Changes of Anterior Clinical Crown Height in Patients Provided with Single-Implant Restorations After More Than 15 Years of Follow-up

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Purpose: To measure the long-term changes of clinical crown height in patients treated with single-implant crowns and compare them to those of an adult population with normal dentition. ***Materials and Methods:*** The test group comprised 23 patients, consecutively restored with a total of 48 single-implant crowns in the anterior maxilla. Mean age was 26.1 ± 11.4 years at inclusion. Original master casts were stored after treatment, and patients were recalled for new study casts an average of 15.8 ± 0.74 years later. The control group comprised 141 dental students with a mean age of 22.9 ± 1.20 years at inclusion. Study casts were made at inclusion and after 10 (n = 141) and 20 years (n = 60). Clinical crown height was measured for maxillary anterior teeth, and data were pooled and compared regarding clinical crown height and changes in height. ***Results:*** Implant clinical crowns were an average of 0.6 ± 1.04 mm longer than the contralateral teeth ($P < .05$). Central and lateral incisors showed mucosal recession at an average of 0.4 ± 0.53 mm ($P < .05$) and 0.6 ± 0.58 mm ($P < .01$), respectively. In the control group, only minor insignificant changes (± 0.1 mm) in mean clinical crown height could be observed during the follow-up period. However, obvious individual variations of changes could be found in the control group, and were more pronounced for women. Altogether, 15% and 9% of measured teeth showed ≥ 1.0 mm increase or decrease of clinical crown height during 20 years, respectively. Initially, shorter teeth presented a trend ($P < .05$ to .001) of more mucosal recession than longer teeth. ***Conclusion:*** Mean values of clinical crown height disguise significant individual variations of changes. To perform a risk evaluation for potential future mucosal recession, it could be suggested that greater changes in clinical crown height may occur in patients provided with implant-supported crowns than in untreated control subjects, possibly more for women than men, and more for initially shorter teeth than for longer adjacent teeth. *Int J Prosthodont 2006;19:455–461.*

The original Brånemark concept of osseointegration was based on a 2-stage surgical protocol, where separate abutment cylinders were placed at the second stage of surgery.[1] These cylinders were placed with the top of the abutments well above the mucosal margin to prevent the prosthesis-abutment margin from interfering with the mucosa, and thus to allow good oral maintenance and healthy soft tissue conditions.[1–3] This protocol was successful for treatment of the edentulous arch for almost 20 years before the implant technique was first tested for single-implant restorations in 1984.[2,3]

The new method of using single implants adjacent to permanent teeth in the anterior maxilla presented esthetic problems that could not be solved by means of the established supragingival abutment technique.[2,3] Therefore, to improve the esthetic result, abutments were for the first time designed and tested to allow subgingival placement of the veneering material.[2,3] By means of these new abutments, a controlled subgin-

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Table 1 Distribution of All Consecutively Treated Patients and Patients Followed-up and Documented with Master and Study Casts with Regard to Age and Gender at the Time of Inclusion

	Treated patients			Followed-up patients (test group)		
	Males	Females	Total	Males	Females	Total
No.	26	13	39	17	6	23
Mean age (y)	25.8	24.8	25.4	25.2	28.3	26.1
SD	11.0	8.1	10.0	13.0	5.4	11.4
Min age (y)	13	14	13	13	21	13
Max age (y)	62	39	62	62	34	62

gival placement of the implant crown margin was possible, while still aiming to have a "safety margin" of titanium between the implant crown margin and the implant head and supporting alveolar bone.[2,3] Accordingly, implants have been used as an alternative method to replace lost single teeth for more than 20 years. Since single-implant treatment has shown good long-term outcomes,[4–8] and today, single implants are placed in many young patients, it is anticipated that these implants may be in function for very long time periods. However, even though the technique of placing single implants in the anterior maxilla is currently used as a routine procedure by many clinicians, very little knowledge is available on the long-term stability of the mucosal margin at these crowns and adjacent teeth. According to early proposed clinical protocols, small changes of the position of the mucosal margin at the single-implant crowns may jeopardize the esthetic result of these restorations. Since it was already suggested that the level of the gingival margin should be considered as temporary and that a gradual physiologic recession of the gingival margin should be considered inevitable,[9,10] it must be important to increase the knowledge on tooth eruption in adults and changes of the gingival margin. In the orthodontic literature, both active tooth eruption into contact with opposing teeth, and passive tooth eruption, which occurs when the gingival margin moves toward the tooth apex,[10–12] have been extensively discussed. However, a deeper understanding of the magnitude and prevalence of gingival and mucosal recession at teeth and single-implant restorations in longitudinal studies covering adult subjects is needed.

