrent with Rapid Palatal Expansion.

Haas[26] and Sandstrom et al.[27] found that maintenance of 3 to 4 mm intercanine width and up to 6 mm intermolar width was possible when expansion was carried out concurrently with maxillary apical base expansion. These two studies, however, are quite misleading. Haas' study was based on 10 cases and primary canines were present in the initial records for two of these. It is questionable how one can extrapolate on the amount of canine expansion achieved, when in 20% of this small sample, the permanent canines were not present at the time of the original records. Sandstrom's statement that mandibular incisor stability is increased when the mandibular intercanine width is expanded in conjunction with maxillary expansion is based on a sample of 17 patients only 2 years postretention.

Moussa et al.[28] reported on a sample of 55 patients who had undergone rapid palatal expansion in conjunction with edgewise mechanotherapy a minimum of 8 years postretention. Their results showed good stability for upper intercanine and upper and lower intermolar widths. Stability of the mandibular intercanine width, however, was poor with the posttreatment position closely approximating the pretreatment dimension.

De La Cruz et al.[29] carried out a 10 year postretention study on 87 patients to determine the long-term stability of orthodontically induced changes in maxillary and mandibular arch form. The results showed that although there was considerable individual variability, arch form tended to return toward the pretreatment shape. They concluded that the patient's pretreatment arch form appeared to be the best guide to future stability. Minimizing treatment change around the pretreatment arch form, however, was still no guarantee of postretention stability.

Periodontal and gingival tissues

Orthodontic movement to correct tooth rotations is proposed to result in stretching of the collagen fibers. These stretched fibers have been implicated in rotational relapse by pulling the teeth back toward their pretreatment position.[30,31] After the placement of a tattoo marker on the attached gingiva in dogs, Edwards[31] also demonstrated incomplete reorganization of gingival tissues over a 5 month postretention period. With this in mind, various experimental approaches have been investigated, ranging from immediate torsion with surgical forceps,[32] removal of cortical bone,[33] and removal of attached gingiva.[34]

Brain[35] and Edwards[36] advocated gingival fiber surgery (Circumferential Supracrestal Fiberotomy) to allow for the release of soft tissue tension and reattachment of the fibers in a passive orientation after orthodontic tooth rotation. In 1971 a prospective study was initiated by Edwards[37] with 160 patients up to 14 years posttreatment. The results were published in 1988 and show a significant difference in the irregularity index between the control and treatment groups at both 6 and 14 years posttreatment. No significant loss of attachment or other periodontal abnormalities were reported, a finding that has been confirmed by others.[38,39]

The theory of stretched collagen fibers as the cause of rotational relapse has recently been questioned by Redlich et al.[40] who analyzed gingival tissue samples obtained from rotated incisors in dogs. They found that the rotational forces caused significant changes in the integrity and spatial arrangement of the gingival tissues, changes that are inconsistent with stretching. After fiberotomy, reorganization of the fibers similar to the control group was evident. They concluded that rotational relapse may actually originate in the elastic properties of the whole gingival tissue rather than stretching of the gingival fibers as previously believed.

Mandibular incisor dimensions

The notion that mandibular incisor dimensions were correlated with lower incisor crowding was reintroduced by Peck and Peck[41] after a study of 45 untreated normal occlusions. They advocated reduction of mandibular incisors to a given faciolingual/mesiodistal ratio to increase stability. Peck and Peck's work, however, was criticized for the following reasons. Their recommendations were based on a study involving untreated rather than treated cases. Young patients with ideal lower incisor alignment were used in the study. It is possible that these cases would show crowding if followed long term. To evaluate whether the Peck and Peck ratio had long-term value, Gilmore and Little[42] studied 134 treated and 30 control cases a minimum of 10 years postretention. They showed a weak association between long-term irregularity and either incisor width or the faciolingual/mesiodistal ratio. Less than 6% of crowding can be explained by this ratio. In addition, the actual mean difference in incisor widths between crowded and uncrowded cases was only 0.25 mm. These findings were also confirmed by other studies[43-47] that suggest that tooth structure plays only a minor role (if any) in the etiology of late mandibular incisor crowding.

