J Clin Periodontol 2008; 35: 346–355 doi: 10.1111/j.1600-051X.2008.01204.x

Journal of Clinical Periodontology

A Retrospective study of root coverage procedures using an image analysis system

Stéphane Kerner[1], Alain Borghetti[2], Sandrine Katsahian[3], Daniel Etienne[1], Jacques Malet[1], Francis Mora[1], Virginie Monnet-Corti[2], Jean-Marc Glise[2] and Philippe Bouchard[1]

[1]Department of Periodontology, Service of Odontology, Hôtel-Dieu Hospital, AP-HP, Paris 7 – Denis Diderot University, U.F.R. of Odontology, Paris, France; [2]Department of Periodontology, University of Marseille, Faculty of Odontology, Marseille, France; [3]Department of Biostatistics, Saint Louis Hospital, AP-HP, Paris 7–Denis Diderot University, Paris, France

Kerner S, Borghetti A, Katsahian S, Etienne D, Malet J, Mora F, Monnet-Corti V, Glise J-M, Bouchard P. A Retrospective study of root coverage procedures using an image analysis system. J Clin Periodontol 2008; 35: 346–355. doi: 10.1111/j.1600-051X.2008.01204.x.

Abstract

Aim: To investigate the efficacy of root coverage procedures and factors that may affect the clinical outcomes in non-experimental patients.

Material and Methods: Two hundred and eighty-seven root coverage surgical procedures in 215 adult patients were evaluated retrospectively. Descriptive statistics were used to determine the patient profile. Comparisons between surgeries were assessed, and the impact of different parameters on the probability of mean/complete root coverage and gingival augmentation was explored.

Results: The mean percentage of root coverage was 72.29 (± 28)%. Complete root coverage was observed in 35.56% of the defects. The difference between the surgical procedures was not significant. The mean percentage of gingival augmentation was 106.18 (± 260)%. The difference between non-submerged grafts and the other techniques was significant ($p<10^{-3}$). A significant negative impact of smoking, and maxillary teeth for both mean and complete root coverage were found. A significant positive impact of the tuberosity donor site was found for complete root coverage. Maxillary teeth and Miller's Class II and III were positive predictive factors for gingival augmentation.

Conclusions: Under non-experimental conditions, root coverage procedures are effective. Smoking, maxillary teeth, donor site, and Miller's Classes are prognostic factors that may affect the results.

Key words: gingival recession/surgery; gingival recession/therapy; grafts; image analysis; retrospective study

Accepted for publication 31 December 2007

Root coverage surgical procedures remain among the most widely used therapeutic strategies for the correction of gingival recession defects. Numerous surgical techniques have been proposed and evaluated clinically. Prospective comparative clinical trials have focused on evaluations and comparisons of various techniques (Pini Prato et al. 1992, Bouchard et al. 1997, Jepsen et al. 1998, Borghetti et al. 1999, Tatakis & Trombelli 2000). Although significant differences between various surgical procedures have been shown in some studies (Jahnke et al. 1993, Paolantonio et al. 1997, Trombelli et al. 1998, Lins et al. 2003), the majority of the randomized clinical trials (RCTs) were not able to find statistical differences, thus concluding on the equivalence of treatments.

This lack of difference in the outcome may be due to a low statistical power because of a small sample size. In parallel-design studies, the number of defects for each group ranges from 12 to 37 (Tatakis & Trombelli 2000, Moses et al. 2006). For example, statistical power calculations indicate that using a power of 90% and an $\alpha = 0.05$, 22 test subjects and 22 control subjects ($N = 44$) are required to observe a statistical difference when the expected clinical difference in linear measurements between groups is 1 mm, with estimated group standard deviations of 1 mm. However, a difference of 1 mm between groups is rarely found. For a more realistic expected difference of 0.5 mm, the sample size per group is 86 ($N = 172$).

To compensate for the effect of a small sample size, an evidence-based approach was proposed, and a meta-analysis was conducted (Roccuzzo et al. 2002, Oates et al. 2003). The

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interests.
No external funding, apart from the support of the authors' institution, was available for this study.

main conclusions of these studies are as follows: (1) several root coverage surgical procedures are effective in reducing gingival recessions; (2) further research is needed to identify the factors associated with successful outcomes; (3) more information is needed to aid in the selection of appropriate treatment options; and (4) the heterogeneity of RCTs is often high, and does not allow comparisons between various surgical techniques. Thus, decision making for root coverage procedures can only be partly based scientific evidence.

Taken together, these considerations make the selection of a surgical technique in daily periodontal practice difficult. To date, no study has evaluated the clinical results of root coverage procedures performed by experienced periodontists in the routine condition of their practices. Therefore, a study including a large number of patients/recessions routinely attending private practices is of interest to determine the impact of the surgical technique in the success of root coverage therapy and to determine the patient profile.

The aim of this retrospective survey is (1) to further explore the mean percentage of root coverage following various surgical procedures and (2) to examine treatment variables that may affect root coverage rates in a non-experimental group of patients.

Material and Methods

This was a retrospective study, with masking of the examiner and the statistician, on the effect of root coverage therapy. The population consisted of consecutive outpatients treated in seven private practices limited to periodontology (three in Marseille and four in Paris). In each private office, all patients had received root coverage surgeries by a single periodontal specialist with >15 years of clinical experience. All specialists hold an academic position, and have published articles dealing with root coverage in peer-review journals. Each periodontist was asked to select from their files clinical cases of root coverage techniques documented with pre-operative and post-operative photographs with a minimum of 6 months follow-up, and to complete a study form corresponding to the surgical procedure.

Study population

Three hundred and sixty-three surgeries, 232 coincident patients, and 691 coincident recessions were submitted for the analysis. All patients underwent root coverage therapy between 1981 and 2005. Figure 1 indicates detailed information on the reasons for excluding recessions from the analysis. All clinical cases entered into the database complied with all the primary inclusion criteria and were excluded if one or more exclusion criteria were found.

Inclusion criteria

All the following criteria must be fulfilled for inclusion:

- Males and females must be at least 18 years of age.
- Patients must be in good general health without any systemic diseases.
- Patients must be free of periodontal disease.
- Patients must have at least one buccal Class 1, 2, 3 or 4 Miller's gingival recession defect to be treated (Miller 1985).
- The experimental teeth must be maxillary and mandibular premolars, canines, and incisors.
- The experimental teeth must be free of endodontic lesions and of caries or restorative dentistry in the defect area on the date of the surgical procedure and on the date of the control.