The aim of this study was to present data on changes of clinical crown height for individual patients provided with single-implant crown restorations, and to compare these measurements with normal dentate subjects, followed-up for 20 years. The hypothesis was that most patients show only small changes of clinical crown height during this period and that only a few may be at risk for obvious passive tooth eruption.

Materials and Methods

Test Group

A total of 39 patients were consecutively restored with single-implant restorations in the anterior maxilla (canine to canine) at 1 clinic between December 1987 and June 1990. All patients were scheduled for a 15-year follow-up examination, including fabrication of study casts of the maxilla. Patients were recalled to the clinic for new study casts an average of 15.8 ± 0.74 years later (range: 15 to 17 years). Twenty-three of these patients, for whom original master casts were saved and available for measurements, formed the test group (Table 1).

The patients in the test group received a total of 27 turned Brånemark implants (Nobel Biocare), according to the standard 2-stage surgical procedure presented elsewhere.[1] After a healing period of 6 to 8 months, standard or healing abutments (Nobel Biocare) were connected at the second surgical procedure.[3] Thereafter, permanent porcelain-fused-to-metal crowns were cemented to single-implant abutments[2,3] or CeraOne abutment cylinders[6] (Nobel Biocare) by means of conventional zinc-phosphate cement[2,3,6] (Table 2).

Control Group

The control group comprised dental students at the Faculty of Odontology, Oslo University, first examined between 1972 and 1982.[13,14] At the first registration (R-0), 62 women and 79 men were included, followed-up for 10 to 20 years (Table 3). None of the subjects had orthodontic treatment or retainers at the first registration, or had any orthodontic or prosthetic treatment during the observation period.

Study casts were made for the control subjects at the 3 different registrations at inclusion (R-0) and after 10 years (R-10) and 20 years of follow-up (R-20).

Table 2 Distribution of Placed and Followed-up (Test Group) Single-Crown Restorations at the Maxillary Canines and Lateral and Central Incisor Sites

	Single-implant restorations				Followed-up restorations (test group)			
	Canines	Lateral incisors	Central incisors	Total	Canines	Lateral incisors	Central incisors	Total
Males	1	13	17	31	–	9	11	20
Females	6	5	6	17	–	3	4	7
Total	7	18	23	48	–	12	15	27

Table 3 Distribution of Age and Gender of Subjects in the Control Group

	0 y (R-0)		10 y (R-10)		20 y (R-20)	
	Women	Men	Women	Men	Women	Men
No.	62	79	62	79	30	30
Mean age (y)	22.0	23.2	32.9	33.5	42.6	43.2
SD	1.03	1.30	1.34	1.44	1.40	1.27
Min age (y)	21	21	31	31	41	41
Max age (y)	25	26	37	37	45	46

Measurements

Except for the single-implant crowns, only 1 patient had 1 additional single-crown restoration (maxillary lateral incisor) placed in the anterior region during the study period. Clinical crown height was measured at the maxillary right canine, maxillary right central incisor, and maxillary left lateral incisor. When these sites were implant sites, the clinical crown height of the contralateral tooth was measured at both casts in the test group. The crown height of the implant crowns was only measured at follow-up. All available master and study casts were measured according to a standard protocol.[10] The measurements were made from the most apical concavity of the gingival margin of the tooth/implant crown to the incisal edge by means of a digital caliper to the closest 0.1 mm.

Statistics

The Wilcoxon signed rank test was used for intraindividual comparisons of changes of clinical crown height and differences between implant crowns and contralateral teeth in the test group. The coefficient of correlation was calculated for relationships between original crown height and changes of crown height after 10 and 20 years of follow-up in the control group. Distributions of changed crown height between genders were tested by means of chi-square tests. Significance was set at 5%.

Results

Study Group

One central incisor in 1 master cast was damaged and could not be measured.

The clinical crown heights for measured teeth are given in Table 4. It was observed that the clinical crown height increased significantly from placement of the implant crown to the follow-up examination for central ($P < .05$) and lateral ($P < .01$) incisors, but not for canines (Table 4). Contralateral teeth did not show significant changes in clinical crown height ($P > .05$). Altogether, 8 measured anterior teeth (17.0%) showed an increase of clinical crown height of ≥ 1.0 mm at the final examination (Table 5).

