Origins of Dental Crowding and Malocclusions: An Anthropological Perspective

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Abstract: The study of ancient Egyptian skeletons from Amarna, Egypt reveals extensive tooth wear but very little dental crowding, unlike in modern Americans. In the early 20th century, Percy Raymond Begg focused his research on extreme tooth wear coincident with traditional diets to justify teeth removal during orthodontic treatment. Anthropologists studying skeletons that were excavated along the Nile Valley in Egypt and the Sudan have demonstrated reductions in tooth size and changes in the face, including decreased robustness associated with the development of agriculture, but without any increase in the frequency of dental crowding and malocclusion. For thousands of years, facial and dental reduction stayed in step, more or less. These analyses suggest it was not the reduction in tooth wear that increased crowding and malocclusion, but rather the tremendous reduction in the forces of mastication, which produced this extreme tooth wear and the subsequent reduced jaw involvement. Thus, as modern food preparation techniques spread throughout the world during the 19th century, so did dental crowding. This research provides support for the development of orthodontic therapies that increase jaw dimensions rather than the use of tooth removal to relieve crowding.

Tremendous advancements have been made in orthodontic diagnostics and treatment in the last 150 years. However, significant limitations still remain in predictably treating some malocclusions to optimal function, health, esthetics, and long-term stability. The need for overcoming these limitations is vast, with nearly two-thirds of the US population having some degree of malocclusion[1] (Figure 1). In contrast, most of modern society's ancestors naturally had ideal alignment without malocclusion and their third molars were fully erupted and functioning.

A common denominator today in the most difficult orthodontic problems appears to be a discrepancy between the volume of alveolar bone and tooth mass (Figure 2A through Figure 2C). In adults, these problems traditionally require longer treatment times in which the orthodontist

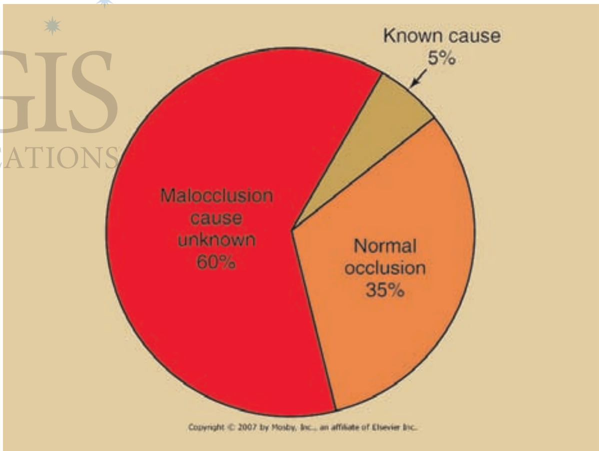

Figure 1 From a broad perspective, only about one-third of the US population has normal occlusion, while two-thirds have some degree of malocclusion. In the malocclusion group, a small minority has problems attributable in a specific known cause. The remainder is the result of a complex and poorly understood combination of inherited and environmental influences. Used with permission from Proffit et al; *Contemporary Orthodontics.* 4th ed; Elsevier.

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may have to compromise relationships, esthetics, and stability through either the extraction of teeth or by positioning the teeth outside the confines of their supporting structures (Figure 2D). To develop better treatment options, determining whether these discrepancies are a tooth-mass excess problem or an alveolar bone deficiency is needed first. Some of the solutions to orthodontic limitations may be found through a better understanding of the causes for the increase of dental crowding and malocclusions in modern society.