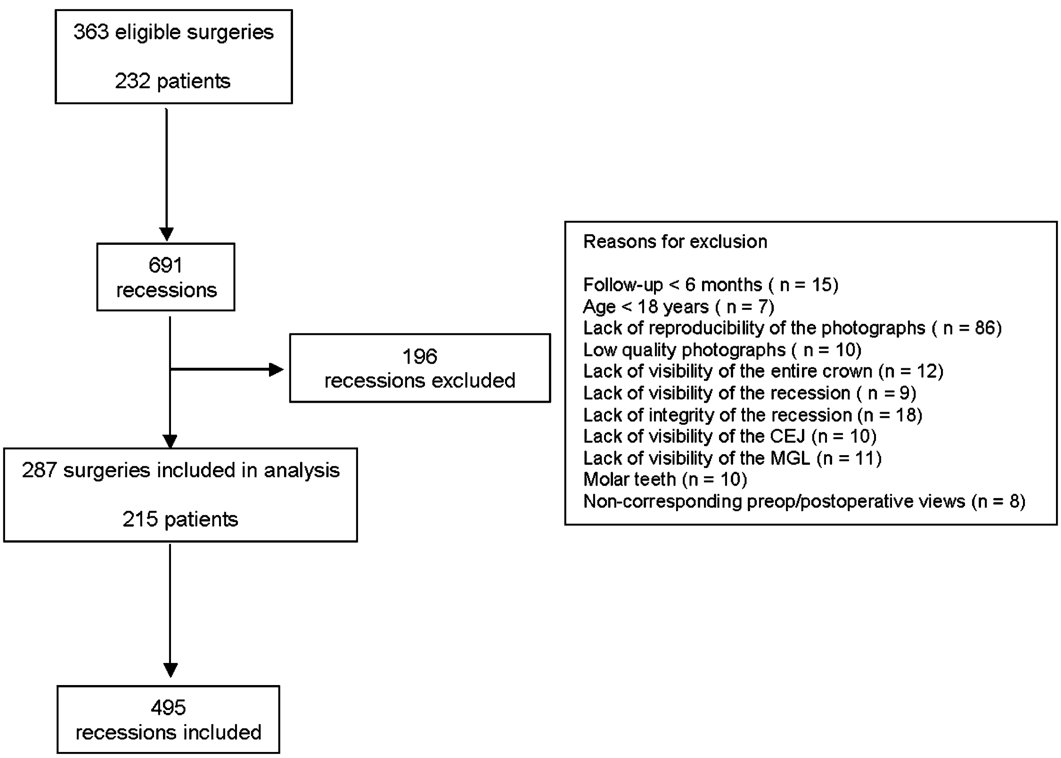

Fig. 1. Diagram of the inclusion cases.

- The experimental teeth must be documented with two high quality photographs – one at the date of the surgery, and one at the date of the control.
- The control will be ⩾6 months after the surgical procedure.

Exclusion criteria

- Any medical conditions that could interfere with normal healing, including current pregnancy at the time of the surgical procedure and during the healing phase.
- Palatal and lingual gingival recessions.
- Molar teeth.
- Lack of visibility of the cementoenamel junction and/or of the mucogingival line on the photographs.

Study procedures and assessments

For each of the surgeries, patient characteristics including age, gender, smoking status, and post-operative antibiotic prescription as well as type of tooth and Miller's classification of the defects were recorded.

The indications of the surgical procedure were recorded as follows:

- Aesthetics
- Root sensitivity
- Pre-prosthetic procedure
- Pre-orthodontic procedure
- Soft tissue augmentation
- Other indications.

When applicable, the donor site was recorded, including palatal, tuberosity, and edentulous ridge.

Surgical techniques were recorded using the following classification (Bouchard et al. 2001):

Pedicle soft tissue grafts

1-Laterally positioned flap
2-Double papilla flap
3-Coronally positioned flap
4-Semilunar flap

Non-submerged graft

5-One stage (free gingival graft)
6-Two stages (free gingival graft+coronally positioned flap)

Submerged grafts

7-Connective tissue graft+laterally positioned flap
8-Connective tissue graft+double papilla flap
9-Connective tissue graft+coronally positioned flap
10-Envelope techniques.

When applicable, additive treatments were recorded as follows:

- Root surface modification agents (citric acid, TTC-HCL, EDTA, others)
- Enamel matrix proteins
- Non-resorbable membrane barriers (ePTFE, ePTFE reinforced, others)
- Resorbable membrane barriers (polymer, collagen, others).

Root coverage and gingival augmentation measurements

To ensure the blinding, photographs were coded independently into a spreadsheet using a proprietary randomization program (under Excel, Microsoft, Redmond, WA, USA). Unblinding was carried out after completion of calculation for merging with clinical worksheets.

Pre-operative and corresponding post-operative slides were digitalized under 300 dpi with a scanner, and displayed using Adobe® Photoshop® software (version 7.0 Adobe Systems Europe Ltd., Uxbridge, UK). Each slide was analysed using Image J for windows, a public domain Java image processing program, which calculated area and pixel value statistics for user-defined selections (Rasband 1997–2007, Abramoff et al. 2004).

In order to ensure the comparability of pre-operative and post-operative photographs, the following lines were drawn on a graphic tablet: (1) a mesio-distal horizontal line at the maximum width of the crown and (2) a mid-facial vertical line from the most coronal edge of the crown to the muco-gingival line (Figs 2 and 3). These two lines were measured with Image J, and used as references to check the comparability of the magnification. The image deformation was evaluated using the following formula:

$$1 - [(\text{pre-op and post-op vertical lines ratio}) \times (\text{pre-op and post-op horizontal lines ratio})].$$

To be included in the database, the image deformation must be ⩽5%.

All measurements were performed by one calibrated examiner (S. K.). The intra-examiner calibration was assessed by reproducibility for linear measurement that was <2%. Results were given in pixel values. Details of the standardization of pre- and post-surgical photographs, and recession evaluation, with Image J have been described and validated previously (Kerner et al. 2007). The percentage of root coverage was calculated using the recession depth

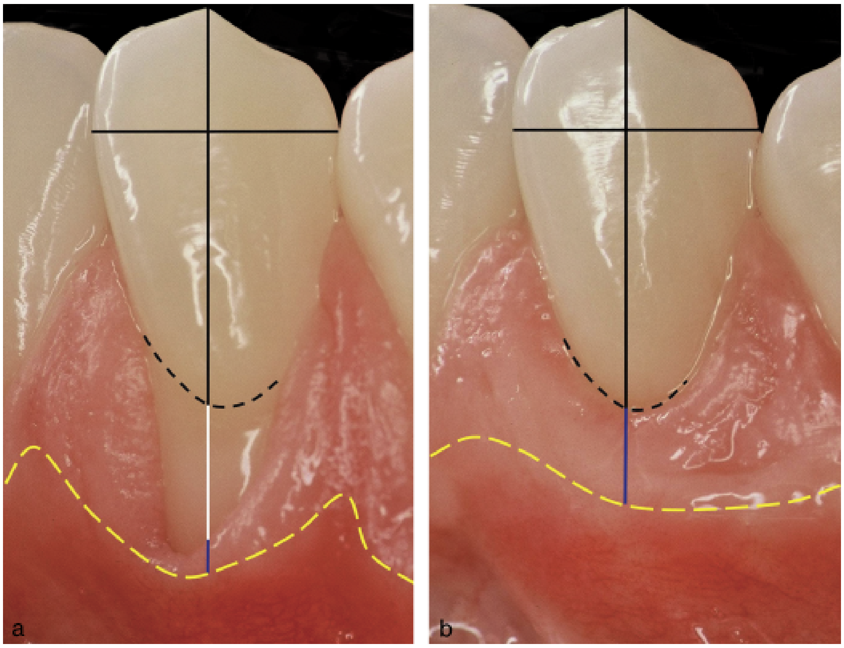

Fig. 2. Pre-operative (a) and post-operative (b) views of a clinical case with complete root coverage. Root coverage = 100%; gingival augmentation = 203%; image deformation = 2%.