Boese[38] introduced the concept of lower incisor

reproximation to provide broader contact points and increase the available arch space in the mandibular anterior region. In a 4 to 9 year follow-up study of 40 patients, treated with four premolar extractions followed by interproximal reduction and supracrestal fiberotomy, he showed good stability with a postretention irregularity index of only 0.62 mm. The mean interproximal reduction was 1.7 mm immediately posttreatment and a further 0.8 mm over the retention period. This, however, was a retrospective study that involved continued intervention during the retention period, even in the presence of minor relapse. For this reason, we are unable to compare the results of this study with results from other retention studies.

Influence of environmental factors and neuromusculature

Strang[48] theorized that the mandibular intercanine and intermolar arch widths are accurate indicators of the individual's muscle balance and dictate the limits of arch expansion during treatment. Weinstein et al.[49] and Mills[17] stated that the lower incisors lie in a narrow zone of stability in equilibrium between opposing muscular pressure, and that the labiolingual position of the incisors should be accepted and not altered by orthodontic treatment. Reitan[50] claimed that teeth tipped either labially or lingually during treatment are more likely to relapse.

The initial position of the lower incisors has been shown to provide the best guide to the position of stability in two separate studies.[51,52] In over 50% of cases the lower incisors ultimately stabilized at a point between the pretreatment and posttreatment positions. These results indicate that if lower incisor advancement is a treatment objective, permanent retention is essential for maintenance of the result.

Consideration of continuing growth

The role of growth in posttreatment changes is controversial. Litowitz[53] stated that cases exhibiting greatest amount of growth during treatment showed less relapse. Riedel[16] reflected on the fact that growth may aid in the correction of orthodontic problems but may also cause relapse of treated cases. Nanda and Nanda[54] agree with this and maintain that any skeletal changes that occur during retention may attenuate, exaggerate, or maintain the dentoskeletal relationship.

It has been suggested that the amount and direction of facial growth in the postretention period may be at least partially responsible for the maturational changes seen in the dentition.[47,53,55]

Facial development may result in secondary crowding especially in extreme growth patterns such as forward mandibular growth rotation where increased lingual movement of lower incisors may be seen.[4,14,56,57] These findings, however, are not universally accepted. Others have stated that growth is not a major influence in development of mandibular anterior irregularity,[7,51,58] and this is likely the case in an average grower.

Nanda and Nanda[54] found that the pubertal growth spurt for patients with skeletal deep bite occurs on average 1.5 to 2 years later than is the case for open bite cases. For this reason, a longer retention period for the skeletal deep bite patients is advocated to counteract the continuing effect of dentofacial growth after the completion of orthodontic treatment.

Posttreatment tooth positioning and establishment of functional occlusion

The importance of a functional and stable occlusion posttreatment is repeatedly stressed in the literature.[22,50,59] Adequate interincisal contact angle may prevent overbite relapse and good posterior intercuspation prevents relapse of both crossbite and AP correction. Less relapse of mesiodistal movement occurs in the absence of occlusal stress.[30] A perfect molar relationship was found to be a significant factor in maxillary incisor alignment in a study of 226 postretention cases,[22] and a RCP - ICP slide was found to have a statistically significant, though clinically only moderate, influence on mandibular incisor irregularity postretention.[60]

Role of developing third molars

The role of third molars in lower incisor crowding has been debated for more than a century. The literature is almost equally divided with arguments for both sides.

One theory commonly reported is that of the third molars creating space to erupt by causing anterior teeth to crowd.[61-65] Woodside[66] postulated that in the absence of third molars, the dentition could settle distally in response to forces generated by growth changes or soft tissue pressures. This implies a passive role of the third molars in the development of late crowding by hindering that adjustment. A recent study shows a statistically significant but not a clinically significant role of third molars in postretention crowding.[22]

Broadbent[67] was an early advocate of the insig-

nificant role played by third molars in late lower incisor crowding. Several studies show a reduction in arch length and an increase in crowding with age. However, no difference in incisor crowding could be found in groups with impacted, erupted, missing, or extracted wisdom teeth.[68-72] Richardson[73,74] demonstrated a significant forward movement of first molars between the ages of 13 and 17 years. This was correlated with the increase in lower arch crowding that occurred during the same period. There was no difference, however, in the forward movement of the first molar, in cases with or without impacted third molars. A recent study on 42 patients from the Belfast Growth Study[75] confirmed these findings. However, although third molar space is discussed in this study, the status of the third molars is not specifically mentioned.