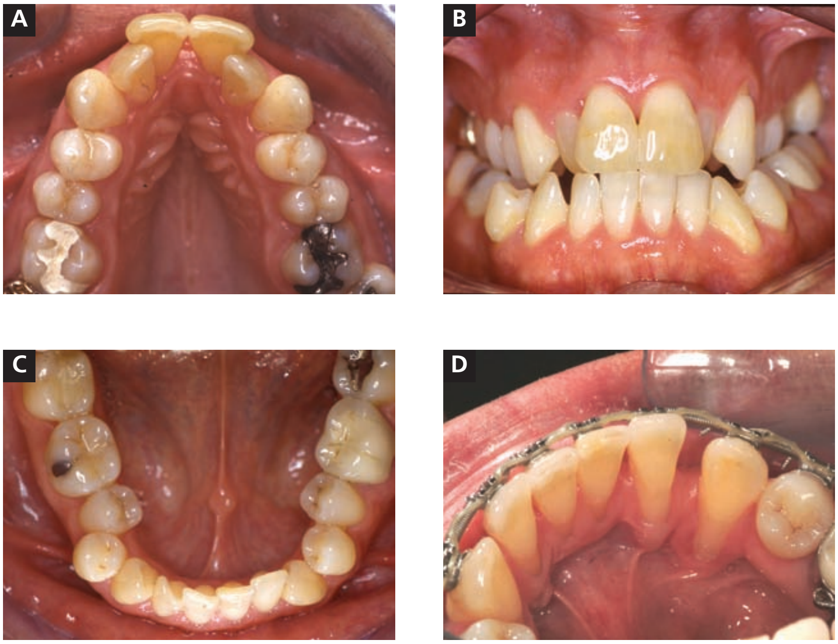

Figure 2A through Figure 2D A 42-year-old male presents for treatment of severe dental crowding and malocclusion. Traditional extraction orthodontic therapy was performed to relieve crowding. Note the roots of Nos. 26 and 27 have been moved through the lingual cortical plate. This patient was treated for excess tooth structure when the underlying problem was an alveolar bone deficiency. Optimal treatment would have included procedures that increased the volume of alveolar bone.

AN ARCHAEOLOGICAL DIG

The reasons for the origins of high malocclusion rates today prompted exploration of Egypt and the Nile Valley where thousands of skeletons—from more than 10,000 years of human history—have been excavated and analyzed. Although dental data is available from a number of Egyptian sites, this paper's specific examples are drawn from the Amarna Project excavations in the Egyptian desert, along the Nile River halfway between Cairo in the north and Luxor in the south (Figure 3). Amarna is the ancient capital of Pharaoh Akhenaton who reigned from 1353 BC to 1333 BC and built his city on empty desert for the monotheistic worship of the sun god the Aten. Three years of excavation in the recently discovered commoners' cemetery yielded 94 individual remains (Figure 4 through Figure 7). Except for the occasional slight incisor crowding and rotation, observation of the teeth indicated that they were well-aligned with very-good-to-excellent occlusion (Figure 8 and Figure 9), in general. Thorough analysis of dental data from the Amarna Project has shown that Egyptian and most ancient teeth have extensive tooth wear with dentin exposure on the occlusal surfaces of even the youngest individuals. Malocclusion is rare in Amarna but very common in America; tooth wear is extensive in Amarna yet rare in America. For almost a century, these contrasting observations have stimulated the search for causes of malocclusion among ancient skeletons.

THE BEGG PHILOSOPHY

Percy Raymond Begg, an innovative Australian orthodontist who trained at the Angle College of Orthodontia in California from 1924 to 1925, wondered why his orthodontic treatments lacked stability even though he followed the methods and philosophy of his mentor, Edward Angle. Angle's idea that malocclusion was a disease of modern society led Begg in the 1920s to study the teeth and jaws of modern and prehistoric Native Australians.[2] Ultimately, Begg found only 13% of approximately 800 Native Australian skulls had Class II malocclusion, while 3% exhibited Class III.[2] He decided that extensive tooth wear with complete loss of cusps and exposure of dentin is the natural condition for humans; this wear transforms the incisor overbite into an edge-to-edge articulation; and interstitial wear reduces the mesiodistal diameters of all teeth so that mesial drift can shorten the tooth arch sufficiently. This enables all the teeth to fit within the jaw.[2] Within three years of returning to Australia and having only begun his research on ancient teeth, he began extracting teeth from his patients' jaws to provide the necessary space for his orthodontic manipulations. In the next decade, Begg completed