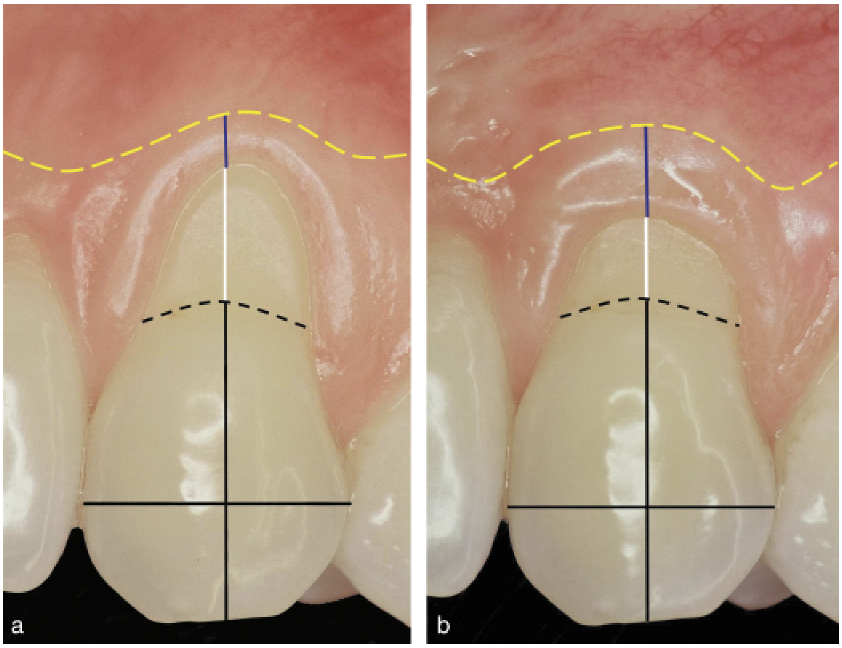

Fig. 3. Pre-operative (a) and post-operative (b) views of a clinical case with partial root coverage. Root coverage = 50%; gingival augmentation = 57%; image deformation = 1%.

(RD) according to the following standard formula:

$$[(\text{pre-operative RD} - \text{post-operative RD})/(\text{pre-operative RD})] \times 100.$$

The width of keratinized tissue (KT) was measured as the distance from the gingival margin to the muco-gingival junction. The percentage of the gingival augmentation (GA) was evaluated using the following formula:

$$[(\text{post-operative KT} - \text{pre-operative KT})/(\text{pre-operative KT})] \times 100.$$

Statistical analysis

Data collected were organized into a spreadsheet using a computer program (Excel, Microsoft, Redmond, WA). After proofing for entry errors, the database was locked and loaded in statistical software. All statistical tests were performed with R 2.4.1 software (R Foundation for Statistical Computing, Vienna, Austria) on PC architecture. The techniques were pooled for statistical analysis into the following three categories: (1) pedicle soft tissue graft; (2) non-submerged grafts; and (3) submerged grafts. Recessions were used as the unit of analysis. The primary variable was the change in the percentage of root coverage based on a single vertical linear midfacial measurement. Secondary variables included change in the percentage of complete root coverage and change in the mean percentage of gingival augmentation. Descriptive statistics are reported as means and standard deviations, or as numbers and percentages. Qualitative variables were compared using the chi square test. The significance of differences between groups was tested using unpaired parametric (normally distributed continuous variables) or non-parametric (non-normally distributed data or frequencies) tests. Intergroup comparison was performed by one-way analysis of variance ($\alpha = 0.05$). If a statistical difference was detected, a post hoc procedure was used for a non-pairwise multiple comparison (Scheffé's test) to identify differences among the groups. Multivariate linear regression was applied to determine which covariates were independently associated with the mean percentage of root coverage. Multiple logistic regression was used to determine independent predictors of complete root coverage. The levels that were identified for the hierarchical analysis were (1) the patient and (2) the surgeon. Given the structure of the data, where recession is considered to be the unit of analysis, with several recessions in the same patient and several patients treated by the same surgeon, we used a linear mixed-effect model. This model accounted for correlations between the several recessions in the same patient through random effects (Goldstein 1995).

Additionally, a second level of correlation was considered using random care provider effects.

The detailed structures of both fixed and random effects best fitting the data were selected using Schwartz's Bayesian Information Criterion (BIC) model selection criterion (Schwartz 1978). Once the final model was fitted, specific hypotheses regarding fixed effects were tested (Venables & Ripley 1997). Analyses were performed using R.2.0.1 software (The R Development Core Team). All variables achieving statistical significance at a 0.20 level in the univariate analysis were considered in the multiple analysis model. A backward variable selection procedure with a p-value cut-off at 0.05 was used to identify the set of independent predictors of primary and secondary variables. The validity of the logistic regression models was checked using the Hosmer and Lemeshow lack-of-fit test.

Results

The final sample, after controlling for inclusion and exclusion criteria, included 287 surgeries corresponding to 215 patients, and 495 coincident recession defects. The mean number of teeth treated per surgery was 1.7 ± 0.9 (median = 1). The mean follow-up was 17.25 ± 17.69 months. The characteristics of the study population are described in Table 1. Females were overrepresented in the sample. The mean age was 38.54 ($\pm$12.36) years, ranging from 18.01 to 92.19 years. Considering age and gender, the majority of the recession defects were treated in 21–40-year-old patients, females accounting for 76% of them (Table 2). The smoking status of nine subjects was unknown. Among 206 patients available for the analysis, non-smokers represented the majority of the sample. No significant adverse events were reported in each intervention categories.

Figure 4 indicates the number of recessions treated according to the 10 recorded initial surgical procedures. Figure 5 shows the number and the type of surgery according to tooth categories after grouping. Maxillary canines ($n = 128$) accounted for 26% of the sample and for 41% of the treated

Table 1. Demographic parameters, mean ± standard deviation, number (percentage)

Parameter	Unit	All ($n = 215$)
Gender	M/F	50/165
Age	Years	38.54 ± 12.36
Smokers*	Non-smokers	172 (83%)
	Current smoker	34 (17%)

*$n = 206$ corresponding to nine missing values.

