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# Interproximal reduction in orthodontics: why, where, how much to remove?

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Interproximal reduction (IPR) is the deliberate removal of part of the dental enamel from the interproximal contact areas, which decreases the mesiodistal width of a tooth. This enamel may be removed for various reasons, but most commonly to create space during orthodontic treatment or to correct tooth-size discrepancies. Several authors have also encouraged its use as a method by which post-orthodontic stability might be enhanced, particularly in the lower anterior region. With the increased use of removable aligners for orthodontic treatment in which non-extraction therapy is often advocated, the use of IPR becomes a valuable tool to relieve crowding without over-expanding the dental arches.

It is possible that inaccurate IPR could result in the over-reduction of enamel, the creation of ledges and notches in the proximal surfaces, increased tooth sensitivity or damage to the surrounding soft tissues. However, carefully conducted IPR performed within the recommended guidelines may be used as a safe method to gain space for the relief of crowding, to correct tooth-size discrepancies and to improve aesthetics and long-term stability in selected orthodontic patients.

(Aust Orthod J 2017; 33: 150-157)

Received for publication: April 2016

Accepted: April 2017

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## Introduction

Interproximal reduction (IPR) is the deliberate removal of part of the dental enamel from the interproximal contact areas, which decreases the mesiodistal width of a tooth.<sup>1</sup> IPR is becoming more popular in orthodontic practice, especially in combination with the use of removable aligners.<sup>2</sup> The aim of the present article is to critically review the indications, the methods, and possible consequences of IPR.

## Indications for IPR

### *Tooth-size discrepancy*

There are now many recognised indications for IPR. Its first reported use was to correct tooth-size discrepancies when aligning anterior teeth.<sup>3</sup> A ratio based on the mesiodistal widths of teeth in the lower arch in relation to the upper arch was created,<sup>4</sup> which determined how well the buccal segments would interdigitate ('overall' Bolton's analysis) and

whether the size of the anterior teeth would support the creation of a Class I canine relationship with acceptable overbite and overjet ('anterior' Bolton's analysis). Using the Bolton's ratio, it is possible to calculate the predicted fit of the teeth following alignment. After a detailed space analysis, in cases in which there are discrepancies between the upper and lower dentitions, the teeth that are oversized may then be narrowed by performing IPR. The reduction in tooth width will eliminate the discrepancy and allow a better interdigitating occlusion at the completion of orthodontic treatment. Cases in which a Bolton's discrepancy is more likely include the circumstance when the patient has diminutive upper lateral incisors; when there are missing teeth; or when there are particularly large, small or unusually shaped teeth in either arch.<sup>4</sup>

A recent review of IPR stated that a Bolton's tooth-size discrepancy remains the main reason that IPR is used to manage orthodontic patients.<sup>5</sup> There

are various methods that enable the calculation of a Bolton's tooth-size discrepancy, since it is often difficult to appreciate without measurement. It was recently concluded that the use of Vernier callipers on plaster models is still considered the 'gold standard' of determination, but that contemporary methods such as the use of digital photographs, laser scanning and stereophotogrammetry may, in fact, be more clinically accurate.<sup>5</sup>

### ***Relief of crowding***

IPR has been described as a method to gain space in a Class II division 2 malocclusion.<sup>6</sup> With an increasing demand from patients to align teeth without extractions, IPR has become more common and it can be used to relieve mild to moderate crowding,<sup>7,8</sup> particularly in non-growing patients in whom excessive expansion or extractions are not possible.<sup>5,9</sup> There have been various reports over the last 50–60 years indicating the amount of space that can be gained from the use of IPR. Earlier studies tended to be more conservative with their recommendations and specified gains of up to 3 mm of space in the mandibular anterior region.<sup>6,10</sup> However, later studies have reported space gains as great as 10 mm when IPR is performed on premolars and molars alone.<sup>11</sup> If the reported amounts of possible reduction from both the anterior and buccal segments are totalled, theoretically, almost 13 mm of space could be gained in the mandible from second molar to second molar.<sup>4,11</sup> However, patients with arch length discrepancies of 13 mm would most likely to be treated with extractions.<sup>12</sup>

### ***Increased stability***

In 1972, Peck and Peck suggested that IPR could be used to increase post-treatment stability of the lower incisors.<sup>13</sup> The rationale for this approach was the observation that naturally well-aligned mandibular incisors had specific mesiodistal (M-D) and labio-lingual (L-L) dimensions.<sup>14</sup> The well-aligned incisors had significantly larger labio-lingual dimension (i.e., broad contact points) and a smaller mesiodistal dimension, suggesting that the shape of the incisors may be a factor determining whether lower incisor crowding occurred. An index was constructed that uses the M-D/L-L ratio to determine whether an incisor is favourably shaped.<sup>13</sup> If a particular incisor falls outside this range, then IPR can be performed

to change its dimensions and restore a favourable morphology, which would theoretically assist in its long-term alignment.