Figure 3 The Amarna Project excavations in the Egyptian desert.

his research on ancient teeth, promoted his theories on the development of malocclusion, and created a number of innovative treatment materials and techniques.[2,3]

DISCUSSION

The Amarna teeth illustrate the rationality of Begg's theory. The mandible illustrated in Figure 8 shows good alignment of the teeth, no evidence of crowding, and extensive wear exposing the dentin. The speed of wear was documented by all occlusal enamel having been removed from the first molars, while only the cusp tips were worn on the third molars. Although rapid, this wear was slow enough so that the odontoblasts could keep pace with filling in the pulp chamber with reparative dentin. Thus, virtually no pathologic consequences of this heavy wear exist at Amarna or elsewhere in the ancient findings. The dentin exposure on all the incisors is the result of an edge-to-edge bite that develops as the incisors erupt and wear both occlusally and interstitially. This high rate of wear also is shown in the maxillary teeth of the 20- to 25-year-old male in Figure 9. Again, good alignment and no crowding are evident. The right central incisor (Figure 10) is loose in the socket from postmortem breakage of the alveolar bone during ancient grave robbing. The incisors are relatively vertical and articulate in an edge-to-edge bite. The first molars were worn flat, while the cusps of the third molars were barely rounded. Figure 10 is a photo of a skull that shows the tooth surfaces worn flat and very good spacing within robust faces. Critical to Begg's interpretation was the extensive interstitial wear that reduced the mesiodistal diameters of all the teeth and hence the jaw space needed to hold the teeth. This loss of interstitial enamel can be seen clearly among teeth Nos. 2 to 5 in Figure 9. Observations such as these prompted Begg to conclude that, without extensive attrition, individuals with a "preponderance of tooth substance over bone substance" would develop malocclusion, while people with high attrition would not.[2] He further justified his unorthodox technique by stating that the removal of teeth to increase space is "not empirical expediency, but a rational procedure with a sound etiological basis."[2]

As logical as Begg's notions appear about the Amarna teeth, anthropologists know that even feral monkeys and apes have as much as 30% malocclusion when slight variations of incisor and premolar rotation are included.[4] In primates and ancient people, a small but significant proportion exists of malocclusions caused by inherited anomalies, developmental disturbances, and other known causes. Thus, it is logical that orthodontic textbooks attribute malocclusion to specific causes, such as teratogens, growth disturbances, developmental anomalies, genetic influences (eg, inherited disproportions between the jaws), genetic admixture of people from many parts of the world, and behaviors (eg, thumb sucking and tongue thrusting).[1] However, most modern malocclusions are caused by disparity between jaw size and total tooth-arch length. Such malocclusions are rare in Amarna and among ancient people worldwide. To see the flaw in Begg's argument, clinicians need to realize that while the degree of occlusal attrition is directly related to the coarseness of the diet (eg, amount of

Figure 4 Excavation of the Amarna commoners cemetery (photograph courtesy of the Amarna Project, Barry Kemp, Director).

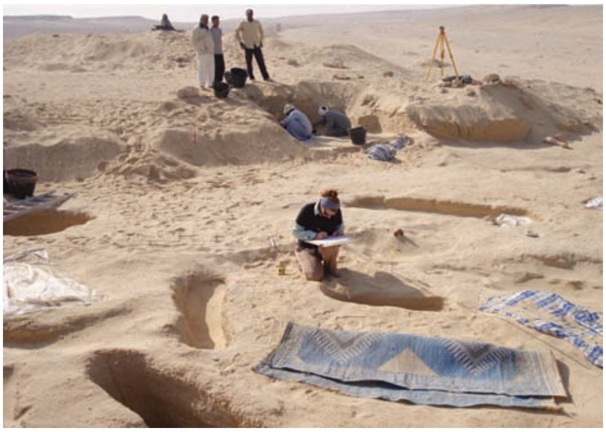

Figure 5 A cemetery that shows hand excavation with trowels (far center) while the grave outlines are being mapped by the archaeologist (near center) (photograph courtesy of the Amarna Project, Barry Kemp, Director).

