Accelerating tooth movement: The case for corticotomy-induced orthodontics

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Increased societal demands have led patients to request shorter orthodontic treatments, yet their expectations for outstanding final results remain high. One option for reducing treatment time is the dual-specialty in-office corticotomy-facilitated bone augmentation approach called the periodontally accelerated osteogenic orthodontics procedure.[1-8] Periodontally accelerated osteogenic orthodontics treatment can often be completed in one third to one fourth of the time required for traditional orthodontic treatment.[9] More importantly, a greater degree of movement can be achieved, reducing the need for extractions while providing increased periodontal support; this can provide orthodontists with a new population of adult and adolescent patients who otherwise might not seek needed orthodontic treatment.

Periodontally accelerated osteogenic orthodontics treatment is appropriate for both adults and adolescents when most of the permanent teeth have erupted.[10-14] Full treatment quickly resolves the entire scope of the patient's treatment needs, including minor facial reshaping. In conjunction with traditional orthodontics, segmental issues such as forced eruptions of impacted teeth[5,10] and molar intrusions[15,16] can be rapidly corrected. Treatment decisions are based on considerations such as severity of the malocclusion, preexisting alveolar deficiencies, extraction vs nonextraction protocols, and patient expectations.

Corticotomy surgery provides for a periodontal ligament-mediated acceleration in tooth movement as a result of a stimulated regional acceleratory phenomenon in conjunction with the proper morphologic situation of a thin layer of bone in the direction of movement. The induced increase in bone turnover and decrease in mineral content of the bone (demineralization) are conducive to accelerated tooth movement.[11] The soft-tissue fraction of the demineralized bone follows the roots and remineralizes as the regional acceleratory phenomenon resolves, but the remineralization process of the soft-tissue fraction is incomplete in adults, resulting in a reduction in bone volume including residual labial and lingual bony dehiscences.[11] The alveolar augmentation will provide for increased alveolar volume and "sandwiching" of the roots of the teeth between intact facial and lingual layers of bone while correcting the preexisting alveolar dehiscences and fenestrations, and compensating for any corticotomy-related reduction in bone volume, including dehiscence formation.[11] Relatively large volumes of particulate bone-grafting material are placed between the intact elevated periosteum and the opposing corticotomized bone. Maintaining the continuity of the periosteum is critical in maximizing the volume of new bone. This new volume of bone facilitates a greater scope of tooth movements and reduces the need for extractions while ensuring adequate periodontal support.

The corticotomy surgery elicits a profound accelerated response in a limited area because of the demineralization. Therefore, facilitated tooth movements will occur only close to the corticotomized teeth. This increased differential in rates of movement between decorticated and nondecorticated teeth creates the ability to alter the relative anchorage between teeth. Essentially, anchorage teeth become more effective anchors if not decorticated; conversely, decorticated teeth move with greater ease. The pattern of decortication is of little consequence; rather, it is the intensity and proximity of the decortication that dictates the extent of the response and therefore the greater ability of teeth to move quickly.

Patients' thoughtful consideration of surgery is expected. When put in perspective with the types of surgeries that we routinely recommend for our patients, they realize that this in-office procedure is routine. Because of the primary closure of the surgical sites, there is minimal postoperative discomfort after corticotomy surgery,[17] and patients have reported less discomfort at their subsequent orthodontic adjustments.[18] Lee

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Accelerating tooth movement: The case against corticotomy-induced orthodontics

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We are pleased to participate in this Point/Counterpoint debate regarding corticotomy-facilitated orthodontics, also known as accelerated osteogenic orthodontics or periodontally accelerated osteogenic orthodontics. Drs Wilcko and Wilcko have presented their beliefs in the "Point" article. Our assignment is to present and justify an opposing viewpoint. Actually, there are some statements by Drs Wilcko and Wilcko with which we agree. We disagree with other statements. Finally, some issues regarding this procedure were not discussed, and we will raise these in our "Counterpoint" article. Our goal is to answer the following question for the orthodontic clinician: Is corticotomy-facilitated orthodontics an efficacious, effective, and efficient method of accelerating tooth movement in adult orthodontic patients? Before we begin, let us define these terms. According to accepted definitions, (1) *efficacy* measures how well treatment works in clinical trials or laboratory studies under ideal conditions; (2) *effectiveness* measures how well a treatment works in routine clinical practice; and (3) *efficiency* measures the outcome of a procedure by evaluating the value received relative to the costs in terms of time, money, and morbidity. With this in mind, we will divide this article into a discussion of 7 major questions.

