Measurements of Tooth Movements in Relation to Single-Implant Restorations during 16 Years: A Case Report

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ABSTRACT

Background: Osseointegrated implants behave as ankylotic abutments, and their positions are not affected by dentofacial changes.

Purpose: To measure changes in occlusion in relation to single implants in one patient after more than 15 years in function.

Materials and Methods: One 25-year-old female was treated with two single implants in the upper central incisor and bicuspid area after trauma. Study casts made prior to treatment (1987) and after 16 years in function (2004) were scanned by means of an optical scanner. Using the palate as the reference, the models were placed in the same coordinate system and analyzed and compared in a computer-aided design (CAD) program. The results of the measurements of the casts were also compared with clinical photographs taken at the time of treatment (1988), after 9 years (1997), and after 16 years (2004) in function.

Results: The clinical photographs showed obvious signs of implant infraposition after 9 years. New crowns were made in the incisor region after 15 years (2002), but signs of infraposition were again present at the final examination (2004). Measurements of the casts indicated small tooth movements with a pattern of slight eruption of upper teeth combined with a palatal inclination, mesial drift, and lingual inclination and crowding of the lower anterior teeth. The small measured vertical eruption of the teeth was less than the observed clinical infraposition of the implant crowns, indicating that the vertical position of the palatal may have changed in relation to the implants as well.

Conclusion: Obvious dentofacial changes may take place in adult patients. Teeth may adjust for this, and no major problems may arise in the dentate patient. However, because the positions of implants are not affected by dentofacial changes, other patterns of clinical problems can be seen when implant patients present with these changes. The character and frequency of these dentofacial changes that may compromise implant treatment in the long term are not yet known.

KEY WORDS: follow-up, growth, infraposition, long term, single implants, tooth migration

Implants have been used as an alternative to other techniques to replace single teeth for more than 20 years.[1] The first efforts in this field were focused on the surgical technique to place the implants correctly and to establish osseointegration, followed by prosthetic development of the abutment components to allow esthetic single-crown restorations that were needed for these demanding cases.[1,2] During the following years, the single-implant procedure has undergone several steps of development and is today a routine prosthodontic procedure,[1–7] and the experience gained to date indicates comparable or better success rates when compared with more conventional methods to restore single teeth.[8–14] However, since the first osseointegrated single crown for the Brånemark system was placed in 1984, most experience with single implants in any great number is of a median 5- to 10-year follow-up period, and cases followed up for more than 15 years must today be very few worldwide.

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Even though one-stage surgery and early loading are increasingly used, the basic concept is still that the implants should eventually be osseointegrated. In the 1960s, Björk and Skieller already used small metal implants as references when studying dentofacial growth in children, and among many observations, they could show that the small implants maintained their internal relationship, even though the bone showed significant changes owing to growth.[15] Ödman and colleagues showed in later studies that osseointegrated implants did not move with the eruption of the adjacent teeth, nor did they become secondarily displaced in the sagittal and transversal dimensions,[16–18] thereby reconfirming Björk and Skieller's earlier observation of ankylotic implants, unaffected by growth.[15] In a sequel study, it was also shown that single implants placed in young patients had a tendency to become in infraposition if they were placed too early, before the patients had reached their growth maximum.[19] Ödman's conclusion was therefore "that it is important to ensure that growth and development have been completed in adolescents before implants are placed,"[18] based on the assumption that the growth of the jaws was basically completed at that time. However, it was early observed that a certain amount of further growth took place after body growth maximum had been observed, occasionally resulting in infrapositioned implant crowns.[18] These observations have been confirmed in further follow-up studies on this early patient group, indicating that some of the patients continue to grow in their early twenties, with a slow but further infraposition of the single-implant crowns as a result.[20,21]

Long-term experience of single-implant treatment has shown many patients with a stable relationship between implants and adjacent teeth (Figures 1 and 2), indicating very small tooth movements in longer time perspectives. However, slow, continuous changes in the occlusion of adult patients have also been reported, basically resulting in a change in the width of the dental arch and crowding of lower anterior teeth.[22] From longitudinal studies using profile radiographs, a posterior rotation of the mandible and corresponding small adjustment of the anterior upper teeth have been indicated.[23–26] In combination with this rotation, Bondevik showed that the anterior face height increases significantly, more for females than for men between the ages of 23 and 34 years.[26] The mean change was about a 1 mm increase in anterior face height, but the range was reported from a reduction of 2.7 mm to an increase of 5.2 mm.[26] Thus, because some patients may present with an obvious change in the face height and because some patients exhibit significant implant infraposition after many years in function (Figures 3 and 4), more knowledge of this process is important.