In summary, all of the conflicting data regarding third molars tends to indicate that if third molars were a contributing factor in the development of late lower incisor crowding, their role is likely to be one of minor importance.

Influence of the elements of the original malocclusion

Overbite increase postretention is related to the amount reduced during treatment, although generally 30% to 50% of the correction is retained.[25,51,76,77] It is suggested that overbite relapse tends to occur in the first 2 years posttreatment and maintenance of intercanine width is thought to increase stability.[78] Stability of anterior open bite correction has been evaluated in 41 patients.[79] The average pretreatment openbite of 5.0 mm was reduced to 3 mm positive overbite during appliance therapy. Forty percent of the sample showed marked relapse averaging 4.5 mm; the other 60% showed stability of the result. The relapse subgroup showed a greater increase in lower anterior face height during the postretention period than did the stable group, but no pretreatment variables could be used to predict posttreatment relapse or stability.

Most studies do not support a greater relapse in Class II Division 1 cases when compared with other malocclusion groups,[72,80-82] however, a slight change in overjet toward pretreatment values was demonstrated in all malocclusion groups. Labially inclined incisors pretreatment tend to be associated with less long-term crowding.[42,83] It is postulated that the weaker labial muscular forces do not induce lingual movement of the dentition and subsequent arch length shortening.

When teeth are aligned by orthodontic treatment, there is a documented tendency for a return toward the original pattern of malocclusion.[84,85] For this reason, rotational overcorrection has been advocated. Little et al.,[25] however, note that there are many exceptions to this rule with greater than 50% of the rotations or displacements relapsing in an opposite direction. A postretention study was carried out on 116 patients by computerized cast analysis.[86] The majority of teeth showed mild rotation 10 years postretention and greater rotational correction during treatment resulted in greater rotational relapse.

Udhe et al.[76] formed a multiple regression analysis of overjet, overbite, intercanine width, and intermolar width changes. They revealed that 41% of late lower incisor crowding could be explained by these variables. The highest single factor at 12.5% was the mandibular intercanine width reduction postretention. This leaves over 50% of the crowding to be explained by other factors, and it is likely that the relative contribution will vary between individuals with a similar degree of irregularity.

TREATMENT MODALITIES

Several long-term retention studies evaluating the stability of different treatment modalities have been reported. The main center for much of this research is the University of Washington. Most of the research is centered on the mandibular arch with the assumption that alignment of the lower arch serves as a template around which the upper arch develops and functions.

Most of the studies report on the Irregularity index,[10] arch length, and intercanine width. It is important to note that the terms crowding and arch length deficiency are not synonymous with the irregularity index. The irregularity index measures displaced anatomic contact points of the teeth and gives an objective value to subjective crowding of the case. Arch length deficiency on the other hand represents the space needed for alignment of teeth. The following treatment modalities have been studied.

Late extraction followed by full treatment

Little et al.[25] report on 65 first premolar extraction patients at least 10 years postretention. Mandibular arch shortening was seen in 63 of the 65 patients. The crowding posttreatment was not associated with the degree of arch length reduction. Intercanine width change during the treatment and the duration of retention were not predictive of postretention crowding. The overall success rate,

defined as an irregularity index of less than 3.5 mm, was less than 30% with 20% showing marked crowding. Shields et al.[51] reevaluated 54 of the patients from the 1981 study[25] and failed to find any clinically significant predictors or associations of value between the dental-cast measurements and cephalometric data. Any change in cephalometric parameters postretention failed to explain postretention crowding.

The overall success rate of 30% found 10 years postretention deteriorated to 10% at 20 years postretention in a further follow-up study.[87] Little et al.[87] concludes that the only way to ensure satisfactory alignment posttreatment is the use of fixed or removable retention for life.