DOES ALVEOLAR CORTICOTOMY RESULT IN ACCELERATION OF TOOTH MOVEMENT?

We agree with Drs Wilcko and Wilcko on the answer to this question; alveolar corticotomy does induce an acceleration of tooth movement. This effect has been documented in rats,[1-4] dogs,[5-7] cats,[8] and humans.[9-13] The best of these experiments were performed using a split-mouth design, with a corticotomy on one side and the opposite side of the dental arch used as the control.[5-7,12] A calibrated force is placed on the teeth in both the right and left quadrants, and the rate of tooth movement is calculated by measuring the distance moved over time. The outcomes of these experiments are typically uniform and show that the rate of tooth movement is accelerated on the corticotomy-treated side.

How much acceleration in the rate of tooth movement can be expected? Most animal experiments show that the amount of movement doubled over the time of the experiment.[1,5-7] Since most animal experiments extend for 2 to 4 months, and the teeth on the control sides in rats and dogs move about .5 mm per month, the teeth on the corticotomy-treated side would move at the rate of about 1 mm per month.

HOW DOES CORTICOTOMY PRODUCE ACCELERATED TOOTH MOVEMENT?

On this topic, we agree partially with Drs Wilcko and Wilcko but would like to differentiate what happens in experimental animal studies and its translation to what is believed to happen in humans. We do agree, and past research has confirmed conclusively, that a corticotomy produces an injury to the alveolar bone that results in an exaggerated response from that organism to send cells to the injured area to facilitate healing. Drs Wilcko and Wilcko have already described this process as the regional acceleratory phenomenon. But how does the regional acceleratory phenomenon facilitate accelerated orthodontic tooth movement?

Drs Wilcko and Wilcko believe that the increase in the rate of tooth movement is due primarily to a demineralization process that occurs in the cancellous bone surrounding the tooth socket and secondarily to alterations within the periodontal ligament. We would propose a different viewpoint.

First, the studies showing demineralization in the interproximal bone surrounding the roots of teeth were performed in rats.[1-4] Can we translate what happens in rats to humans? Is the extent of the

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et al[19] described in a microtomographic study the different responses after corticotomy surgery vs osteogenic distraction. Unlike osteogenic distraction, when segments of bone are mobilized at the time of surgery,[20-24] or outlined sections of interseptal bone are quickly displaced with the immediate activation of orthopedic devices,[25] we recommend against luxation in corticotomy-based surgeries.

HISTORICAL REVIEW AND RATIONALE FOR CORTICOTOMY-ACCELERATED TOOTH MOVEMENT

Europe is the birthplace of corticotomy-related surgeries. In 1931, Bichlmayr[26] introduced a surgical technique for rapid correction of severe maxillary protrusion with orthodontic appliances. Wedges of bone were first removed to reduce the volume of bone through which the roots of the maxillary anterior teeth would need to be retracted. In 1959, Köle[27] expanded on this philosophy by addressing additional movements, including space closure and crossbite correction. Similar to the method of Bichlmayr, a reduction in bone thickness was often used. Major movements were corrected in 6 to 12 weeks without significant apical root resorption. Some of Köle's surgical preparations resulted in the appearance of outlined blocks of bone; when taken in conjunction with his incorrect assumption that the mineralized bone was moving with the roots of the teeth, others deemed the mechanism "bony block" (tooth-bone unit) movement.[28-30] Consequently, corticotomy surgery evolved mostly into circumscribing cuts, and bone thinning was deemphasized, thus leading to almost 4 decades of confusion concerning the correct mechanism of facilitated movement.