However, this work was later criticised since the recommendations were based on a sample of untreated cases in relatively young patients, who may well have gained lower incisor crowding in the future had they been followed for a longer period.<sup>15</sup> The Peck and Peck ratio was then investigated in a sample of treated cases over a post-retention minimum period of 10 years.<sup>16</sup> The findings showed only a weak association between the ratio and long-term alignment, suggesting that the shape and dimensions of the teeth may play only a limited role in the long-term stability of the lower incisors.

A two-part study from 1980 assessed the stability of the lower incisors four to nine years after treatment without retention but after circumferential supracrestal fiberotomy (CSF) and IPR had been performed.<sup>17,18</sup> All cases had either first or second premolars removed and CSF was performed on teeth in which the supragingival fibres had been markedly displaced. The IPR was conducted on all cases in three phases. The first phase was early in treatment, as soon as alignment of the lower anterior teeth had been achieved; the second, shortly after band removal (usually over a period of four to six months); and the third phase (not often needed) occurred subsequently whenever contact points became tight or malalignment was noted. In the second part of the study, the Peck Irregularity Index<sup>13</sup> before treatment was, on average, 9.2 mm.<sup>18</sup> During the post-treatment period the Irregularity Index decreased to 0.6 mm, which is still considered within the limits of 'perfect alignment'. The average amount of total IPR from the lower incisors was 1.7 mm and the inter-canine widths increased by only 0.9 mm. There was no measurable alveolar bone loss. It was concluded that reproximation of the lower incisors used in combination with CSF (where indicated) may increase the long-term stability of the lower incisors even without the use of retention. This conclusion was not supported by a later study investigating the relationship of mandibular incisor dimensions and long-term stability in orthodontically-treated cases, in which only weak associations were found.<sup>16</sup>

The preservation of inter-canine width has been advocated to increase long-term stability in the mandible and, if IPR is used to gain space rather than expanding in the lower anterior region, the inter-canine

width is more likely to be preserved.<sup>19,20</sup> A study examining cases 10 years post-retention investigated the long-term stability of treatment-induced changes of the maxillary and mandibular arch forms.<sup>21</sup> It was found that the arches tended to return to their pretreatment shape and that pretreatment arch form is the best guide for future arch form stability. This corroborated earlier findings, which reported that 70% of orthodontically-treated cases would return to their original arch form after treatment.<sup>22</sup> However, it was also stated that maintenance of the pretreatment arch form is not a guarantee of future stability either.<sup>21,23</sup>

### ***Improved aesthetics of anterior teeth***

The use of IPR has been advocated to improve anterior tooth shape and aesthetics.<sup>5,21</sup> Through IPR and lengthening of the contact area, there is a reduction in the incidence of black triangles (dark spaces visible between the papilla up to the contact point when the contact point is farther from the alveolar crest than normal). It has been reported that, if the distance from the interproximal bony alveolar crest to the contact point is 5 mm or less, then there is almost 100% infill from the interdental papilla.<sup>24</sup> If the teeth are triangular in shape then the contact point will be farther from the alveolar crest, increasing the likelihood of black triangles. In this circumstance, the use of IPR to alter the proximal surface contour can be beneficial; however, care must be taken when IPR is performed in only one arch, as a Bolton discrepancy might be created that did not previously exist.<sup>5</sup> A reduction of the opposing dentition may be necessary in these cases to balance the created discrepancy.<sup>25</sup>

Conversely, it has been reported that an acceptable occlusion can be obtained when a Bolton discrepancy does exist, suggesting that IPR should not be performed in advance to correct a discrepancy but, rather, its necessity should be reassessed following alignment and an assessment of the final occlusion.<sup>26</sup>