It was also observed that the single-implant crown restorations were an average of 0.6 mm (SD = 1.04) longer than the contralateral teeth at the final examination ($P < .05$).

No obvious correlations ($P > .05$) were observed between original crown height at baseline and changes of crown height during follow-up or between changes of clinical crown height and age at the time of implant surgery.

Control Group

One study cast (R-20; male) showed a fractured central incisor, and a further 3 casts (R-0; 2 females and 1

Table 4 Mean Clinical Crown Height of Permanent Maxillary Teeth in Test (Baseline and After 15 Years) and Control Groups (0 Years and After 10 and 20 Years)

	Mean clinical crown height (mm) (SD)		
	13	11	22
Test group			
Baseline	9.6 (1.0)	9.7 (0.9)	8.8 (0.9)
15 y	9.9 (1.3)	10.2 (1.0)*	9.5 (1.5)*
Control group			
0 y	9.6 (1.1)	9.9 (1.0)	8.6 (0.9)
10 y	9.6 (1.1)	9.9 (1.0)	8.5 (1.0)
20 y	9.5 (1.1)	9.8 (1.1)	8.4 (0.8)

*Significant increase compared to baseline ($P < .05$).

Table 5 No. of Measured Permanent Teeth with Regard to Changes of Clinical Crown Height and Maximum Increase and Decrease of Height in the Test Group

	No. of teeth			
Tooth	Right canine	Right central incisor	Left lateral incisor	Total (%)
No.	21	12	14	47
Longer	15	10	13	38 (80.9)
Shorter	6	2	1	9 (19.1)
≥ 1.0 mm longer (%)	4 (16.6)	1 (8.3)	3 (21.4)	8 (17.0)
Max increase (mm)	2.2	1.4	1.7	2.2
Max decrease (mm)	0.9	0.4	0.1	0.9

Table 6 Mean Clinical Crown Height of Maxillary Anterior Teeth at the Time of First Registration (R-0) for Control Subjects and Distribution of Individual Teeth in Relation to Crown Height

	Females			Males		
	Right canine	Right central incisor	Left lateral incisor	Right canine	Right central incisor	Left lateral incisor
No.	62	62	60	79	79	78
Mean (mm)	9.3	9.7	8.6	9.9	10.0	8.6
SD	0.89	0.97	0.78	1.18	1.08	1.01
Max (mm)	11.5	11.6	10.4	12.6	12.6	11.0
Min (mm)	7.7	7.1	7.1	7.2	7.9	6.2
Distribution						
> 11.0 mm	2	7		11	14	
11.0–10.0 mm	11	20	3	24	28	7
9.9–9.0 mm	24	22	18	28	25	20
8.9–8.0 mm	21	11	23	13	10	31
7.9–7.0 mm	4	2	16	3	2	16
< 6.9 mm						4

male) showed missing right lateral incisors caused by partial anodontia (1.8%). These 4 tooth positions were excluded from measurement and analysis. For the remaining teeth and study casts, mean values of clinical crown heights are given in Tables 4 and 6.

Changes of clinical crown height in relation to the baseline measurements are given in Table 7. No changes of group mean values were observed for any measured tooth position, but obvious individual variations of changed clinical crown height were noted. Altogether, 7.9% and 15.3% of the teeth increased clinical height by ≥ 1.0 mm in 10 and 20 years period of time, respectively. The corresponding percentages of teeth showing a reduced clinical height of ≥ 1.0 mm were 5.5% and 9.0%, respectively. The remaining 86.6% and 77.7% of the teeth presented changes of crown height of less than ±1.0 mm after 10 and 20 years of follow-up, respectively. The distribution of shorter and longer teeth was not significant between genders ($P > .05$).

A general trend was observed that shorter teeth at baseline (R-0) became longer and longer teeth became shorter after 10 to 20 years in function (Table 8). This trend was most significant in canines and central incisors in females ($P < .001$), while males showed overall weaker correlations to the regression lines.