Table 2. Distribution of recessions considering age and gender

	Males (%)	Females (%)	Total (%)
18–20 years	7 (1.4)	8 (1.6)	15 (3)
21–40 years	70 (14.1)	227 (45.9)	297 (60)
41–60 years	33 (6.7)	109 (22)	142 (28.7)
61–80 years	9 (1.8)	30 (6.1)	39 (7.9)
81–100 years	0 (0.0)	2 (0.4)	2 (0.4)
Total	119 (24)	376 (76)	495 (100)

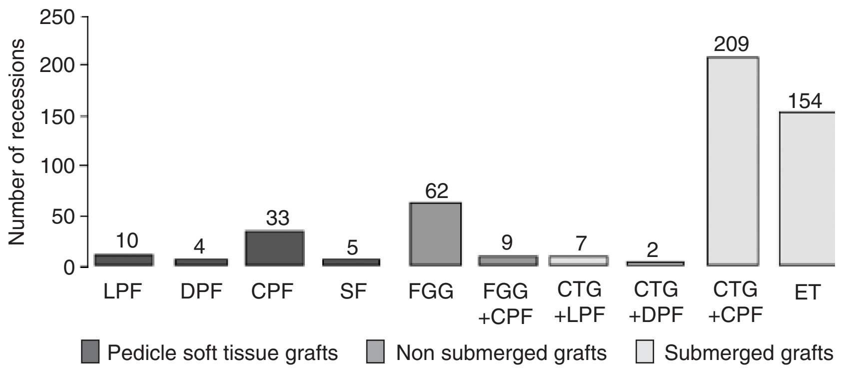

Fig. 4. Number of treated teeth according to the surgical technique. LPF: laterally positioned flap; DPF: double papilla flap; CPF: coronally positioned flap; SLF: semilunar flap, FGG: free gingival graft; CTG: connective tissue graft; ET: envelope technique.

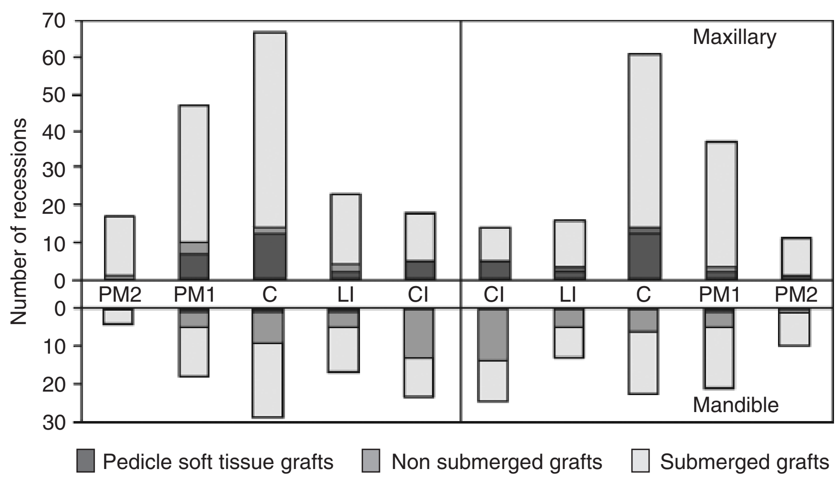

Fig. 5. Distribution of the category of surgery according to the tooth type.

defects at the upper jaw. Similarly, canines ($n = 52$) accounted for the majority of the treated defects at the mandible (28%). The sample characteristics according to categories of root coverage procedure indicate that most of the defects were treated with submerged grafts (Table 3).

Table 3 also shows the percentage distribution of the main indications for root coverage surgeries in the sample. Aesthetic reasons account for the majority of the sample, whereas root sensitivity and soft tissue augmentation account for only 27.35% and 10.81%, respectively. Submerged graft techniques were the most frequently chosen procedures for aesthetic indications. The distribution of the recession defects in the sample according to Miller's categories was limited to the first three classes, Class 1 and 2 accounting for 91% of the recession defects. Among the teeth that received a non-submerged or a submerged graft ($n = 443$), 29 were treated with a graft retrieved from the maxillary tuberosity (7%).

One hundred and thirty-seven recessions (28%) were treated with an additive treatment. Table 3 shows the distribution of these treatments. Forty-six, 74, and one received citric acid, TTC-HCL, and EDTA, respectively, in the root surface modification group. In the GTR group, one recession was treated with a reinforced titanium membrane; the remaining 15 received a resorbable polymer membrane. Membrane barriers were only used in the pedicle soft tissue graft group.

The antibiotic prescription was not recorded for five surgeries corresponding to the treatment of six recession defects. A post-operative antibiotic prescription was given for 33 surgical procedures (11%), corresponding to 53 treated recession defects. Two hundred and forty-nine surgeries (89%), corresponding to 436 recession defects, were performed without antibiotics.

The overall mean percentage of root coverage was 72.29 (± 28)%. Figure 6 shows the mean percentage of root coverage according to the categories of the root coverage procedures. The difference between groups was close to, but did not reach significance ($p = 0.06$).

The overall percentage of complete root coverage was 35.56% (176/495). Complete root coverage was achieved in 15/52 (29%), 23/71 (32%), and 138/372 (37%) recession defects for the pedicle soft tissue grafts, non-submerged grafts, and submerged grafts groups, respectively. The difference between groups was not significant.

The corresponding mean percentage of gingival augmentation was 106.18 (± 260.58)%. The difference between groups was significant ($p < 10^{-3}$) as

Table 3. Sample characteristics according to categories of root coverage procedure, number (percentage)

Parameter	Unit	Categories of root coverage procedure				
		pedicle soft tissue graft	non-submerged graft	submerged grafts	total	*p*
Treated defects	Number	52 (10.51)	71 (14.34)	372 (75.15)	495 (100)	
Indications*						< 0.0001
	Aesthetic	42 (8.57)	9 (1.84)	243 (49.59)	294 (60)	
	Root sensitivity	4 (0.82)	39 (7.96)	91 (18.57)	134 (27.35)	
	Soft tissue augmentation	6 (1.22)	22 (4.49)	25 (5.10)	53 (10.81)	
	Others**	0 (0)	1 (0.20)	8 (1.64)	9 (1.84)	
Miller's category						< 0.0001
	Class 1	41 (8.28)	27 (5.45)	255 (51.52)	323 (65.25)	
	Class 2	9 (1.82)	31 (6.26)	88 (17.78)	128 (25.86)	
	Class 3	2 (0.40)	13 (2.63)	29 (5.86)	44 (8.89)	
Donor site***						0.099
	Palate	NA	70 (15.80)	344 (77.65)	414 (93.45)	
	Tuberosity	NA	1 (0.23)	28 (6.32)	29 (6.55)	
Additive treatment	Root surface modification	6 (4.38)	12 (8.76)	103 (75.18)	121 (88.32)	0.01
	Membrane barrier	16 (11.68)	0 (0.00)	0 (0)	16 (11.68)	NA
Antibiotics****	No/yes	46/6 (9.41/1.23)	60/9 (12.27/1.84)	330/38 (67.48/7.77)	436/53 (89.16/10.84)	0.79

*$n = 490$; **Not included in the analysis; ***$n = 443$; ****$n = 489$; NA = not applicable.