### ***Extraction avoidance***

With an increasing number of patients using removable, aesthetic, orthodontic appliances, for whom extractions are often not advocated, the use of IPR as an alternative to gain space is becoming more popular.<sup>5,20</sup> The benefit of using IPR rather than extraction therapy to gain space is that it decreases overall treatment time, since the amount of stripping

corresponds exactly with the amount of crowding.<sup>27</sup> Performing IPR when treating a case without any extractions also means that excessive advancement of the mandibular incisors can be avoided,<sup>28</sup> as well as over-expansion of the dental arches, while at the same time satisfactory alignment is still achieved.<sup>20,27,28</sup>

There are well-accepted guidelines regarding orthodontic treatment in relation to extractions.<sup>11,12,28,29</sup> Generally, crowding of 5 to 9 mm may be treated with or without extractions depending on the characteristics of the case; however, in patients in whom there is an arch length discrepancy of 10 mm or more, extractions are almost always indicated, despite the reported amounts of space that can be created by the use of IPR.<sup>20,30</sup>

### **Enamel thickness and amount of enamel reduction**

There have been many studies conducted to investigate the thickness of tooth enamel.<sup>11,31-40</sup> Radiographs have been used to compare the thickness of enamel between males and females.<sup>36</sup> Although it was found that the teeth in males were larger than in females, this difference was due to an increase in the thickness of dentine rather than enamel.<sup>11</sup> This was supported by an additional study which found that there was thicker dentine in males than in females.<sup>37</sup>

The relationship between the thickness of proximal enamel, tooth type, tooth width, gender and ethnicity has been investigated.<sup>36,39</sup> It was reported that the lateral incisors had thicker enamel than the central incisors and that the distal enamel was thicker than the mesial enamel.<sup>31</sup> Generally, Caucasian subjects had thinner enamel than African-American subjects and, overall, tooth width correlated positively with enamel thickness.<sup>39,40</sup> It was mentioned, however, that there was substantial variability in enamel thickness between, and within, the subjects. Based on proximal enamel thickness, it was suggested that 0.20 mm or less on the proximal of mandibular incisors could be safely removed.<sup>39</sup>

A more recent investigation into enamel thickness, in which enamel was measured directly histologically (as opposed to radiographically), provided similar results.<sup>40</sup> Based on these findings, it was suggested that up to 0.5 mm per anterior contact area (i.e., 0.25 mm per surface) and up to 1 mm per posterior contact (i.e., 0.5 mm per surface) may be safely removed using IPR.<sup>11,40</sup>

There have been a large number of papers that have suggested the amount of enamel that can be safely removed by IPR. Interestingly, the initial recommendation (of up to 50% enamel reduction<sup>10</sup>) was made with no scientific justification, yet this has been repeatedly quoted with authority. Initially, it was reported that 3 mm might be gained from IPR of the mandibular incisors,<sup>10</sup> and it was later stated that over 6 mm of space could be gained from IPR of the premolars and molars by reducing each of their proximal contacts by 0.4 mm.<sup>9</sup> Later, it was reported that as much as 9.8 mm of space might be gained through IPR of each proximal surface of the premolars and molars alone.<sup>11</sup>

An investigation of enamel thickness in the mandibular anterior teeth found that the average thickness of enamel at the contact points of the central incisors was 0.54 mm, 0.65 mm at the lateral incisors and at the canines was 0.76 mm<sup>10</sup> (Table I). From this, it was suggested that approximately 0.20 mm of enamel could be removed from the proximal surfaces of each of the central incisors, 0.25 mm from each of the lateral incisors and 0.30 mm from the canines. It has been proposed that only 0.25 mm per surface be removed from the upper laterals and the lower incisors, since they have thinner enamel.<sup>7</sup>

The move from initially restricting IPR to the anterior region to subsequently involve the buccal segments has meant that much larger amounts of space may be gained by the use of this technique.<sup>32</sup> There is substantially more proximal enamel in the buccal segments,<sup>11,37</sup> making them amenable to IPR. The difficulty of buccal segment IPR is gaining clear access to the contact areas so that careful, accurate reduction can be performed. The benefit of potentially inaccurate IPR and damage to several posterior teeth, versus the extraction of only one or two teeth to gain the required space, must be questioned. A recent study has investigated the amount of enamel actually removed by IPR compared with the intended amount.<sup>41</sup> It was found that, generally, slightly less enamel is removed

than intended, which is probably reassuring for most clinicians.<sup>41,42</sup>

### Consequences of IPR

It is prudent that safe practices based on scientific evidence are established. References have been made to a number of theoretical risks of IPR related to an increased caries risk due to surface roughening, gingival recession, alveolar bone loss associated with root proximity, increased susceptibility to demineralisation and increased temperature sensitivity of the narrowed teeth.<sup>27,43-46</sup> However, from the available literature, it seems that there is no evidence to suggest that there are any long-term negative effects from properly conducted IPR.<sup>31,43-45</sup>