The aim of this study was to present one patient with significant movements of teeth adjacent to single implants and to measure the dentoalveolar changes of this patient by means of scanning study models made before and 16 years after treatment.

PATIENT AND METHODS

Patient

A 25-year-old woman was treated with single implants in the right bicuspid and right central incisor areas in the

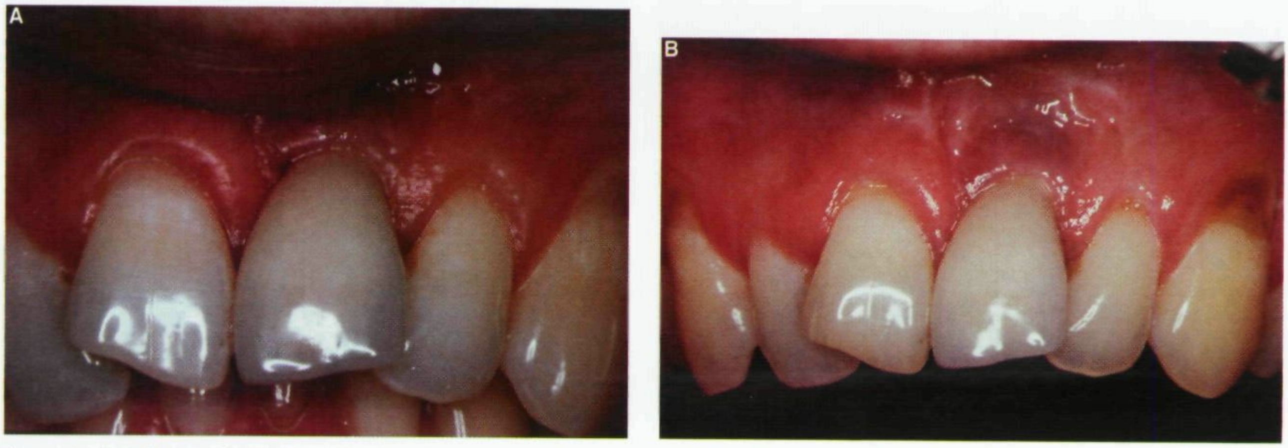

Figure 1 *A*, Left central incisor restored with a single-implant crown (1985). *B*, Follow-up situation after 10 years in function (1995). Notice the stable tooth-implant relationship.

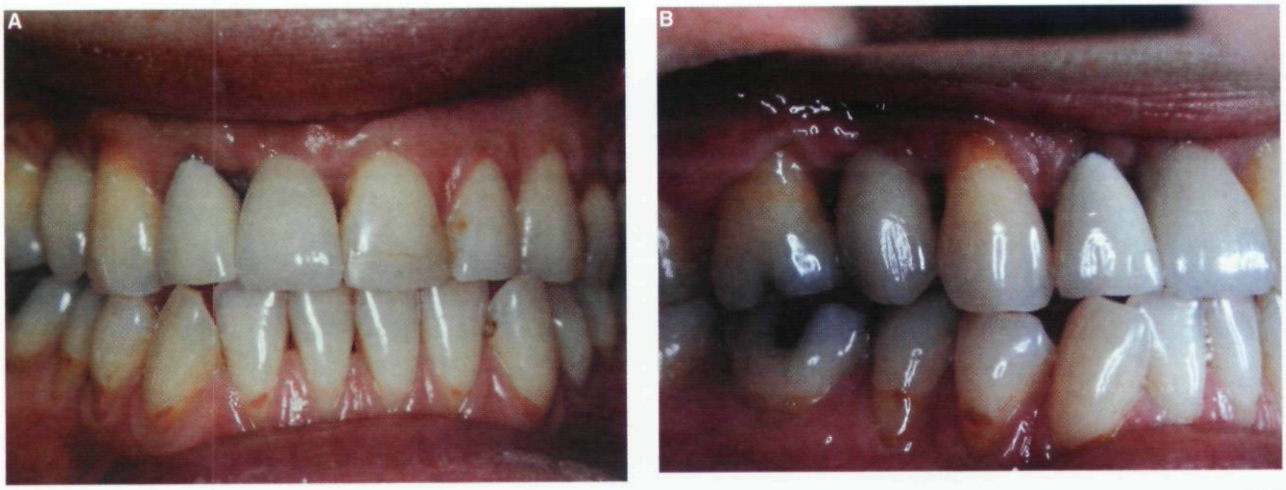

Figure 2 *A*, A 25-year-old female treated with a single implant in the right central incisor area. The right lateral incisor was provided with a crown (1988). *B*, A 25-year-old female treated with a single implant in the right first bicuspid area (1988).