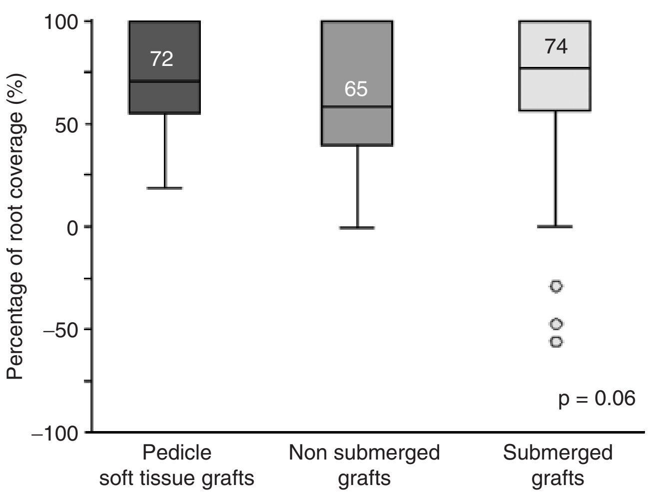

Fig. 6. Box plots showing the mean percentage of root coverage according to the category of surgery.

shown in Fig. 7. *Post hoc* analysis indicates a statistical difference between the pedicle soft tissue group and the non-submerged group ($p < 10^{-3}$), the submerged group and the non-submerged group ($p < 10^{-3}$), but the difference between the pedicle soft tissue group and the submerged group was not significant.

The multivariate analysis (Table 4) performed to identify variables associated with the mean percentage of root coverage demonstrates that current smoking reduces the chance to achieve root coverage by 5% compared with non-smoking habits ($p = 0.01$). Similarly, the chance of root coverage is decreased by 7% at the upper jaw compared with the mandible ($p = 0.01$).

We then applied a logistic regression model to identify the parameters associated with complete root coverage (Table 5). The model indicates that current smokers have a 63% risk of not achieving complete root coverage compared with non-smokers ($p < 0.05$), and that maxillary teeth have 49% less chance of achieving complete root coverage compared with the teeth at the mandible ($p = 0.03$). This model also indicates that the tuberosity donor site increases the chance of complete root coverage by 278% compared with palatal grafts ($p = 0.02$).

Regarding gingival augmentation, the linear regression model (Table 6) shows that the teeth at the maxilla have 122% more chance than the teeth at the mandible ($p < 10^{-3}$). This model also indicates that Miller's class 3 have 126% more chance of gingival augmentation than Miller's class 1 ($p = 0.004$) and that Miller's class 2 have 56% more chance ($p = 0.04$).

Discussion

Patient characteristics

In our study, the sample included adults only in order to eliminate the risk of distorting results by including child recession defects, which may be spontaneously healed over time (Andlin-Sobocki et al. 1991). Thus, no conclusion can be drawn from the present survey on recession defects in children. However, the effect of age on root coverage has been advocated, although the literature does not demonstrate evidence. If the percentage of complete root coverage is taken into consideration, a trend towards a better response has been observed in younger age groups (Vergara & Caffesse 2004). Table 2 shows that young adults between 21 and 40 years of age account for 60% of the sample. The table also indicates that young females, less than the age of 40, were the most frequent candidates for root coverage techniques (45.9%). The female gender *per se* contributed to 76% of the recessions

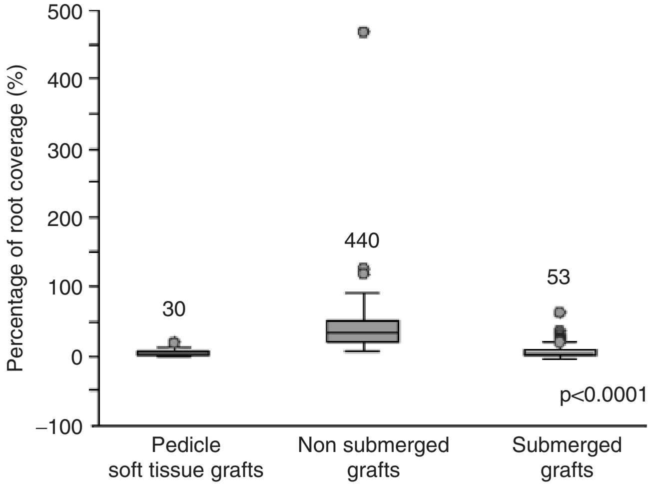

Fig. 7. Box plots showing the mean percentage of gingival augmentation according to the category of surgery.

Table 4. Multivariate analysis (linear regression model) explaining the predictive factors for the mean percentage of root coverage

Independent variables	Parameter estimate	Standard error	*t* value	*p* value
Intercept	0.7671	0.0272	28.160	$<10^{-3}$
Smoking habits	– 0.0473	0.0190	– 2.481	0.0137
Maxillary teeth	– 0.0724	0.0296	– 2.444	0.0151

Table 5. Multivariate analysis (logistic regression model) explaining the predictive factors for complete root coverage

Independent variables	Parameter estimate	Standard error	*t* value	*p* value	OR	$CI_{95\%}$
Intercept	– 1.8666	0.6642	– 2.811	0.0049	0.15	0.04–0.57
Smoking habits	– 0.4567	0.2293	– 1.992	0.0463	0.63	0.40–0.99
Donor site	1.3311	0.6027	2.208	0.0272	3.78	1.16–12.33
Maxillary teeth	– 0.7163	0.3301	– 2.170	0.0300	0.49	0.26–0.93

Table 6. Multivariate analysis (linear regression model) explaining the predictive factors for the mean percentage of gingival augmentation

Independent variables	Parameter estimate	Standard error	*t* value	*p* value
Intercept	0.3924	0.1954	2.007	0.0456
Maxillary teeth	1.2205	0.2628	4.644	$<10^{-3}$
Miller class 2	0.5599	0.2791	2.005	0.0462
Miller class 3	1.2596	0.4367	2.884	0.0043

defects. This may be interpreted in light of the aesthetic indication for this procedure, which accounts for 60% in our study.

Epidemiological studies suggest that smokers are patients with greater root coverage treatment needs compared with non-smokers (Martinez-Canut et al. 1995, Susin et al. 2004). Recent studies indicate that smoking should be viewed as a factor negatively influencing the degree of root coverage (Martins et al. 2004, Erley et al. 2006, Silva et al. 2006). Interestingly, 17% of smoking patients were subjected to root coverage procedures in the present study. This means that the practitioners involved in this study did not consider smoking as a contraindication for root coverage procedure but as a severe limitation. It must also be kept in mind that until recently, the influence of smoking in root coverage procedures was still considered to be a controversial issue, except for GTR procedures, where smoking was accepted as a negative factor (Wennström & Pini Prato 2003). The reasons for the discrepancy between the outcomes of the various studies have recently been presented in an excellent discussion by Silva et al. (2006).