### Periodontal issues

In 1987, Artun and colleagues investigated root proximity and long-term periodontal health at least 16 years after orthodontic treatment,<sup>47</sup> and concluded that there was no increased risk of loss of periodontal attachment in the anterior teeth when their roots were in close proximity to one another, usually due to the roots not being parallel. 'Close proximity' was defined as less than 0.8 mm between adjacent cement-enamel junctions. Although the initial sample of 400 patients was large, the number of molars with roots in close proximity was small and therefore no conclusions were drawn for those teeth.<sup>47</sup>

Earlier studies examined the periodontium of the mandibular anterior teeth subjected to CSF and IPR.<sup>17,18</sup> Similarly, it was concluded that, in the cases seen between four and nine years after treatment, there was no measurable alveolar bone loss or increase in either gingival recession or periodontal pocketing.

### Surface roughness

It has long been debated whether the performance of IPR (either by hand held strips, discs, or diamond

Table I. Enamel thickness of lower anterior teeth (adapted from Hudson, 1956<sup>10</sup>).

Tooth	Mesial enamel (mm)			Distal enamel (mm)		
	Min	Max	Average	Min	Max	Average
Central incisor	0.37	0.88	0.54	0.36	0.70	0.52
Lateral incisor	0.47	1.05	0.65	0.50	0.98	0.68
Canine	0.38	1.11	0.76	0.55	1.80	0.90

burs) leaves the enamel surface rougher than untreated teeth. This is of interest since, logically, a rougher surface might increase plaque retention and therefore increase the risk of caries at that site.<sup>48</sup> There are conflicting published statements. Several early studies indicated that the furrows and scratches produced by IPR could not be removed by polishing,<sup>49-52</sup> but more recent reports have suggested that the enamel can, in fact, be polished to become even smoother than the untreated surfaces.<sup>1,42,52,53</sup> This is probably because of the development of improved polishing equipment, and most studies now recommend the use of thorough polishing following IPR.<sup>1,48,51-54</sup>

A scanning electron microscopic (SEM) study evaluated the roughness of enamel following IPR for comparison with IPR used in combination with acid etching.<sup>49,51</sup> The teeth were first subjected to regular IPR through the use of burs or discs, and then a finishing strip was lightly coated with 37% phosphoric acid and passed over the surface 20 times. Interestingly, the teeth with the combined stripping and etching showed smoother surfaces with a distinct flattening of the grooves and furrows compared with the other groups. As well as showing a smoother surface, the authors suggested that the surface was capable of 'self-healing' and had increased potential to remineralise.<sup>49</sup> An additional SEM study showed that, in most cases, the enamel grooves and furrows produced by IPR cannot be removed; however, it was also stated that one particular method, using an 8-straight blade tungsten carbide bur and Soflex discs for polishing, could produce a surface smoother than untreated enamel.<sup>51</sup>

Further SEM studies have concluded that the surface roughness produced by IPR could be minimised to a degree so that the enamel is smoother than an untreated tooth.<sup>54,55</sup> However, this was disputed in 2006 in a study involving not only SEM, but also profilometry, to evaluate the surface roughness following IPR.<sup>52</sup> It was concluded that all methods resulted in a roughened enamel surface; however, smoother surfaces were obtained when fine Soflex discs were used to polish teeth following stripping.

The surface roughness of enamel following IPR was investigated using profilometry and digital subtraction radiography, to assess the amount of enamel that was removed using this technique.<sup>49</sup> All treatment groups showed a significantly smoother surface following polishing and the digital subtraction radiography

showed that an insignificant amount of enamel was removed by polishing with the fine Soflex discs (0 to 0.02 mm).<sup>1,52</sup> It was strongly recommended that all stripped surfaces be polished to minimise the possible risk of plaque accumulation.