Discussion

A difference in the changes of clinical crown height between the study group and control group was observed. The average values for clinical crown height were basically stable for the control group during the follow-up period, which is in accordance with earlier publications.[10,12] On the contrary, the study group presented a significant increase of clinical crown height of anterior central incisor teeth, irrespective of age at the first surgical stage. This observation corroborates results reported by Jemt and Lekholm,[15] who indicated a significant increase of the crown height of lateral incisors adjacent to single-

Table 7 Mean Changes of Clinical Crown Height After 10 and 20 Years in the Control Group and Maximal and Minimal Registration and Distribution of Teeth with Regard to the Degree of Change After 10 and 20 Years

	10 y (R-10)			20 y (R-20)		
	Right canine	Right central incisor	Left lateral incisor	Right canine	Right central incisor	Left lateral incisor
No.	141	141	138	60	59	58
Mean (mm)	0.0	0.0	0.0	0.1	0.1	0.1
SD	0.70	0.60	0.58	0.86	0.82	0.85
Min (shorter*)	–2.2	–1.3	–1.5	–2.0	–3.2	–2.8
Max (longer**)	2.1	1.8	1.5	1.8	2.3	1.8
Distribution						
< –2.0 mm*	2				1	1
–1.5 to > –2.0*			1	2		1
–1.0 to > –1.5*	8	7	5	5	5	1
< –0.5 to > –1.0*	19	18	19	7	7	7
–0.5 to 0.5	84	97	92	26	25	31
> 0.5 to < 1.0**	17	8	10	8	17	6
1.0 to < 1.5**	8	8	10	9	3	9
1.5 to < 2.0**	2	3	1	3		2
> +2.0 mm**	1				1	

*Shorter teeth/wear.
**Longer teeth/recession.

Table 8 Correlations and Calculated Regression Lines for the Relationship Between Original Clinical Crown Height at Baseline (R-0) and After 10 (R-10) and 20 Years (R-20)

Follow-up/group	No.	Slope*	Intercept†	*r*	*P*
Correlations between baseline (R-0) and 10 y (R-10)					
Canine					
Male	79	–0.5	9.9	–0.238	< .05
Female	62	–0.6	9.3	–0.594	< .001
Total	141	–0.6	9.6	–0.412	< .001
Central incisor					
Male	79	–0.4	10.0	–0.214	> .05
Female	62	–0.6	9.8	–0.400	< .001
Total	141	–0.5	9.9	–0.303	< .01
Lateral incisor					
Male	78	–0.4	8.6	–0.197	> .05
Female	60	–0.3	8.5	–0.248	> .05
Total	138	–0.3	8.5	–0.218	< .05
Correlations between baseline (R-0) and 20 y (R-20)					
Canine					
Male	30	–0.5	9.7	–0.389	< .05
Female	30	–0.6	9.4	–0.501	< .001
Total	60	–0.5	9.6	–0.431	< .001
Central incisor					
Male	29	+0.2	9.8	0.111	> .05
Female	30	–0.6	9.6	–0.512	< .001
Total	59	–0.2	9.7	–0.241	> .05
Lateral incisor					
Male	29	–0.4	8.5	–0.338	> .05
Female	29	–0.3	8.4	–0.375	< .05
Total	58	–0.3	8.5	–0.356	> .05

*A negative slope (–) of the regression line indicates that originally (R-0) shorter teeth may show more gingival recession by time, and originally longer teeth may present more wear by time.
†The intercept indicates the original clinical length of teeth where the regression line crosses the zero line for changes (+/-) of clinical crown length.

implant crowns after 1 year but not after 5 years of follow-up.[15] Whether the increase of clinical crown height in the present study is an early response to the surgical and prosthetic treatment or a slow continuous process during the entire follow-up period is not possible to determine from the data. Nevertheless, the results indicate that the gingival margin at teeth adjacent to single-implant restorations should be expected to present a higher risk of gingival recession than teeth in a group of normal untreated persons in long-term perspectives.

It is a well-established observation that clinical crown height increases by age in young patients,[10,12] in whom an active eruption takes place and continues until the teeth come into contact with the opposing dentition.[10,12] This active eruption is followed by a passive eruption[10–12] when the gingival margin moves toward the tooth apex. This process is assumed to stabilize at the end of the teenage years.[12] Thereafter, the gingival margin is considered stable enough to allow rehabilitation with fixed partial dentures.[12] The present data in the control group support this assumption, showing stable average values for clinical crown height in persons with ages ranging from the mid-twenties to mid-forties (Table 4). However, mean values seemed to conceal important individual variations in the group, in which subjects showed clear reductions of the clinical crown height as well as obvious gingival recession after 10 to 20 years of follow-up (Table 7). A reduction of clinical crown height of ≥ 1.0 mm was only observed in the control group, which indicates wear of teeth (Tables 5 and 7); however, signs of obvious recession were observed in both groups. In the present study, the distribution of patients showing ≥ 1.0 mm passive eruption was somewhat higher for the test group after 15 to 17 years (17%) compared to the control group (9% to 15%) after 10 to 20 years. If this trend of difference is consistent in larger groups, it may imply that single-implant treatment may increase the risk of more pronounced gingival recession at teeth in close relationship to the single-implant crowns.