The outcomes of the present study confirm that the main indication for root coverage is the aesthetic demand. This is in accordance with a recent survey showing that aesthetic concern was the major indication for root coverage procedures (Zaher et al. 2005). Indications other than aesthetic, root sensitivity, and soft tissue augmentation were so low that they were grouped in the ''Other'' category, accounting for 1.84% of the indications. The fact that pre-prosthetic indications were recorded in the aesthetic category by the operators cannot be disregarded. It is also of interest that pre-orthodontic indications were found to be low. This may be explained by the minimum age inclusion (18 years), excluding children and teenagers.

Defect and tooth characteristics

Figure 5 shows a rather symmetrical distribution of the recession defects. From an epidemiological standpoint, this treatment need corresponds to the distribution of mean attachment loss that can be observed in adults (Bourgeois et al. 2007). The distribution of the recession defects according to the type of tooth is not in accordance with the landmark epidemiological study of Albandar & Kingman (1999) showing that the maxillary first molars and the mandibular central incisors were the most prevalent teeth to be affected by gingival recessions. Even if, in our study, the molars were not included in the sample to avoid a bias related to aesthetic indications, this means that decision making in root coverage widely depends on the patient demand, and not on the presence of the defect *per se*. Our results demonstrate that maxillary canines are the most frequently treated teeth with root coverage procedures. When submerged grafts are not taken into account, pedicle soft tissue graft techniques are more prevalent at the upper jaw, whereas non-submerged grafts are more prevalent in the lower jaw. This confirms that practitioners are sensitive to aesthetical procedures at the maxillary.

The present investigation demonstrated a higher prevalence of Miller's Class 1–2 treated defects (91%)

compared with Class 3 (9%). No Class 4 was available for the analysis. This means that the operators' indications are in accordance with the literature, showing poor clinical outcomes in Classes 3 and 4, where complete root coverage cannot be achieved.

Only four teeth were non-vital in the database. Consequently, no conclusion could be expected from the analysis with this parameter. Nevertheless, it is interesting to note that non-vital teeth are rarely subjected to root coverage procedures. Non-vital teeth are often treated with restorative/prosthetic dentistry. This may prevent the surgical attempt to cover the root surface.

Treatment modalities

The results of clinical trials have often been challenged in contrast to those expected in a routine practice. Subject selection biases, such as volunteer bias and Hawthorne effects, may affect the daily clinical applicability of the conclusions. The major strength of our study is that the patients included in the analysis were routinely treated in a private periodontal practice. Incorporation of routine patients may have facilitated gathering of data that represent actual use situations, giving a realistic snapshot of the expected results.

However, the present study has some limitations inherent to the retrospective design, which is prone to bias but may be very useful to generate hypotheses. First, the sample is not representative of the entire population attending periodontal private practices. It includes consecutive patients treated by seven exclusive periodontists operating in a private practice. Thus, the external validity of this study and its applicability to other settings must be considered with caution. Also, large sample sizes need to pool the outcomes of interest into categories. Consequently, part of the information is lost. For example, in our study, no conclusion can be drawn regarding the indications/results of the various procedures that were included in the pedicle soft tissue grafts category. Another limitation is inherent to the methodological approach using an image analysis system, which cannot take into account the absolute value of the recession depth. This point has been discussed previously in a companion paper (Kerner et al. 2007).

Our study fails to demonstrate a significant difference between the three main surgical approaches. The comparison approached but did not reach significance ($p = 0.06$). There is only a trend towards better results with submerged grafts. Similarly, the difference between groups was not significant for complete root coverage.

Regarding the overall mean percentage of root coverage, it may be assumed that the results are optimistic because it is possible that worse results were not documented with photographs. However, the operators were encouraged to provide all available documents recorded in their files, whatever the results. Blinding was a key point to ensure the anonymonity of the operators. Interestingly, the box plots in Fig. 6 show the presence of outliers, indicating that failures were also included in the sample.

The mean percentage of gingival augmentation has not yet been submitted to systematic reviews dealing with root coverage procedures. The main reason may be that gingival augmentation procedures and root coverage techniques are classified as distinct therapies due to the distinctive goals of the surgeries. In the present report, the mean percentage of gingival augmentation between groups was highly significant ($p < 10^{-3}$) in favour of non-submerged grafts. In this group, the gingival augmentation was evaluated at 440% (Fig. 7). It is not surprising that the non-submerged grafts perform better than the other procedures because they are commonly used for a gingival augmentation purpose. Interestingly, the outcomes of our study confirm that keratinized tissue increases following pedicle soft tissue and submerged grafts (Trombelli 1999, Zucchelli & De Sanctis 2000). This may be the reason why these approaches were used by the operators in soft tissue augmentation indications (Table 3).

In the present study, 53 defects (10.84%) were treated with adjunctive systemic antibiotics therapy. To be included in this study, the patients have to be healthy. This means that antibiotics were prescribed for the procedure itself, and not to prevent a systemic risk. There is no consensus in the literature on the use of systemic antimicrobial therapy in root coverage procedures. Normally, the antimicrobial preventive treatment consists of improvement of mechanical and chemical plaque control by means of oral hygiene instructions and adjunctive antiseptic therapy with a mouthrinse, respectively. However, when additive treatments including the use of biomaterials are used in conjunction with the root coverage procedure, an antibiotic prescription seems to be mandatory. In the present sample, 16 defects were treated with membrane barriers. All of them were in the pedicle soft tissue graft group including only three defects treated with antibiotics. This means that 13 defects treated with membrane barriers did not receive antibiotics, and that 50 defects received an antibiotic prescription without any specific indication. We do not have an explanation for this, but international guidelines for the use of antibiotics in root coverage procedures should be published to prevent resistances.

The maxillary tuberosity may be used to retrieve a connective tissue graft in root coverage procedures (Azzi et al. 1998). In the present study, this area has been used as the donor site in a limited number of defects (7%). This low percentage may correspond to the limits inherent to the technique requiring (1) the lack of wisdom tooth, (2) a sufficient thickness of the soft tissue behind the second molar, and (3) a recession defect at the recipient site limited to one single tooth.