maxilla after a trauma (see Figure 2). A conventional single crown was also made for the right lateral incisor at the same time. During the sequel years, an obvious tooth eruption adjacent to the single-implant restorations was noticed (see Figure 3). After 15 years, the right lateral incisor and both central incisors were provided with new single-crown restorations, but the right bicuspid was not replaced. Already after 1 year, further tooth migration of the left central incisor could be observed (see Figure 4A). Study casts were made prior to implant treatment (October 1987) and 1 year after the new crowns had been placed in the incisor region (March 2004).

Scanning Procedure

The study casts were placed in an optical three-dimensional scanner[27] (Atos, GOM International AG, Switzerland) for measurements of the contour of the models from the two different clinical situations. First, the models were scanned separately, followed by scanning the upper and lower models together, arranged in centric occlusion. The scanner measured the surfaces of the models by projecting different fringe patterns onto the object, which were recorded by two video cameras. The information from the two cameras was then calculated to three-dimensional coordinates with a calculated three-dimensional accuracy of 0.1 to 0.2 mm for this set-up.

Thereafter, the three-dimensional images of the models were placed in the same three-dimensional coordinate system in the computer by orientation of the palate of the two upper models into the same position, thereby using the palate as the reference for the further

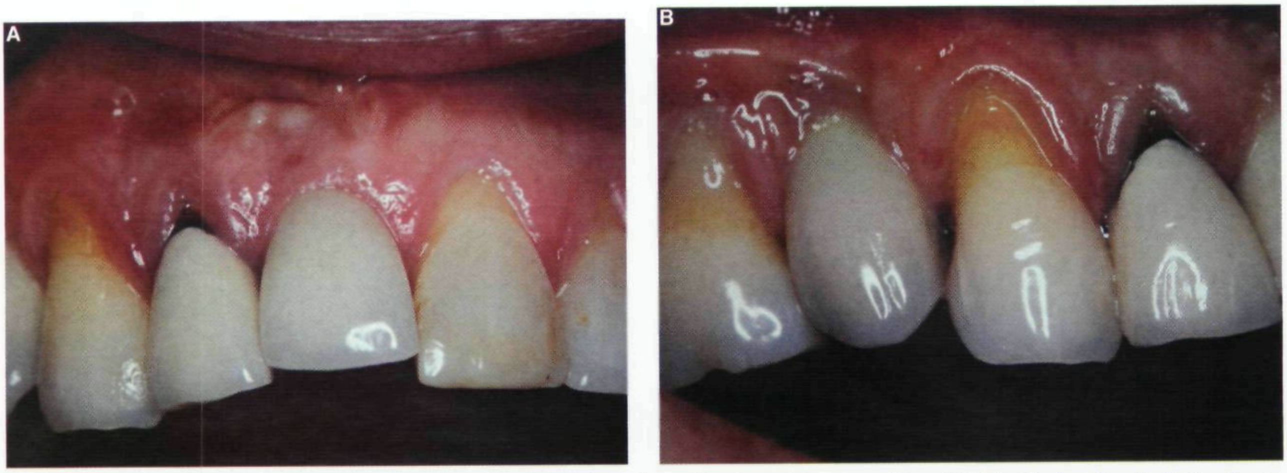

Figure 3 *A*, Follow-up situation after 9 years in function when the patient was 34 years of age (1997). Notice the single-implant crown (right central incisor) in infraposition and gingival recession. *B*, Follow-up situation after 9 years in function (1997). Notice the single-implant crown (right first bicuspid) in infraposition and gingival recession.