Interestingly, in 1987, Rynearson[31] demonstrated in nonhuman primates that the cortical plates in corticotomized maxillary second premolars did not move during space closing. The misconception of "bony block" movement prevailed, however, until 2001, when Wilcko et al[1] reported that a surface-computed tomographic evaluation of corticotomized patients clearly showed a transient localized demineralization-remineralization process consistent with the accelerated wound-healing pattern of the regional acceleratory phenomenon. The apparent demineralization of the alveolar bone over the buccal and lingual root prominences left a collagenous soft-tissue matrix of bone, which was carried with the root surfaces (bone matrix transportation) and then remineralized in retention. The remineralization was fairly complete in adolescent patients, but in adults only partial remineralization of the soft-tissue matrix was observed. Therefore, in adults there was a net loss in bone volume with lingering labial and lingual dehiscences that had still not resolved after 11.5 years of retention.[11]

As early as 1965, many effects of regional acceleratory phenomenon were introduced by Kolář et al.[32] It was not until 1983, however, that Frost[33] introduced the regional acceleratory phenomenon as an operational entity to clinicians. In 1994, Yaffe et al[34] were the first to report a robust regional acceleratory phenomenon response in the jawbones of rats by merely reflecting and replacing mucoperiosteal flaps. In 2007, Sebaoun et al[35] reported that intramarrow penetrations in rats resulted in a transient demineralization-remineralization process and increased bone turnover. In 2011, Baloul et al[36] reported on tooth movement in rats after intramarrow penetrations. In the mesial movement of maxillary first molars, the total displacement in the selective alveolar decortication plus tooth movement group was 6.94 mm compared with 5.3 mm for the traditional orthodontic group. The corticotomized teeth showed only a 24% increase in the distance of tooth movement. We suggest that an even greater differential in the amount of tooth movement would have been realized if a different morphologic situation had been provided (a thin layer of bone in the direction of movement) in addition to the regional acceleratory phenomenon.

Corticotomy surgery provides for a periodontal ligament-mediated acceleration in tooth movement as a result of a stimulated regional acceleratory phenomenon in conjunction with the proper morphologic situation of a thin layer of bone in the direction of movement.

When closing extraction spaces, our findings agree with those of Iino et al[37] and Gantes et al.[17] If space closure is performed at first premolar sites with only circumscribing corticotomy cuts or with inadequate bone thinning such as partial ostectomies, the space closure can take 7 or more months to complete.[38] This can result in total treatment times expanding to a year or longer. However, if the bone is thinned adequately in the direction of the intended tooth movement, premolar site closure can be accomplished in 3 to 4 weeks with orthopedic forces or in 6 to 8 weeks with lighter orthodontic forces.[38] With the proper

damage inflicted on the alveolus via corticotomy in a rat similar to or perhaps more pronounced than the injury that occurs during corticotomy in a human? Similar studies on the impact of corticotomies in dogs[5-7] and cats[8] have not reported the demineralization effect seen in rats. Perhaps the demineralization effect is not as pronounced in humans. Although Drs Wilcko and Wilcko stated that a transient localized demineralization-remineralization process can be verified by a surface-computed tomographic scan, we seriously doubt that this type of scan has sufficient resolution to identify accurately the differences in cancellous bone mineralization in humans.[14]

We must also remember that the tooth root is not moving through the bone. The tooth socket is translating through the bone, and the periodontal ligament facilitates this movement. Animal experiments have clearly shown that an alveolar corticotomy produces a difference in the periodontal ligament during initial tooth movement that results in accelerated tooth movement. Let us explain.

Many studies have documented the histologic and physiologic effects of the initial stages of tooth movement and have shown that compression of the periodontal membrane between the tooth root and the socket wall on the pressure side results in damage and hyalinization of the periodontal ligament.[5,8,15,16] When hyaline forms in the periodontal ligament, bone resorption is inhibited as long as the hyaline is still present. Experiments in dogs have shown that the hyaline is gradually removed from the periodontal ligament by macrophages that differentiate from mesenchymal cells that travel to the area.[5] However, in these experiments, it can take up to 4 weeks for the hyaline to be removed. During this initial period, no tooth movement occurs.[5]

When an alveolar corticotomy is performed near the tooth to be moved, histologic results show that the regional acceleratory phenomenon accelerates the appearance of the macrophages that remove the hyaline as early as 1 week after the initiation of orthodontic force.[5,8] Earlier removal of the hyaline allows earlier bone resorption, resulting in more rapid tooth movement compared with the noncorticotomy side. So, it is clear that the regional acceleratory phenomenon facilitates the acceleration in the rate of tooth movement.