Serial extraction without treatment

Kinne[88] reported on 55 patients who had undergone serial extraction without any appliance therapy. The patients, examined at least 10 year after the extraction of premolars, showed an increase in posttreatment irregularity.

Persson et al.[89] reported on 42 patients an average of 20 years after serial extraction therapy. Most of the cases showed redevelopment of crowding, however, it was less pronounced than pretreatment and when compared with untreated normals there was no difference in the crowding evident between the two groups.

Serial extraction followed by appliance therapy

Anticipated future stability is one of the objectives of serial extraction therapy. Tweed[90] postulated that early self-alignment should result in improved stability. Engst[91] studied 30 patients at 5 years postretention, and Little et al.[92] reported on the same sample at least 10 years postretention. Clinically unsatisfactory mandibular anterior alignment occurred in 73% of the cases and decreases in intercanine width and arch length was found in 29 of the 30 cases.

McReynolds and Little[93] found no difference in postretention irregularity between first and second premolar extraction cases. Both the first and second premolar extraction cases showed a reduction in arch length and width and were unpredictable relative to long-term alignment. When compared to the late premolar extraction group, the success rate of less than 30% was no different.

Nonextraction therapy with expansion

Twenty-six patients who had at least 1 mm of arch development during the mixed dentition were studied at least 6 years postretention.[94,95] All the patients showed a reduction in arch length after treatment and only five patients maintained an overall increase of 1 mm. This is in agreement with Amott[20] who found that only 2 of the 55 patients studied maintained any arch length increase. The irregularity posttreatment was the highest of all the treatment groups studied at 6.06 mm; the overall success rate was only 11%. For this reason, Little[96] advocates the use of permanent retention after mandibular arch development. Moussa et al.[97] reported on a sample of 55 patients who had undergone rapid palatal expansion in conjunction with edgewise mechanotherapy a minimum of 8 years postretention. Their results showed good stability for upper intercanine, upper and lower intermolar widths, and lower incisor irregularity. Stability of the mandibular intercanine width, however, was poor with the posttreatment position closely approximating the pretreatment dimension. These findings correlate well with those of Glynn et al.,[47] who studied the stability of nonextraction orthodontic treatment in 28 patients a minimum of 3 years postretention.

The stability of nonextraction treatment with prolonged retention was studied by Sadowsky et al.,[98] who looked at 22 patients an average of 8.4 years postretention (minimum, 5 years). The mandibular incisor irregularity increased during the postretention period but at 2.4 mm was still in the acceptable range. They conclude that the prolonged mandibular retention may play a role in this finding. The postretention period of 5 years, however, is relatively short, and the incisor irregularity would probably be greater if the study period or the sample size was increased.

Elms et al.[82] recently reported on a sample of 42 patients with Class II Division I malocclusion, who were treated without extraction and with headgear and fixed appliances. Final records were taken an average of 6.5 years postretention (minimum, 3 years). Some incisor reproximation was preformed on removal of the mandibular bonded retainer. Ninety percent of the sample had incisor irregularity of less than 3.5 mm postretention. They conclude that the factors responsible for the stability seen are the application of proper mechanics, a cooperative patient, and favorable downward and forward mandibular growth. This success rate may, however, be reduced if the postretention period was extended.

The above cases showed only minimal crowding pretreatment. No data are available to date on the

long-term maintenance of the nonextraction treatment of cases with moderate crowding.

Early mixed dentition treatment without fixed appliance therapy

Dugoni et al.[99] recently reported on the postretention stability of cases who had early mixed dentition treatment followed by the placement of a mandibular bonded retainer. No appliance therapy was carried out in the permanent dentition. Circumferential supracrestal fiberotomy or interproximal enamel reduction was carried on removal of the bonded retainers. The irregularity index in this sample at the postretention stage showed satisfactory mandibular incisor alignment in 76% of the cases. In contrast to other studies,[25,87,92,93] maintenance of postretention intermolar width was also noted. It is suggested that the early establishment of an intermolar width and improved occlusion in the mixed dentition provides better long-term stability. In this study, 72% showed a reduction in arch length postretention, yet no associations were found between this finding and the increase in irregularity index. However, the sample size in this study was small (n = 25), and the minimum postretention period was only 5 years.