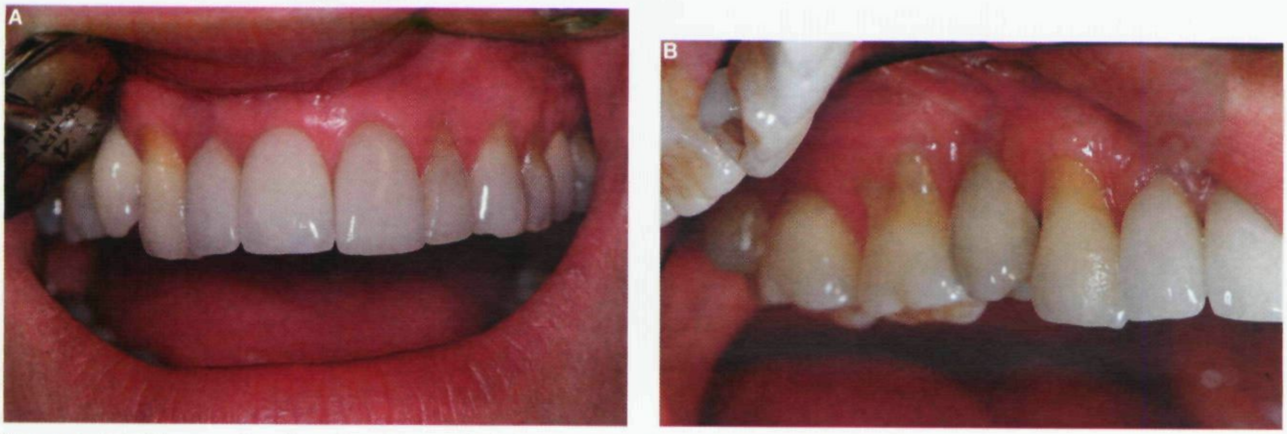

Figure 4 *A*, Follow-up situation after 16 years in function when the patient was 41 years of age (2004). The central incisors and right lateral incisor had been provided with new crowns 1 year earlier (2003). Notice the single-implant crown (right first incisor) in slight infraposition 1 year after placement. *B*, Follow-up situation after 16 years in function when the patient was 41 years of age (2004). Notice the single-implant crown (right first bicuspid) in infraposition and gingival recession.

comparison. By means of this procedure, it was then possible to also place the lower models in the coordinate system by means of the scanning of the upper and lower models in centric occlusion.

Analysis of the scanned models was performed in a computed-aided design (CAD) program (*DeskArtes*, Oy, Helsinki, Finland) in which sagittal and transversal slices were made with a distance of 2 mm. Visual analysis of the sagittal and transversal slices was performed, and deviations between the models could be measured in the CAD program. Thereafter, certain reference positions were identified (Figure 5) in which the CAD system calculated the three-dimensional coordinates for both situations before treatment (1987) and at the 16-year follow-up (2004), followed by calculation of the three-dimensional differences between these positions of the two models.

RESULTS

The palate of the two upper models showed good agreement, indicating good orientation of the models in relation to the reference in both sagittal and transversal orientations (Figures 6 to 8).

When using the palate as a reference, it is not possible to observe any obvious vertical eruption of the upper or lower teeth corresponding to the vertical eruption observed in the clinical photographs (see Figures 6 to 8). Thus, the occlusal surfaces of the molars