Figure 6 Excellent preservation of the skeleton and teeth of a 13-year-old child in a wooden coffin. Skeletons and artifacts were taken to the on-site laboratory and residential facility for analysis and permanent storage (photograph courtesy of the Amarna Project, Barry Kemp, Director).

Figure 7 A human skeleton arranged in anatomic order for data collection and recording on printed forms (photograph courtesy of the Amarna Project, Barry Kemp, Director).

grit and fiber), the amount of interstitial wear needed to shorten the tooth row is caused by the chewing forces exerted during mastication of food because this wear is caused by enamel rubbing on enamel as the teeth move up and down in their sockets. Again the Nile Valley might provide answers for causes of dental arch to jaw disparity.

David Greene studied the teeth of skeletons excavated in the Sudan just south of Egypt along the Nile and documented a long-term trend in dental-size reduction for the 10,000-year period.[5] He suggested this reduction in tooth size was from changes in diet and methods of food processing as agriculture was adopted and refined. Analysis of more samples by numerous researchers has established this general trend in tooth-size reduction that is associated with changes in diet. As the diet has become more refined, the consequent increase in dental decay selected for smaller and less complex teeth has moved distally in relation to the skull, such that the body of the mandible now protrudes forward underneath the alveolar bone producing a chin.[6] Because teeth have become smaller without producing excess room in the jaws, other evolutionary mechanisms must have been at work on the alveolar bone and supporting structures of the maxilla and mandible.

While it was common to use cranial measurements to document migrations, ancient Egyptian skulls also were employed to demonstrate that the development of Egyptian civilization was produced by the arrival of a "dynastic race" that had a different skull shape.[7] To contradict this racial approach, Carlson and Van Gerven proposed the masticatory function hypothesis, which maintains that changes in the face and skull between the Mesolithic and Christian periods (10,000-year span) in the southern Nile Valley were caused by dietary changes initiated by the adoption of agriculture and changing food processing technology[8] (Figure 11). The maxilla and mandible have moved posteriorly, rotating underneath the forehead, while also becoming less robust. Furthermore, the tooth rows have moved distally in relation to the skull, such that the body of the mandible now protrudes forward underneath the alveolar bone, producing a chin. This description and the associated skull drawings have been so frequently republished that they are now iconic with publication in the most widely used osteology texts and through these have entered the orthodontic literature.[1,9] Carlson and Van Gerven argued most of the facial changes were not the result of genetic changes but caused by reduced chewing stress during development.[6] Furthermore, in contrast to Begg, they contended that the switch to modern diets had so reduced chewing stress that the jaws did not develop to a sufficient size to hold all the teeth and thus malocclusion became common. However, many clinicians and anatomists today still maintain that facial robustness is genetically controlled.[1]

Into this fray stepped Robert Corruccini—with his seminal 1991 book chapter for dental anthropologists and subsequent 1999 book for orthodontists—who marshaled 20 years of research on cross-cultural differences in occlusal anomalies to support the masticatory functional explanation of malocclusion.[10,11] Corruccini and his colleagues favored the explanation that reduced chewing stress in childhood produced jaws that were too small for the teeth despite the ubiquitous trend in dental size reduction.[10] Because genetic explanations for malocclusion were common, Corruccini reviewed previously published studies from eight geographic regions that demonstrated a significant increase in malocclusion when a switch occurred from that of a coarser traditional diet consumed by an older generation to a more refined commercial diet of a younger generation. He documented a clear genetic continuity between the two age groups in populations, such as Americans in rural Kentucky, Punjabi and Bengali Indians, Solomon Islanders, Pima Native Americans, rural and urban African Americans, and Native Australians. Corruccini also documented a clear association of alveolar bone growth with the functional stimulation of chewing forces[10] that includes measurements of bite-force variation between generations of Eskimos and experimental studies showing changes in mandibular growth of rats and primates between groups consuming hard and soft diets.[10] For example, Lieberman et al raised hyraxes on either cooked or raw foods and showed an approximate 10% difference in facial growth.[12] They not only supported the idea that diet-associated reduction in chewing stress resulted in decreased growth of the mandibular and maxillary arches, but also that animal studies, in general, show both facial reduction and increased malocclusion in the low-force groups.