Thus, it is reasonable to assume that single-implant treatment increases the prevalence and magnitude of gingival recession at the adjacent teeth. To test a possible technique that would allow at least a preliminary clinical risk evaluation for gingival recession, the regression line for the change of clinical crown height in relation to initial crown height was calculated for the control group (Table 8). The calculations showed an almost consistent trend for all teeth, more obvious for women, of more gingival recession for initially clinically shorter teeth (Table 8). The intercept indicated the critical clinical crown height, below which shorter teeth could possibly be at a higher risk for gingival recession than longer teeth. The clinical implication of this data may be that when measuring the thickness of the mucosa from the mucosal margin down to the implant head to decide the placement of the implant crown margin,[2,3] clinically shorter adjacent teeth should suggest a slightly deeper placement of this margin to compensate for the possibility of more future mucosal recession. Also, a deeper placement of the implant head could be considered at surgery when adjacent teeth present clinically short crowns.

When it comes to single-implant crowns, longitudinal data on changes of the mucosal margin are not available in the present study. However, in accordance with an earlier publication by Jemt and Lekholm,[15] the implant crowns presented significantly longer clinical crowns than the contralateral teeth at the termination of the study ($P < .05$). In the previous study, this significant difference ($P < .05$) was already present at the placement of the implant crown, indicating that tooth extraction and implant surgery may cause an early vertical loss of the alveolar ridge. In the present study, where more basic surgical techniques were used, this difference could also have been established at implant crown placement. However, long-term difference in wear patterns of permanent teeth and implant crowns, as well as long-term changes of the mucosal margin at the implant crowns, should also be considered. The latter option suggests a similar pattern of more mucosal changes at the implants, as also observed at the adjacent teeth.

As discussed earlier, active and passive eruption have been investigated and defined in the literature.[10–12] Most of these studies are based on young patients, in many cases as part of orthodontic treatments. When implants are introduced in the dentition, a new situation arises with regard to observing longitudinal changes in the dentition. Since dental implants are ankylotic, they are not affected by growth, and thereby maintain their internal relationship.[8,16–20] Thus, implants can be used as references, and other aspects of tooth eruption and growth of the arch can be observed.[20] Certainly, increased clinical crown height at implant crowns must be explained by loss of vertical height of the crest before or during implant treatment or as a result of mucosal recession toward the implant apex (Figs 1a and 1b). However, the discussion of changes of clinical crown height at teeth during tooth eruption may become slightly more complex when implants are used as a reference.[20] Active eruption has been defined as tooth eruption into contact with the opposing dentition, and is assumed to be completed during adolescence.[20] However, in the presence of single-implant crowns, active eruption of teeth has been reported in a patient between the ages of 25 and 41 years,[20] indicating that eruption may progress later in life in some patients. Furthermore, in this same patient,[20] migration of the entire maxilla was indicated, which resulted in a down growth of all maxillary teeth, except the implants, thus indicating an additional "skeletal eruption" as a result of adult facial growth.[20]

Conclusions

In conclusion, this study has indicated that mean values of clinical crown height may disguise significant individual variations of changes of crown height in larger groups of adult patients. A trend ($P < .05$) was observed


Figs 1a and 1b A 22-year-old male patient provided with a single-implant crown at the left central incisor position after placement *(left)*, and after 16 years in function *(right)*. Note the vertical recession at the implant crown.

that clinically initially shorter maxillary anterior teeth, especially in women, show more passive eruption than initially longer teeth in adults. It also seems possible to conclude that single-implant treatment increases the pattern of gingival recession at the adjacent teeth, and that single-implant crowns become longer than the contralateral teeth ($P < .05$). When measuring the mucosal thickness for placement of the margin of single-implant restorations,[2,3] it may be recommended to consider a sufficient "safety width" between the crown and implant head, preferably in titanium,[2,3,21] but also to place the veneering margin deep enough to avoid titanium exposure caused by mucosal recession over the long-term. This decision is based on a risk evaluation, where more passive eruption may be anticipated for treated patients compared to untreated, for women compared to men, and for initially shorter teeth compared to longer adjacent teeth.

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