### *Caries risk*

One of the main concerns regarding IPR is the possible increase in caries risk due to the increased plaque accumulation on the roughened enamel surfaces. To date, several studies have shown no increase in caries susceptibility,<sup>27,56</sup> and some cases were followed for as long as 10 years after the procedure.<sup>48</sup>

In an evaluation of patients who had IPR performed one to six years previously, no significant difference between the treated and untreated surfaces was found.<sup>27</sup> Remarkably, there was an increase in DMFT and DMFS scores over the study period, implying that the group was at higher risk for caries overall. Of the carious lesions observed, however, only three out of the nine were on treated surfaces, the other six were on untreated surfaces. The conclusion was that there was no increase in caries risk following IPR and this was in agreement with earlier studies.<sup>27,57-59</sup>

A retrospective investigation reviewed a sample of 61 cases who received IPR on the six mandibular anterior teeth at least 10 years prior.<sup>60</sup> The findings confirmed that there was no increased susceptibility to caries on the treated enamel surfaces. This was investigated again, but with a shorter follow up period, in patients having received IPR only four to six years earlier.<sup>56</sup> Out of the 278 surfaces that were reduced in this study, only seven had new carious lesions (2.5%), and of the 84 untreated (control) surfaces, two had new carious lesions (2.4%). The patients were not categorised by their caries risk, and the seven new carious lesions had come from three patients, indicating that these patients may have had a higher initial caries risk. Of the 43 patients examined, none reported an increase in tooth sensitivity. However, in the earlier study, two out of the 59 patients reported an increase in sensitivity; one who had sensitive teeth in general, and the other reported sensitivity in the lower anterior region only.<sup>56,60</sup> The conclusions drawn were that there was no increase in caries risk following IPR, and that it could be carried out safely if the correct technique was used within recognised limits.<sup>27</sup>

A recent systematic review of IPR stated that no

reliable conclusions could be drawn from the studies completed due to the diversity of the methodologies.<sup>53</sup> However, the incidence of caries on surfaces that had been subjected to IPR was the same as for the untreated surfaces, indicating no increased risk after the procedure.

## Conclusion

Interproximal reduction (IPR) is a technique that has been used in orthodontic practice since the 1940s. Its use is common in circumstances in which space is required to relieve crowding, especially when extractions are not wanted or not indicated. It is useful in these circumstances and can decrease treatment time compared with extraction therapy since the amount of tooth reduction achieved in one session corresponds exactly to the amount of crowding. It may also be used in cases in which there is a tooth-size discrepancy and removal of dental hard tissue from one arch may be necessary to gain a well interdigitated occlusion at the completion of orthodontic treatment. It has been shown that IPR of the mandibular incisors (particularly if combined with CSF) may enhance long-term stability, even without retention, and can be carried out on patients with black triangles, or triangular shaped teeth, to lengthen the contact area and encourage infill of the papilla, thereby enhancing aesthetics.

Since the introduction of IPR, there have been many claims related to the safe removal of enamel. Generally, it is accepted that up to half the thickness of enamel may be reduced from the proximal contact area; however, the thickness of enamel may vary substantially between and within individuals. As a general indication, up to 0.2 mm can be removed safely from each proximal surface of the mandibular central incisors, 0.25 mm from the laterals and 0.3 mm from the canines. Since there is significantly thicker enamel in the buccal segments, up to 0.4 mm or even 0.5 mm could be removed from the proximal surfaces of each premolar and molar. Although it is reported that a significant amount of space could be gained through use of this technique, generally where there is crowding of 6 mm or more extraction therapy should at least be considered as an alternative.

The potentially harmful consequences of IPR have been documented, yet there seems to be no evidence suggesting there are any long-term negative effects. Many studies have evaluated the characteristics of

the enamel surfaces following IPR and stated that, with careful polishing, a surface as smooth as, or smoother than, untreated enamel may be obtained. Several long-term studies have also evaluated the incidence of new carious lesions in both the anterior and posterior regions where IPR has been performed; however, no increase in caries risk has been identified. In addition, there have been no reports of any increase in periodontal problems, including gingival recession, periodontal pocketing or alveolar bone loss.

It is possible that inaccurate IPR could result in the over-reduction of enamel, the creation of ledges and notches in proximal surfaces, increased tooth sensitivity or damage to the surrounding soft tissues as well as a reduction in the ability to keep the surfaces clean. However, carefully conducted IPR performed within the recommended guidelines may be used as a safe method to gain space for the relief of crowding, to correct tooth-size discrepancies and to improve aesthetics and long-term stability in selected orthodontic patients.

## Acknowledgments

This study was funded by a University of Otago Research Grant (UORG) and the Foundation for Research and Education, New Zealand Association of Orthodontics (FORENZAO).

## Conflict of interest

The authors declare they have no conflict of interest.

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