Not only is basic research continuing into the 21st century on all of the components of the malocclusion story,

Figure 8 Mandible of a 39-year-old female showing extensive dental wear and dentin exposure on all occlusal surfaces from the incisors to the first molars (photograph courtesy of the Amarna Project, Barry Kemp, Director).

Figure 9 Skull of a young adult male with good occlusion and extensive dentin exposure and interstitial wear between teeth Nos. 2 to 5 and Nos. 12 to 15 (photograph courtesy of the Amarna Project, Barry Kemp, Director).

Figure 10 Frontal view of a skull showing extensive wear and occlusion, with a robust face to withstand the forces of mastication (photograph courtesy of the Amarna Project, Barry Kemp, Director).

but recently, anthropologists and orthodontists reprised the entire issue of Begg's contributions to understanding the causes of malocclusion. Published in *The American Journal of Physical Anthropology* (the major journal for biologic anthropology reviews), Kaifu et al noted the virtual absence of dental wear in modern populations fails to explain the increase in malocclusion as Begg contended.[13] However, underdevelopment of the maxillary and mandibular alveolar bone is clearly implicated.[13] They essentially support some of Begg's concepts but criticize many of his other ideas, while acknowledging Begg's pioneering work. The researchers conclude that human teeth are designed to accommodate very heavy wear without impairing oral health; however, given adequate growth of the jaws, normal occlusion can be achieved without heavy wear. The critical conclusion provided for the clinician is that "attritional occlusion should not be regarded as a treatment model for contemporary dentistry."[13] In other words, therapies designed for reducing tooth substance, which occurs naturally in ancient and traditional populations, clearly are misdirected. Conversely, following the lead of the functional approach, clinicians should move forward on therapies that would provide expansion of the jaws to the appropriate size to fit the teeth.

CLINICAL APPLICATIONS

Although true tooth-mass excess problems exist that require tooth-mass reduction therapy (extractions or reshaping) optimally, it now appears that most dental crowding and malocclusion problems actually are alveolar bone deficiencies. The entire interdisciplinary team