It is interesting to observe that the wide majority of the root coverage procedures (72%) were conducted without any additive treatment. This must be interpreted in view of systematic reviews that fail to see an advantage to the tissue engineering approach for the treatment of gingival recessions (Roccuzzo et al. 2002, Oates et al. 2003). However, recent studies show additional benefits to the use of enamel derivative matrix agents (Castellanos et al. 2006, Pilloni et al. 2006, Cheng et al. 2007). No treatments with this agent were recorded in the database. It can be assumed that new products need major evidence in order to be included in the daily therapeutic armamentarium. Interestingly, the root surface modification was the most frequently used additional therapy. This is inconsistent with the outcomes of the clinical trials from which data do not support the use of root modification agents to improve root coverage (Sanz & Addy 2002). The decision to use an additive treatment seems to be based more on the operator's opinions and personal experience, rather than on an evidence-based approach. On the other hand, the retrospective design of the present study cannot take into account the influence of surgical advances and information on the choice of the operator's procedure.

Prognostic factors

Few data are available in the literature dealing with root coverage about prognostic factors. Retrospective studies, including a large sample size, have an appropriate design to identify independent parameters through multivariate analysis.

The present analysis revealed that smoking habits and maxillary teeth parameters deteriorated the prognosis of both mean (Table 4) and complete root coverage (Table 5). It is not surprising that smoking impacts the results negatively. This observation is in accordance with the previously discussed literature results. Including smokers for a root coverage procedure may depend on the tobacco consumption. In our study, patients smoking >5 cigarettes per day were classified as smokers. Thus, the present investigation was not designed to explore a putative dose-dependent effect, and our analysis must be viewed in light of this concern. However, there is no evidence that smoking has a dose-dependent effect on the outcomes of the root coverage procedures (Harris 1994).

An interesting finding concerns the higher risk found with complete root coverage in the logistic regression model (63%, $p<0.05$) as compared with the risk associated with mean root coverage in the linear regression model (5%, $p=0.01$). In a daily practice, including smokers for a root coverage procedure also depends on the result to be expected by the practitioner according to the indication. It is not certain that if complete root coverage is the ultimate goal for the surgeon that this goal corresponds to patient demands in terms of aesthetics. The results of our multivariate analysis indicate that if complete root coverage is mandatory to satisfy patient demand, smokers should be excluded.

The thickness of the covering tissues is positively associated with mean and complete root coverage (Hwang & Wang 2006). It has been shown that the tuberosity allows for the harvesting of deep grafts. This region is significantly thicker than the hard palate (Studer et al. 1997). In the present analysis, we found that the tuberosity donor site positively influences the complete root coverage. This finding must be interpreted cautiously. In the tuberosity area, the graft size is limited by the width of keratinized tissue. It cannot be excluded that tuberosity grafts corresponding to single-tooth recession defects may explain why the tuberosity parameter appears to be a positive prognosis factor. Nevertheless, the literature does not show evidence for a more favourable prognosis for root coverage in single-tooth recession defects compared with multiple defects. Further investigations are needed to explore the ability of tuberosity donor sites to perform better than palate sites.

The multivariate analysis (Table 6) shows that maxillary teeth have more chance of gingival augmentation than the teeth at the mandible. We do not have an explanation for this finding. The analysis also demonstrates that Miller's Class III and Class II are positive parameters for gingival augmentation compared with Class I. This interesting point may strengthen the clinical availability of the Miller's classification regarding gingival augmentation. It may be assumed that the deeper the attachment loss related to gingival recession, the higher the need for gingival augmentation, leading to an adequate surgical procedure that nonetheless aims to cover the defect but also aims to increase the keratinized tissue dimension.

Conclusion

This multi-centre retrospective study demonstrated that it is possible to provide beneficial outcomes to patients having recession defects in private practice settings with the use of root coverage surgical procedures. Within the limits of this study, the following descriptive conclusions can be drawn: (1) in terms of root coverage, no surgical technique category is superior to another, (2) in terms of gingival augmentation, the non-submerged grafts perform better than the others, (3) submerged grafts are the preference of the operators, and (4) the maxillary canines and premolars are the most treated teeth. From the results, the profile of the candidate for root coverage procedure fits a female non-smoker, less than 40-years of age, having an aesthetic demand, and exhibiting Class I or II recession defects. From a predictive point of view, (1) the tuberosity donor site seems to be more efficient than the palate to achieve complete root coverage, (2) the maxillary teeth have less chance of root coverage but more chance of gingival augmentation compared with the teeth at the mandible, and (3) the chances of complete root coverage are negatively influenced by cigarette smoking and maxillary teeth.

Further studies are needed to explore the prognostic factors that may impact the results of root coverage procedures. The present methodology using image analysis associated with questionnaires may allow for international databases that may be useful to analyse large non-experimental samples, retrospectively leading to a better determination of the patient profile.

References

Abramoff, M. D., Magelhaes, P. J. & Ram, S. J. (2004) Image Processing with Image J. *Biophotonics International* **11**, 36–42.

Albandar, J. M. & Kingman, A. (1999) Gingival recession, gingival bleeding, and dental calculus in adults 30 years of age and older in the United States, 1988–1994. *Journal of Periodontology* **70**, 30–43.

Andlin-Sobocki, A., Marcusson, A. & Persson, M. (1991) 3-year observations on gingival recession in mandibular incisors in children. *Journal of Clinical Periodontology* **18**, 155–159.

Azzi, R., Etienne, D. & Carranza, F. (1998) Surgical reconstruction of the interdental papilla. *The International Journal of Periodontics and Restorative Dentistry* **18**, 466–473.

Borghetti, A., Glise, J. M., Monnet-Corti, V. & Dejou, J. (1999) Comparative clinical study of a bioabsorbable membrane and subepithelial connective tissue graft in the treatment of human gingival recession. *Journal of Periodontology* **70**, 123–130.

Bouchard, P., Malet, J. & Borghetti, A. (2001) Decision-making in aesthetics: root coverage revisited. *Periodontology 2000* **7**, 97–120.

Bouchard, P., Nilveus, R. & Etienne, D. (1997) Clinical evaluation of tetracycline HCl conditioning in the treatment of gingival recessions. A comparative study. *Journal of Periodontology* **68**, 262–269.

Bourgeois, D., Bouchard, P. & Mattout, C. (2007) Epidemiology of periodontal status in dentate adults in France, 2002–2003. *Journal of Periodontal Research* **42**, 219–227.

Castellanos, A. T., de la Rosa, M. R., de la Garza, M. & Caffesse, R. G. (2006) Enamel matrix derivative and coronal flaps to cover marginal tissue recessions. *Journal of Periodontology* **77**, 7–14.

Cheng, Y. F., Chen, J. W., Lin, S. J. & Lu, H. K. (2007) Is coronally positioned flap procedure adjunct with enamel matrix derivative or root conditioning a relevant predictor for achieving root coverage? A systemic review. *Journal of Periodontal Research* **42**, 474–485.

Erley, K. J., Swiec, G. D., Herold, R., Bisch, F. C. & Peacock, M. E. (2006) Gingival recession treatment with connective tissue grafts in smokers and non-smokers. *Journal of Periodontology* **77**, 1148–1155.

Goldstein, H. (1995) *Multilevel Statistical Models*. New York: Halstead Press.