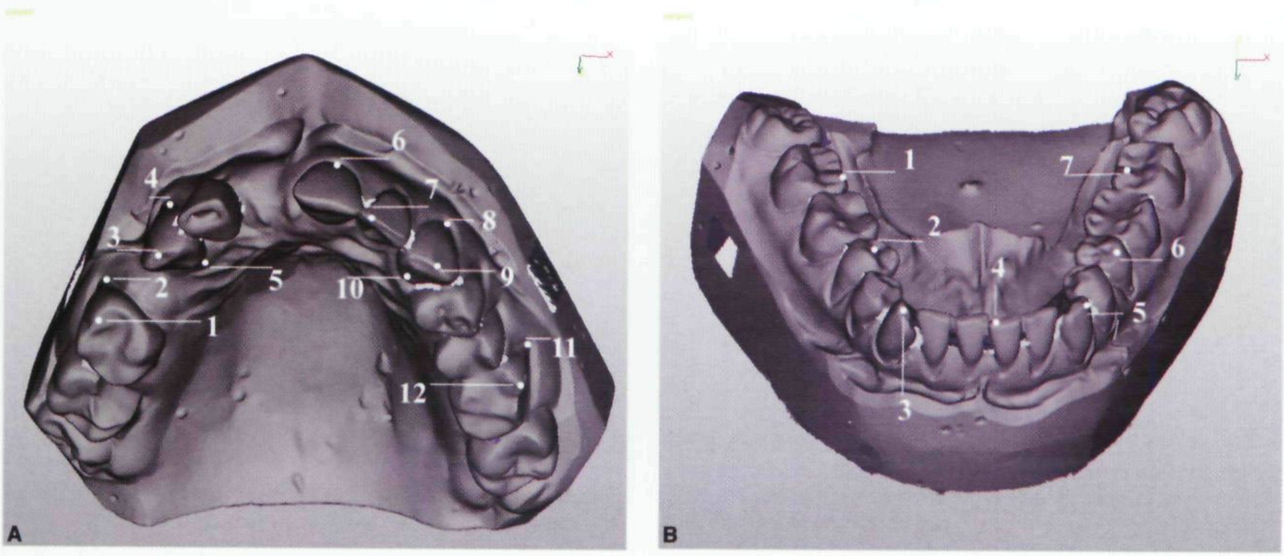

Figure 5 *A*, Measuring points in the upper jaw. *B*, Measuring points in the lower jaw.

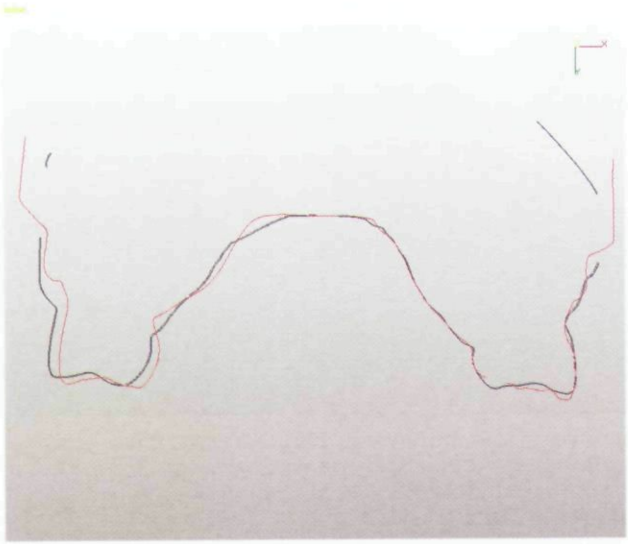

Figure 6 Transversal slices through the two models in the region of the distal cusps of the first molars. Notice the good agreement of the two models in the palate, the similar vertical positions of the molars, and the palatal movement of the molar on the right side after 16 years (*red line*).

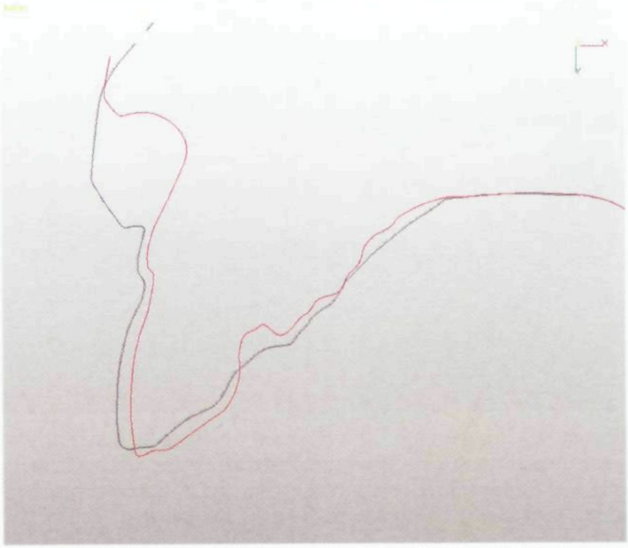

Figure 8 Toward the midline, 45° slices through the two models in the region of the right cuspid. Notice the good agreement of the two models in the palate and the slight vertical eruption of the canine in a palatal direction after 16 years (*red line*). Palatal defect of the canine owing to wear of palatal composite resin after root canal treatment in 1987.

(see Figure 6) did not change much in vertical relation to the palatal.

A minor eruption of the upper anterior teeth could be seen in the CAD system (see Figures 7 and 8), also combined with a palatal inclination of the upper and the lower incisors (Figure 9); however, visually, this was not to the same extent as noticed in the clinical pictures (see Figures 2 to 4). The lower right bicuspid, occluding to the upper implant bicuspid, showed a combined lingual but also vertical eruption (Figure 10).