HOW LONG DOES THE REGIONAL ACCELERATORY PHENOMENON PERSIST AFTER THE CORTICOTOMY?

Drs Wilcko and Wilcko did not discuss the duration of the regional acceleratory phenomenon after corticotomy, but we believe this question is of utmost importance to determine the effectiveness and efficiency of this procedure. Obviously, if the rate of tooth movement were accelerated by the regional acceleratory phenomenon, then it would be important to know how long this effect can be expected to last. Two studies, one in humans[12] and the other in dogs,[7] provide some insight into the duration of the regional acceleratory phenomenon and its influence on the rate of tooth movement.

In a study comparing the rate of tooth movement in foxhounds with a split-mouth design with a corticotomy performed on one side, the authors reported that the rate of tooth movement peaked between 22 and 25 days and then decelerated.[7] During this 3-week period, the corticotomy-facilitated side moved twice as far as the opposite side. The authors then performed a second corticotomy procedure in some animals after 28 days and found that the higher rates of tooth movement could be maintained over a longer period of time with a second surgery.

[T]he length of the regional acceleratory phenomenon is probably about 4 months. . . . Therefore, we conclude that corticotomy-facilitated tooth movement is only effective during the 4 months of the regional acceleratory phenomenon. After that, the rate of tooth movement would return to normal.

Similar findings were reported in a sample of 13 adults whose maxillary canines were being retracted after first premolar extractions.[12] Corticotomy was performed on one side, and the other side was not operated. The rate of maxillary canine retraction was then documented over time. During the first 2 months, the rate of tooth movement on the corticotomy side was twice that of the unoperated side. However, during the third month, the rate was 1.6 times greater, and by the fourth month, the rates of tooth movement on both sides were similar.

Based on the results of these 2 studies, it seems that the length of the regional acceleratory phenomenon is probably about 4 months. Perhaps it could be a bit longer, but the regional acceleratory phenomenon does

surgical technique, these space-closing cases can be routinely completed in 8 to 10 months or less. If orthopedic appliances are used for space closing or other movements, it is advisable to wait 3 to 4 weeks after surgery before activating them to allow the thinned bone to demineralize. All indications are that a coupled bone remodeling response is taking place, but with a thin layer of activated bone, the rate of demineralization will outweigh the rate of remineralization, and the demineralized bone matrix can be sustained with continued tooth movement.[36,39]

Excessive root resorption does not appear to have been an issue with corticotomy-facilitated orthodontics.[27,28] Because of the demineralized state of the bone during treatment and the fact that normal orthodontic forces are used, rapid movement occurs from the lack of osseous resistance and not from excessive orthodontic force. In an evaluation of maxillary central incisors, the findings of Machado et al[40] would actually indicate a slight (1.1 mm) decrease in apical root resorption. This decrease might not be clinically significant, but at least it is reassuring to know that rapid tooth movement after corticotomy surgery will not result in increased root resorption. Iino et al[41] have additionally demonstrated decreased hyalinization of the periodontal ligament in corticotomized dogs, and it is well known that hyalinization can be a precursor to root resorption.[42,43]

Rothe et al[44] reported that patients with thinner mandibular cortices are at increased risk for dental relapse, and this could certainly be used as one argument for increasing the alveolar volume. Additionally, we suggest that increased alveolar volume could increase the probability of maintaining attachment levels, especially when there is a discrepancy involving a wide root and a narrow alveolus.[45] It will not provide for improved attachment levels. Clinicians must also be aware that if there is preexisting bone loss from periodontal disease, corticotomy surgery becomes pocket reduction surgery, and the teeth will appear longer commensurate with the degree of preexisting bone and attachment loss regardless of whether alveolar augmentation is performed.

There are limitations to what corticotomy-facilitated orthodontics can offer. We do not represent that ankylosed teeth can be reliably moved nor can teeth be moved through devitalized bone, a situation that can occur in conjunction with long-term cortical steroid or bisphosphonate therapy.[46] Corticotomy-facilitated tooth movement is a periodontal ligament-mediated sterile inflammatory process, so the use of nonsteroidal anti-inflammatory drugs will reduce the inflammatory response and therefore tend to counteract the regional acceleratory phenomenon effect.[47] Since its benefits and capabilities are impressive, doctors sometimes think of periodontally accelerated osteogenic orthodontics when nothing else works. This is not a rescue technique but, rather, a tool to be used with knowledgeable thought and design.