Harris, R. J. (1994) The connective tissue with partial thickness double pedicle graft: the results of 100 consecutively-treated defects. *Journal of Periodontology* **65**, 448–461.

Hwang, D. & Wang, H. L. (2006) Flap thickness as a predictor of root coverage: a systematic review. *Journal of Periodontology* **77**, 1625–1634.

Jahnke, P. V., Sandifer, J. B., Gher, M. E., Gray, J. L. & Richardson, A. C. (1993) Thick free gingival and connective tissue autographs for root coverage. *Journal of Periodontology* **64**, 315–322.

Jepsen, K., Heinz, B., Halben, J. H. & Jepsen, S. (1998) Treatment of gingival recession with titanium reinforced barrier membranes versus connective tissue grafts. *Journal of Periodontology* **69**, 383–391.

Kerner, S., Etienne, D., Malet, J., Mora, F., Monnet-Corti, V. & Bouchard, P. (2007) Root coverage assessment: validity and reproducibility of an image analysis system. *Journal of Clinical Periodontology* **34**, 969–976.

Lins, L. H., de Lima, A. F. & Sallum, A. W. (2003) Root coverage: comparison of coronally positioned flap with and without titanium-reinforced barrier membrane. *Journal of Periodontology* **74**, 168–174.

Martinez-Canut, P., Lorca, A. & Magán, R. (1995) Smoking and periodontal disease severity. *Journal of Clinical Periodontology* **22**, 743–749.

Martins, A. G., Andia, D. C., Sallum, A. W., Sallum, E. A., Casati, M. Z. & Nociti, F. H. Jr. (2004) Smoking may affect root coverage outcome: a prospective clinical study in humans. *Journal of Periodontology* **75**, 586–591.

Miller, P. D. (1985) A classification of marginal tissue recession. *The International Journal of Periodontics and Restorative Dentistry* **5**, 8–13.

Moses, O., Artzi, Z., Sculean, A., Tal, H., Kozlovsky, A., Romanos, G. E. & Nemcovsky, C. E. (2006) Comparative study of two root coverage procedures: a 24-month follow-up multicenter study. *Journal of Periodontology* **77**, 195–202.

Oates, T. W., Robinson, M. & Gunsolley, J. C. (2003) Surgical therapies for the treatment of gingival recession. A systematic review. *Annals of Periodontology* **8**, 303–320.

Paolantonio, M., di Murro, C., Cattabriga, A. & Cattabriga, M. (1997) Subpedicle connective tissue graft versus free gingival graft in the coverage of exposed root surfaces. A 5-year clinical study. *Journal of Clinical Periodontology* **24**, 51–56.

Pilloni, A., Paolantonio, M. & Camargo, P M. (2006) Root coverage with a coronally positioned flap used in combination with enamel matrix derivative: 18-month clinical evaluation. *Journal of Periodontology* **77**, 2031–2039.

Pini Prato, G. P., Tinti, C., Vincenzi, G., Magnani, C., Cortellini, P. & Clauser, C. (1992) Guided tissue regeneration versus mucogingival surgery in the treatment of human buccal gingival recession. *Journal of Periodontology* **63**, 919–928.

Rasband, W. S. & Image, J 1997-2007. U.S. National Institutes of Health, Bethesda, MD, USA, http://rsb.info.nih.gov/ij/ [accessed 27 August, 2007].

Roccuzzo, M., Bunino, M., Needleman, I. & Sanz, M. (2002) Periodontal plastic surgery for treatment of localized gingival recessions: a systematic review. *Journal of Clinical Periodontology* **29** (Suppl. 3), 178–194.

Sanz, M. & Addy, M. (2002) Group D summary. *Journal of Clinical Periodontology* **29** (Suppl. 3), 195–196.

Schwartz, G. (1978) Estimating the dimension of a model. *The Annals of Statistics* **6**, 461–464.

Silva, C. O., Sallum, A. W., de Lima, A. F. & Tatakis, D. N. (2006) Coronally positioned flap for root coverage: poorer outcomes in smokers. *Journal of Periodontology* **77**, 81–87.

Studer, S. P., Allen, E. P., Rees, T. C. & Kouba, A. (1997) the thickness of masticatory mucosain the human hard palate and tuberosity as potential donor sites for ridge augmentation procedures. *Journal of Periodontology* **68**, 145–151.

Susin, C., Haas, A. N., Oppermann, R. V., Haugejorden, O. & Albandar, J. M. (2004) Gingival recession: epidemiology and risk indicators in a representative urban Brazilian population. *Journal of Periodontology* **75**, 1377–1386.

Tatakis, D. N. & Trombelli, L. (2000) Gingival recession treatment: guided tissue regeneration with bioabsorbable membrane versus connective tissue graft. *Journal of Periodontology* **71**, 299–307.

Trombelli, L. (1999) Periodontal regeneration in gingival recession defects. *Periodontology 2000* **19**, 138–150.

Trombelli, L., Scabbia, A., Tatakis, D. N. & Calura, G. (1998) Subpedicle connective tissue graft versus guided tissue regeneration with bioabsorbable membrane in the treatment of human gingival recession defects. *Journal of Periodontology* **69**, 1271–1277.

Venables, W. N. & Ripley, B. D. (1997) *Modern Applied Statistics with S-PLUS*, 2nd edition. New-York: Springer-Verlag.

Vergara, J. A. & Caffesse, R. G. (2004) Localized gingival recessions treated with the original envelope technique: a report of 50 consecutive patients. *Journal of Periodontology* **75**, 1397–1403.

Wennström, J. L. & Pini Prato, G. P. (2003) Mucogingival therapy-periodontal plastic surgery. In: Lindhe, J., Lang, N. P. & Karring, T. (eds). *Periodontology and Implant Dentistry*, 4th edition, pp. 576–649. Oxford: Blackwell Munksgaard.

Zaher, C. A., Hachem, J., Puhan, M. A. & Mombelli, A. (2005) Interest in periodontology and preferences for treatment of localized gingival recessions. *Journal of Clinical Periodontology* **32**, 375–382.

Zucchelli, G. & De Sanctis, M. (2000) Treatment of multiple recession-type defects in patients with esthetic demands. *Journal of Periodontology* **71**, 1506–1514.

Address:
Philippe Bouchard
U.F.R. d'Odontologie
5, rue Garancière
75006 Paris
France
E-mail: phbouch@noos.fr

Clinical Relevance

Scientific rationale for the study: The prognosis of root coverage procedures depends on numerous patient-related factors. Practice-based studies taking into account patients, and surgeons, variability may improve the surgical decision-making process.

Principal findings: The overall mean percentage of root coverage was 72.29 ($\pm$ 28)%. Complete root coverage was achieved in 35.56% of the recession defects. Smoking, maxillary teeth, donor site, and Miller's Classes are parameters influencing the chances of success.

Practical implications: Smoking status, defect location, donor site, and Miller's classification should be viewed as major factors in the individual decision-making process.