Measurements of the reference positions (see Figure 5) are given in Tables 1 to 3. More tooth movements could be observed on the implant side (right). The first molars in the upper jaw show a small eruption of their mesiobuccal cusps (0.8 mm and 0.6 mm; see Table 1, "Vertical") combined with a reduced width in the arch

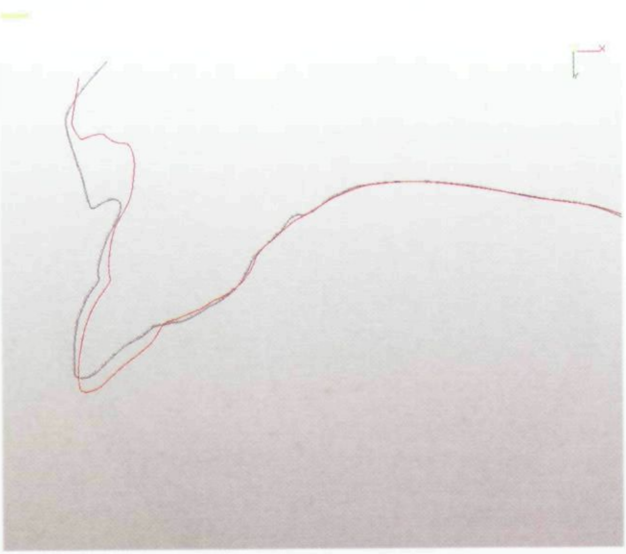

Figure 7 Sagittal slices through the two models in the region of the mesial part of the left central incisor (new crown 2004). Notice the good agreement of the two models in the palate and the vertical eruption of the incisor in a palatal direction after 16 years (*red line*).

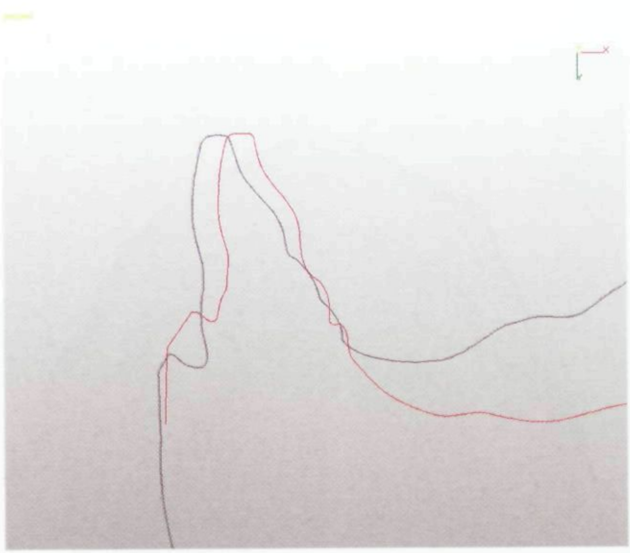

Figure 9 Sagittal slices through the two models in the region of the right central incisor. Notice the lingual movements of the incisor with the maintained vertical position after 16 years (*red line*).

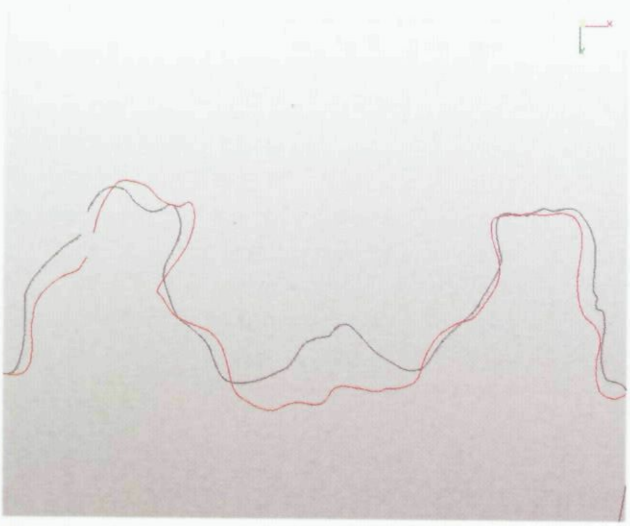

Figure 10 Transversal slices through the two models in the region of the second bicuspids. Notice the slight vertical eruption combined with a lingual movement of the right bicuspid after 16 years (*red line*).

between the teeth of 2.0 mm (see Table 1, "Lateral"). The intact upper canines and left lateral incisor all show a similar pattern of minor eruption (from 0.7 to 1.1 mm; see Table 1) combined with a retroclination (from 0.7 to 1.4 mm; see Table 1, "Sagittal").