Many surgical and nonsurgical methods and devices are being used and represented to accelerate tooth movement. Each might have its merits, but in the absence of correct surgical intervention, these can only provide a degree of the regional acceleratory phenomenon. Accelerated movements require both physiologic and morphologic issues to be addressed. However, inadequate decortication techniques do not create the robust regional acceleratory phenomenon needed for many accelerated movements, and they actually reduce the amount of bone support by the nature of the procedure. An important aspect of the periodontally accelerated osteogenic orthodontics technique, in addition to shortened treatment times, is the ability to address alveolar insufficiencies with bone augmentation to increase the likelihood of creating intact buccal and lingual plates of bone.

CONCLUSIONS

The periodontally accelerated osteogenic orthodontics procedure is gaining in popularity with patients and doctors because of the much shorter treatment times and the increased range of treatment capabilities and possibilities. Many misunderstandings and misconceptions about this procedure are being dispelled as knowledge of the technique and results are becoming better known. Over time, it has been transformed into a successful treatment option for many orthodontic problems when used properly, including complicated cases that require a multidisciplinary in-office approach between dental specialties. Treatment planning can be challenging for difficult cases and will perhaps require a different set of parameters to realize the full potential of this technique. It can often make the treatment of severe dental malocclusions more practical while reducing the treatment time for patients from one third to one quarter of the time typically required to treat most dental malocclusions. Additionally, the alveolar volume can be increased to aid in supporting the teeth while correcting preexisting dehiscences and fenestrations when there is a vital root surface. This technique belongs in a specialty arena where both orthodontists and periodontists work together from diagnosis through treatment and retention.

end, and its impact on accelerating tooth movement would also come to an end. Therefore, we conclude that corticotomy-facilitated tooth movement is only effective during the 4 months of the regional acceleratory phenomenon. After that, the rate of tooth movement would return to normal. To determine whether corticotomy is efficient, we need to determine whether its effect produces a decrease in treatment time for adults.

DOES CORTICOTOMY RESULT IN REDUCED TREATMENT TIMES FOR ADULTS?

From what we have just stated regarding the acceleration of tooth movement in experimental animals and humans, it would seem logical that if teeth move twice as fast, treatment times for adults should be lessened substantially. However, no studies have documented this claim. Yes, if you review articles about case series or case reports on this topic, you will find claims and testimonials of shortened treatment times.[9,11,14,17-22] However, one cannot measure treatment time without measuring treatment quality.

Yes, teeth can be aligned in a shorter time, but alignment is only 1 measure of the quality of orthodontic treatment. The American Board of Orthodontics has developed a detailed grading system that is used by certifying boards worldwide to assess the quality of orthodontic treatment.[23] Alignment is 1 of 8 measures of treatment quality.

To prove that corticotomy-facilitated orthodontics truly reduces treatment time in adult patients, one would need to perform a randomized controlled trial and randomly assign subjects with similar malocclusions to either a conventional or a corticotomy-facilitated treatment group, and then compare the quality of the treated result (measured with the American Board of Orthodontics' grading system) relative to the length of time needed to treat the patient. Only in this way can one claim an overall reduction in treatment times for clinical patients. To date, no randomized controlled trial has been done.

DOES GRAFTING OF THE ALVEOLUS ENHANCE THE ORTHODONTIC TREATMENT?

Drs Wilcko and Wilcko claim that bone grafting of the facial and lingual cortical bones will enhance the stability of orthodontic treatment, facilitate a greater scope of tooth movement, and create intact buccal and lingual plates of bone by repairing fenestrations and dehiscences. Let us apply our measures of efficacious, effective, and efficient to these claims.

There is a paucity of information in the scientific literature to help us answer these assertions. At best, there are case reports and expert opinions regarding these issues. In past publications, proponents of periodontally accelerated osteogenic orthodontics claim that bone grafting enhances the stability of the orthodontic results.[9,10,14,20] Based on the available science, there is no evidence in the literature that bone grafting of the alveolus enhances the stability of the orthodontic result. To document this claim, one would need to compare a sample of subjects who had corticotomy and bone grafting with a similar group of subjects treated without these surgeries at a minimum of 5 years after removal of all orthodontic retention. These studies are certainly difficult to complete, and none are available currently in the orthodontic literature.