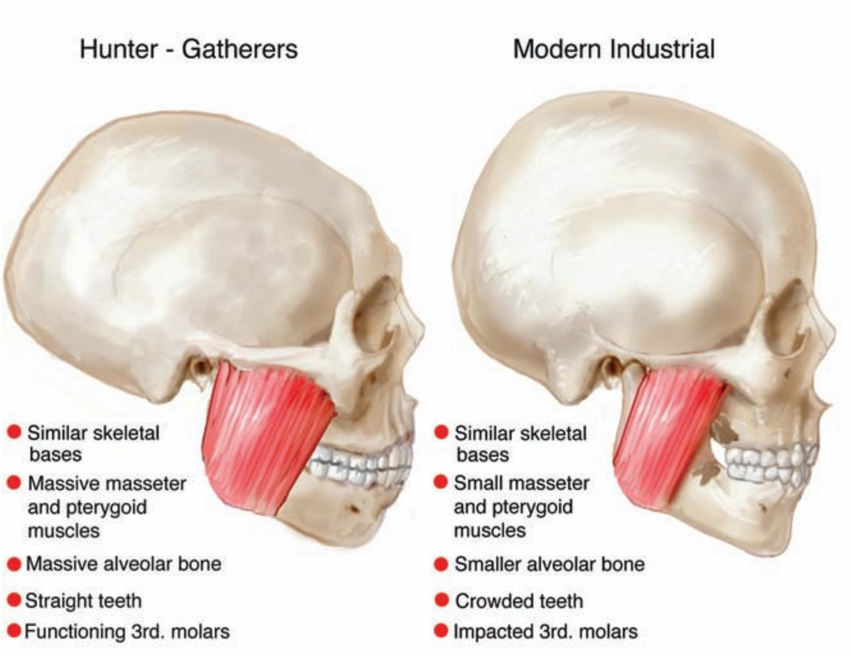

Figure 11 Drawing of a facial profile of a preagricultural skull and profile of a typical modern skull showing posterior location of alveolar bone and teeth (adapted from Carlson and Van Gerven[8] by William Winn).

Figure 12 The best approach for increasing the volume of alveolar bone supporting the teeth and expanding the dental arches is with orthodontics and dentofacial orthopedics during growth and development. A 10-year-old female presented with severe malocclusion and dental crowding **(A and B).** Habit control therapy was performed along with arch development (hyrax rapid palatal expander and lip bumper) and full-mouth orthodontics **(A and B).** Final occlusion 2.5 years after removal of appliances **(C and D).** Note stability of result and robustness of dentoalveolar complex.

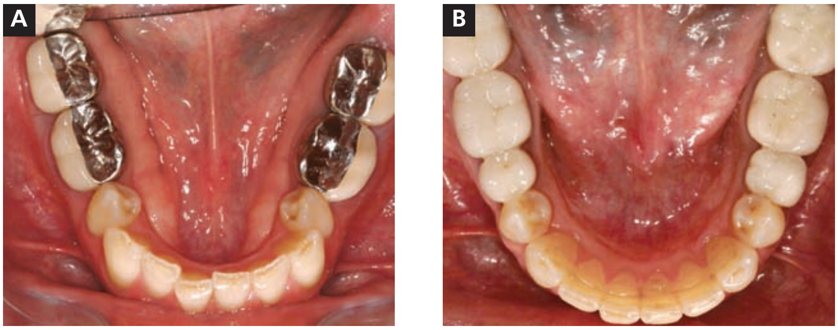

Figure 13 Extractions at an early age or a congenitally missing tooth can significantly complicate problems by creating a permanent defect in the already deficient alveolar bone and further constrict a deficient arch. A 46-year-old female presented for treatment of her malocclusion and correction of dentoalveolar retrusion that was leading to insufficient lip support **(A).** Her first premolars were extracted at an early age to resolve dental crowding. Note collapsed arch and constriction of buccal cortical plates that limit traditional orthodontic development. Final-arch form 3 years after treatment was completed **(B).** Surgically facilitated orthodontic therapy was performed, utilizing corticotomies, single-tooth osteotomies, and the principles of distraction osteogenesis.[14] Optimal implant sites were opened in Nos. 20 and 29 sites. Note the extreme amount of alveolar bone and arch development. These procedures can significantly expand the traditional limitation of orthodontic therapy by addressing the actual underlying bone volume and relationship problems and finish with excellent long-term stability.

should understand this and be able to properly diagnose this underlying problem to predictably treat to optimal long-term function, health, and esthetics. The dental profession also needs to improve current methods and develop new techniques for expanding dental arches and increasing alveolar bone volume.

The effects of dietary consistency on the dental arch must be expressed early in life because dental-arch dimensions are established at a young age.[1] The last time alveolar bone volume increases naturally is during the eruption of the teeth. That is why the best approach for increasing the volume of alveolar bone supporting the teeth and expanding the dental arches is with orthodontics and dentofacial orthopedics during growth and development[1] (Figure 12). However, a congenitally missing tooth or one that is extracted at an early age can significantly complicate problems by creating a permanent defect in the already deficient alveolar bone[14] (Figure 13A). These complications can be minimized by moving another tooth into the area relatively rapidly.