In the lower jaw, the second molars indicate a mesial drift (0.6 and 1.2 mm; see Table 2, "Sagittal") combined with small vertical changes and reduced width of the arch (0.9 mm; see Table 2, "Lateral"). The right second bicuspid (tooth 45), occluding to the implant crown, shows a different movement pattern compared with the contralateral tooth (tooth 35), indicating an eruption, combined with an obvious lingual movement. However, the lower anterior teeth show a general pattern of movements, indicating an intrusion combined with a retroclination (from 0.7 to 1.7 mm; see Table 2, "Sagittal"), resulting in a crowding of the lower front teeth.

With the exception of the gingival position buccal to the right upper canine (see Table 3), the gingival margin shows obvious vertical recession at the teeth adjacent to the bicuspid implant crown (see Table 3, "Vertical"), not comparable to the contralateral positions. Buccal to the upper right canine, the gingival margin was basically at the same level in relation to the palate in the two different models (see Table 3, "Vertical"; 0.1 mm), even though the canine tooth shows some recession clinically at the site after 16 years (see Figure 8).

DISCUSSION

Only small vertical tooth movements could be observed in the upper jaw during 16 years of follow-up when using the palate as a reference. This is to some extent in contrast to the clinical observations, in which tooth movements seem to be greater when using the osseointegrated implant as the reference (see Figures 2 to 4 and Figures 6 to 8). Accordingly, it does not seem possible to observe obvious vertical changes when using the palate as the reference in this patient. This can be assumed to be due to the fact that the palate may follow the change in the dentoalveolar process, thereby basically maintaining the height of the alveolar crest. However, when ankylotic implants are present, these vertical changes become more evident and the vertical distance between the palate and the implants is probably reduced. These observations coincide with earlier publications, showing that implants are not affected by growth, thereby maintaining their internal relationship.[16–18,20,21]

The present patient shows a pattern of minor eruption of upper anterior teeth in combination with

TABLE 1 Change of Measured Tooth Positions in the Upper Jaw

Tooth	Position of Measurement (see Figure 5A)	Change of Position in mm (1987–2004)			
		Vertical*	Lateral†	Sagittal‡	3-D
16	2; mesiobuccal cusp	+0.84	+1.76	+0.14	1.96
13	4; cusp	+0.68	+0.85	−0.66	1.27
22	9; mesioincisal edge	+0.94	+0.16	−1.38	1.68
23	11; cusp	+1.14	+0.20	−1.01	1.54
26	14; mesiobuccal cusp	+0.59	−0.28	+0.32	0.73

*Coronal direction: "+."
†Palatal direction: teeth 16 to 11: "+"; teeth 21 to 26: "−."
‡Anterior direction: "+."

TABLE 2 Change of Measured Tooth Positions in the Lower Jaw

Tooth	Position of Measurement (see Figure 5B)	Change of Position in mm (1987–2004)			
		Vertical*	Lateral†	Sagittal‡	3-D
47	1; mesiolingual cusp	+0.14	+0.64	+0.64	0.92
45	2; buccal cusp	−0.23	+1.25	−0.06	1.27
43	3; cusp	+0.85	+0.22	−0.69	1.12
31	4; mesioincisal edge	+0.38	+0.43	−1.73	1.82
33	5; cusp	+0.72	−0.39	−1.26	1.50
35	6; buccal cusp	+0.29	−0.21	−0.29	0.46
37	7; mesiolingual cusp	−0.30	−0.28	+1.17	1.24

*Coronal direction: "−."
†Lingual direction: teeth 47 to 41: "+"; teeth 31 to 37: "−."
‡Anterior direction: "+."