Is bone grafting to augment the alveolus during periodontally accelerated osteogenic orthodontics efficacious? No randomized controlled trials substantiate this claim.

Is bone grafting effective? Case reports show a greater volume of bone in computerized tomographic scans.[10] Is this bone incorporated into the native cortical plate, or is it a fibro-osseous material encapsulated on the outside of the cortical plate? The scans suggest that it is a fibro-osseous encapsulation.[10]

Is bone grafting during periodontally accelerated osteogenic orthodontics efficient? To answer this question, let us examine animal studies that show what happens to the alveolus when teeth are proclined, and when teeth are retracted back into the alveolar housing without grafting. Animal studies show conflicting outcomes when teeth are proclined. Some show no change in the labial bone,[24] and others show that dehiscences were created.[25] Engelking and Zachrisson[26] showed that retraction of mandibular incisors leads to repair of dehiscences with 2.5 to 3.1 mm of new bone formed. Histologic evaluation of tetracycline-labeled sections shows that osteogenesis occurs in the periosteum to a significant degree.[26]

In their previous articles, Drs Wilcko and Wilcko have shown case reports of bone-grafted sites that were reevaluated after surgical flap reflection. Some of these sites showed repair of dehiscences and fenestrations on teeth that had been retracted orthodontically.[10] Is this grafted bone attached to the previously dehisced root surfaces with new bone, cementum, and periodontal ligament? Would this repair have occurred without additional bone grafting? The literature suggests that perhaps these defects will repair without grafting.

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Drs Wilcko and Wilcko claim that this is a routine periodontal procedure with minimal discomfort. However, in a previous article, they stated that "a distinct disadvantage of this procedure is the additional cost and morbidity associated with surgery."[9] We agree that it is a routine periodontal procedure, similar to periodontal osseous surgery. However, with periodontally accelerated osteogenic orthodontics, there is additional surgery to the bone, along with periosteal release of the flaps to aid in covering the additional bone graft material. The additional releasing of the periosteum adds further inflammation, swelling, and discomfort.[27] It is an invasive procedure with moderate morbidity.

WHAT IS THE FINANCIAL COST OF THE CORTICOTOMY PROCEDURE?

Drs Wilcko and Wilcko did not discuss costs, but we believe it must be addressed if we are to determine whether there is value in performing this procedure before tooth movement. Obviously, the fees for alveolar corticotomy would vary greatly depending on the extent of the procedure (1 arch or 2 arches), the type of procedure (corticision, corticotomy, or piezocision), and the location in the world where the procedure is performed. So, it would be better to relate the surgical fee to the orthodontic fee; this would eliminate most geographical differences. We have questioned surgeons and orthodontists regarding the surgical fees, and the answer that we commonly receive is that the fee for the corticotomy is typically the same as that for the orthodontic treatment.

CONCLUSIONS

Based on the information that we have presented, let us now answer the initial question that we posed at the outset of this article: Is corticotomy-facilitated orthodontics an efficacious, effective, and efficient method of accelerating tooth movement in adult patients?

It is not possible at this time to determine whether corticotomy-induced tooth movement is efficacious. As mentioned previously, this question can only be answered by conducting highly controlled trials, which are not yet available.

Alveolar corticotomy is effective at accelerating tooth movement. However, it is not appropriate to conclude from this statement that corticotomy-induced tooth movement reduces orthodontic treatment times. This claim can only be made by measuring the quality of the treatment relative to the time of treatment in 2 matched cohorts of patients. This type of study has not yet been performed.

Whether alveolar corticotomy is an efficient procedure depends on the value received relative to the cost of the treatment in terms of time saved, money spent, and morbidity experienced. Obviously, only the patient and the orthodontist can determine whether sufficient value would be achieved in a specific clinical situation. However, we believe that (1) the limited duration of the regional acceleratory phenomenon, (2) the significant additional expense, and (3) the lack of evidence of a significant reduction in orthodontic treatment time lead us to question the efficiency of this procedure.

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