Options for correcting alveolar bone deficiencies in adults are much more limited.

After teeth eruption, the cortical plates establish the boundaries for orthodontic development of the dental arches.[15] In fact, some refer to the cortical plates buccal and lingual to the apices of the teeth as "orthodontic walls."[16] Encroaching on these walls during traditional orthodontic tooth movement can not only lead to unstable results, but also iatrogenic tissue loss of the involved tooth, bone, and periodontium[1,17-19] (Figure 2D). These problems are obviously more common when alveolar bone development is lacking because there is less area to move teeth in the alveolar trough between the cortical plates (Figure 2B). Orthodontic correction can be further complicated in severe alveolar deficiencies by cortical plates and the dentoalveolar complex developing in an improper relationship to its skeletal base[20] (Figure 2A, Figure 13A, Figure 14A, and Figure 14B).

Some excellent options are available for treating alveolar bone discrepancies. When teeth are moved in the absence of periodontal disease, they bring alveolar bone with them.[1] Because of this, orthodontic extrusion or orthodontic tooth movement through the alveolar trough between the cortical plates can be used sometimes to create the alveolar bone needed to support an implant to replace a missing tooth.[21,22] (Please turn to page 250 to read *Management of Dentoalveolar Ridge Defects for Implant Site Development: An Interdisciplinary Approach.*) In the past, though, there has not been a predictable method for overall development of alveolar bone and dental arches in adults. However, new and exciting procedures are becoming popular; they surgically facilitate orthodontic therapy to increase alveolar bone volume and allow correction of the relationship of the dentoalveolar complex to its skeletal base[20] (Figure 13 and Figure 14). (Please turn to page 264 to read *Surgically Facilitated Orthodontic Therapy: A New Tool for Optimal Interdisciplinary Results.*) These procedures use corticotomies, interdental osteotomies, and the principles of distraction osteogenesis to greatly accelerate tooth movement and directly address the issues caused by alveolar bone deficiency. Surgically facilitated orthodontic therapy can optimally resolve dental crowding and malocclusion problems that traditional orthodontics alone could not, and, as a result, has a more robust and esthetic dentoalveolar complex (Figure 14C). They also can decrease treatment time, minimize the indications for dental extractions, and increase stability of the result.

Figure 14 Orthodontic correction can be further complicated in severe alveolar deficiencies by cortical plates and the dentoalveolar complex developing in an improper relationship to its skeletal base.[14] A 42-year-old female presented for treatment of her malocclusion and severely constricted maxillary arch **(A and B).** She pursued orthognathic surgical options for 10 years unsuccessfully because of financial limitations. Attempting traditional orthodontic development would certainly lead to compromised and unstable results with iatrogenic tissue loss. Final result 3.5 years after treatment was completed **(C and D).** Surgically facilitated orthodontic therapy was performed, using a jack-screw appliance, corticotomies, single- and multiple-tooth osteotomies, and the principles of distraction osteogenesis.[14] Alveolar bone and arch deficiencies were resolved optimally in less than 14 months. Note the reduced gingival recession after alveolar bone development. These procedures allow changes in the relationship of the dentoalveolar complex to its skeletal base. The stable result has a more robust dentoalveolar complex similar to those seen in the ancient skulls of Amarna.

Anthropologists believe increases in dental crowding and malocclusion occurred with the transition from a primitive to modern diet and lifestyle, to the point that Corrucini labeled malocclusion a "disease of civilization."[10] The resultant underlying problem from the adaptations to the changes in diet appears to be an alveolar bone deficiency. All dental professionals should consider alveolar bone discrepancies as a leading cause of dental crowding and malocclusion. When indicated, treatment should focus on the development of alveolar bone and dental arches and not the reduction of tooth structure.

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