retroclination and crowding of upper and lower incisor teeth and mesial drift of the molars, which coincides with reports by others in adult subjects.[22–25] Measurements of these movements seem to be less than those observed in the clinical photographs, again further indicating that the palate, used as the reference, may follow the growth of the teeth to some extent. The observed pattern of slow change in tooth positions seems to be a relatively common pattern of tooth movements in adult patients, whereas the present, more pronounced vertical changes in the incisor and premolar regions have been reported earlier only in relation to implants.[20,21] Since stable vertical relationships have also been observed in relation to implants in the long term (see Figure 1), different individual dentoalveolar changes may be present. Bondevik reported during a 10-year period a small average posterior rotation of the mandible combined with a small average increase in the anterior face height in young adults.[26] In agreement with the present patient, this pattern was more obvious in females,[26] and skeletal long-face subjects may be at a higher risk of this pattern of dentoalveolar changes. Thus, the present patient may be one of the more extreme patients, with a greater change in vertical anterior face height than average patients, as reported by Bondevik.[26]

Measurements of tooth positions indicated somewhat asymmetric changes in tooth positions on the right (implant) side compared with the left side in the upper jaw. This is also the case for the lower second bicuspids, in which the right bicuspid, occluding to the implant, loses its contacts as the upper bicuspid implant comes

TABLE 3 Change of Measured Gingival Margin Positions in the Upper Jaw

Tooth	Position of Measurement (see Figure 5A)	Change of Position in mm (1987–2004)			
		Vertical*	Lateral†	Sagittal‡	3-D
16	3; mesiobuccal gingival margin	−2.59	+0.79	+0.34	2.73
13	5; buccogingival margin	+0.14	+0.89	−0.40	0.99
13	6; palatogingival margin	−2.98	+0.42	−1.03	3.18
21	7; buccogingival margin	−0.47	+0.78	−0.38	0.99
22	8; buccogingival margin	−0.38	−0.54	−0.30	0.73
23	10; buccogingival margin	+0.31	−0.09	+0.09	0.34
23	12; palatogingival margin	+0.10	−0.25	−0.22	0.35
26	13; mesiobuccogingival margin	−0.62	−0.63	+1.77	1.98

*Coronal direction: "+."
†Palatal direction: teeth 16 to 11: "+"; teeth 21 to 26: "−."
‡Anterior direction: "+."

into infraposition. The vertical eruption, combined with lingual movements, of the lower right bicuspid could be interpreted as a response to the vertical change in the dentoalveolar process to maintain contact with the implant crown (see Figure 10). Thus, the right lower bicuspid seems to be the only tooth that shows a movement pattern that is clearly different from the other lower teeth, and this is probably a response to the slow changes of the occlusion opposing the implant crown.

Furthermore, measurements of tooth positions in the upper jaw show a clear pattern of slight eruption, combined with a palatal inclination of the upper anterior teeth (see Figures 7 and 8). It can also be observed that the alveolar crest follows the palatal inclination of the anterior teeth (see Figures 7 to 9). If this is a general pattern of tooth migration in adult patients, it means that the volume on the buccal side of the crest will be reduced in time. This implies that if implants are placed too buccally, implants and abutment-crown restorations may come closer to the buccal surface, thereby occasionally jeopardizing esthetics and possibly implant function in the long term. A more palatal placement of the implant to compensate for this palatal movement may be considered, in line with the early discussion of implant placement and "ridge lapping techniques."[2]

Measurements of the gingival margin show obvious vertical recession at the teeth adjacent to the bicuspid implant crown (see Table 3). This is not comparable to the contralateral positions and should probably be referred to the surgical procedure and possibly the ankylosis of the implant. Each gingival margin on the buccal sides of the right and left intact upper canines has moved 0.1 and 0.3 mm coronally in relation to the palatal (see Table 3, "Vertical"). This means that the soft tissue has followed the eruption of the teeth to some extent, but considering the vertical eruption of the canine teeth (0.7 and 1.1 mm; see Table 1, "Vertical"), the soft tissue recession has increased further during the follow-up period.

CONCLUSIONS

1. Obvious vertical eruption of teeth can be clinically observed in relation to the osseointegrated implants during 16 years of follow-up.
2. Using the palate as the reference in a CAD system, measurements seem to show smaller vertical tooth movements than observed clinically, indicating that the palate may follow the "eruption" of the teeth to some extent.
3. As described by others, small tooth movements were observed as mesial drift of molars, eruption combined with retroclination of upper anterior teeth, and lingual inclination of lower anterior teeth combined with crowding of the front in the mandible.
4. Upper anterior teeth may in the long term show a slight eruption combined with a palatal inclination. The alveolar process follows this movement, implying that implants, placed in between the teeth, may in time show reduced thickness of buccal tissue.

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