Nonextraction therapy with generalized spacing

Thirty patients with mandibular spacing pretreatment were studied 10 years postretention.[100] Of all the treatment modalities studied, this treatment displayed the most long-term stability with an irregularity index value of 3.38 mm. This was still slightly higher, however, than the value of 2.7 mm for untreated norms. Minimal relapse of overjet and overbite was evident. Some intercanine width reduction was evident in most cases. The overall success rate in this group was 50% postretention. Mandibular spaces did not reopen in any case. However, the maxillary arch showed more variation; the midline diastema was the most common areas of space recurrence.

Lower incisor extractions

Riedel[24] observed an increase in posttreatment stability after an informal review of patients who had two mandibular incisors removed. He then carried out a long-term study to specifically determine the stability and relapse of the mandibular incisor extraction therapy.[101] Twenty-four patients who had a single mandibular extraction followed 6.5 years postretention and 18 patients with two mandibular incisor extractions followed for a period of 9.75 years were studied. Twenty-nine percent of the single incisor extraction group and 56% of the two incisor extraction group demonstrated unacceptable mandibular incisor alignment at the postretention stage. This compares favorably to the results of previously reported premolar extraction cases,[25,51] however, the sample size of the two incisor extraction group was small (n = 18) and the postretention period of the one incisor extraction group was relatively short (minimum, 6.5 years).

SUMMARY OF POSTTREATMENT CHANGES

Similar long-term alterations in arch form are seen in most of the treatment groups studied. Arch length reduction is evident to some extent after orthodontic treatment. Variables such as Angles classification, length of retention, patient's age, gender, pretreatment overbite, overjet, arch width, or arch length cannot be used to predict these posttreatment arch changes. A lingual displacement of the anterior mandibular segment relative to the body of the mandible is seen.[102] This has also been described during normal growth.[13]

Intercanine width reduction is seen posttreatment whether the case was expanded during treatment or not. The intermolar width tends to return to the pretreatment value during the postretention period in most of the studies. These reported changes in intercanine and intermolar width are greater in the mandibular arch than the maxillary arch. Although most of the arch changes are seen before age 30, mandibular anterior crowding continues into the fifth decade. As summarized by Little et al.[25] "treated cases should be viewed as dynamic and constantly changing, at least through the third and fourth decade and perhaps throughout life." Of all the treatment modalities studied only three showed acceptable long-term mandibular incisor alignment postretention. These were the early mixed dentition treatment with no fixed appliance therapy,[99] the nonextraction therapy with generalized spaces,[100] and the lower incisor extraction cases.[101] In the other treatment groups studied, the overall long-term success at maintaining the alignment of the mandibular anterior teeth was less than 30% with nearly 29% likely to show marked crowding postretention.[25,92,93,95]

CONCLUSION

Permanent retention is cited by several authors[87,96,103] as the only way to ensure long-term posttreatment stability. However, as trained orthodontists it is incumbent on us to take a more proactive approach in dealing with the

factors associated with relapse. We should aim to remove the primary burden of preventing relapse from our patients and would be well advised to maintain as treatment goals the following well documented basic principles:

1. The patient's pretreatment lower arch form should be maintained during orthodontic treatment as much as possible.[15,16,19-22,26,28]
2. Original lower intercanine width should be maintained as much as possible because expansion of lower intercanine width is the most predictable of all orthodontic relapse.[15,16,19-22,28,47,48,97]
3. Mandibular arch length decreases with time.[3,6-11]
4. The most stable position of the lower incisor is its pretreatment position. Advancing the lower incisors is unstable and should be considered as seriously compromising lower anterior posttreatment stability.[17,49-52]
5. Fiberotomy is an effective means of reducing rotational relapse.[35-38]
6. Lower incisor reproximation shows long-term improvements in posttreatment stability.[38,41,99]

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