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Review Article

Direct composite restorations for the worn mandibular anterior dentition: a 7-year follow-up of a prospective randomised controlled split-mouth clinical trial

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SUMMARY **The purpose of this study was to report on the 7-year follow-up of 15 patients who took part in a prospective randomised controlled split-mouth trial to evaluate the performance and patient satisfaction of 107 direct composite restorations bonded to their worn anterior mandibular dentition. This is the continuation of a study by Poyser *et al.*, which investigated the performance of the same direct composite restorations on this cohort of patients at 2·5 years. The results of the present study suggest that direct composite restorations bonded to the worn anterior mandibular dentition to have an approximate survival of 85% at the 7-year follow-up. Approximately 53% of patients experienced survival of all of their restorations. Pre-operative circumferential preparation did not influence restoration survival, patient satisfaction or other clinical variables (restoration staining, marginal discolouration, shade match, surface roughness and marginal adaptation). The time taken to initially build-up the restorations was shown to be statistically significant with a longer procedural time meaning less chance of the restoration being present at 7 years. This treatment modality exhibited no biological complications for the teeth, supporting periodontium or TMJ apparatus. The placement of these restorations provided an improvement in the aesthetics of the teeth, a reduction in the concern over the longevity of the worn lower anterior teeth, and improvements with regard to sensitivity experienced with hot or cold foods or drinks. Marginal breakdown was the most frequently recorded clinical complication. Thus, for the majority of patients, the restorations offered a high degree of patient satisfaction and required an acceptable level of maintenance in the 7-year follow-up period.**

KEYWORDS: **composite resin, vertical dimension, tooth attrition, tooth erosion, patient satisfaction, prospective study**

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Introduction

The management of worn mandibular incisor and canine teeth presents a difficult restorative challenge for dentists. The majority of localised tooth surface loss occurs slowly and allows for dento-alveolar compensation. This compensation maintains contact between the upper and lower dentition and thus leaves little or no interocclusal space for restorations. In addition, lower incisors are often the smallest teeth in the adult dentition. For these reasons, a conventional prosthodontic approach to the

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restoration of the anterior dentition has fallen out of favour.

Modern management of worn lower anterior teeth involves the placement of direct composite restorations at an increased vertical dimension. This represents a time efficient and biologically sound method of managing localised tooth surface loss.

To date, however, there has been little clinical evidence that reports on the outcome of direct composite restorations placed on worn lower anterior teeth. Similarly, there is little published evidence on patients' views of this form of treatment and its outcome.

Poyser *et al.* (1) evaluated the clinical outcome and satisfaction of a group of patients at 2·5 years following placement of direct composite restorations to restore their worn anterior mandibular dentition affected by multifactorial aetiology. They assessed the performance of 168 Herculite XRV* direct composite restorations bonded to the upper and lower anterior teeth of 18 patients with localised erosive and attritional tooth surface loss. These restorations lead to an increase in the vertical dimension of between 0·5 and 5 mm.

Of the 168 restorations, 107 were placed on the worn mandibular anterior teeth. The rapid increase in anterior vertical dimension resulted in many of the posterior teeth not being in contact immediately following placement of the restorations. Clinical adaptation to the re-establishment of occlusal contacts following the altered occlusion was variable but in the slowest cases took up to 6 months for the posterior teeth to re-establish contact with the opposing dentition. The split-mouth design of this study allowed direct comparison between the survival of restorations placed with a circumferential tooth preparation and those placed with no preparation. It further described the relationship between the survival of these restorations and the height of the restorations.

Poyser *et al.* (1) found that 6% of the 107 direct restorations did not survive to the 2·5-year assessment. It was found that neither of the aforementioned variables influenced the survival nor the performance of the restorations.

In addition, this study also used a visual analogue scale (VAS) to assess the patients' opinions on sensitivity, aesthetics, longevity, chewing function and overall satisfaction.

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The patients reported a high level of satisfaction in all categories at 2·5 years. Most notably, there was a significant decrease in the patients' concerns regarding the aesthetics and the longevity of their teeth.

The aim of the present study is to report on a further clinical assessment of the direct composites placed in the same cohort of patients carried out at 7 years. This study also analyses the relationship between the survival and clinical performance of the restorations in relation to three variables (circumferential preparation, height of the restoration and time taken to place the restoration).

Finally, we report on the patients' views on their treatment and its outcome using a similar VAS to Poyser *et al.* (1).

Methodology

The original study

Poyser *et al.* (1) original prospective study obtained ethical approval from the St George's Hospital ethical standards committee. The study included 18 patients who had direct composite restorations placed on their worn anterior maxillary and mandibular teeth at an increased vertical dimension. The study reported on the performance, survival and satisfaction of the composite restorations placed on the mandibular anterior teeth only. The split-mouth design of the trial allowed direct comparison between restorations placed after a circumferential preparation with those placed without preparation.

The inclusion criteria for this original study were that the patient needed to have significant tooth surface loss affecting at least four teeth in the anterior mandible that required treatment. Specifically, there had to be involvement of dentine and a reduction in the clinical height of the tooth. Furthermore, the worn teeth had to be un-restored and had to be periodontally stable.

For further information including details of the clinical procedure, the reader should refer to this original study.

The 7-year follow-up

The written records of all of the patients from the original study were identified through the hospital administration system, and an attempt was made to

contact them by two of the authors (ASAK and SE). Only 15 of the original 18 patients were contactable, as two of the patients had died and one patient had no recorded contact details. All of the patients were offered a follow-up appointment by the team of examiners (ARC, NJP, PFAB, RWJP, MGDK and SE) for reassessment of their mandibular restorations. The general dental practitioner of each patient was informed of the reassessment appointment.

It was not possible to include all of the original examiners from the 2·5-year study. Four of the original examiners (NJP, PFAB, RWJP and MGDK) and two new examiners (ARC and SE) were invited to take part in this assessment. All of the visual and tactile observations on the patients were carried out by five examiners. One examiner, who provided the original treatment (NJP), only carried out assessment of specific parameters using the data collection sheets from the original study. This included a measurement of periodontal status, that is, pocket depth, bleeding on probing, mobility and gingival recession. Pulpal vitality was also assessed using both ethyl chloride[†] and an electric pulp tester (Kerr Vitality Scanner[‡]).

On the assessment day. Prior to clinical examination, the patients were asked to complete the horizontal 100 mm VAS and patient satisfaction questionnaire used in the original study. Patients did not have access to their previously completed VAS and questionnaires. The VAS questionnaire asked the patients to mark their responses to four questions, which were later measured to the nearest millimetre.

Digital colour photographs of the upper and lower anterior teeth were taken in those patients who provided consent using a Canon EOS 300D Digital SLR Camera (Patient ID 1, 7, 9, 10 and 15–18).

During the patient examination, the examiners had access to some of the pre-operative and post-operative study casts that had been stored since the original study. This allowed the examiners to determine the amount of lost restorative material in comparison with the initial anatomic form. Unfortunately, the pre-operative and post-operative casts were not available for all of the patients (Patient ID 8, 9 and 15).

Each patient remained in their allocated dental chair, and each examiner independently assessed the patient in turn. The visual assessment was carried out using the dental light without any magnification. Tactile assessment was carried out using a World Health Organisation 'WHO' ball-ended basic periodontal examination probe (Hu-Friedy;[§] CP-11·5B) on the dried teeth for 'Restoration Roughness' and 'Marginal Adaptation'. The re-establishment of posterior occlusal contacts was assessed with Shimstock metal foil (Hanel-GHM-Dental GMBH[¶]) by only one examiner (RWJP).

The patients were questioned by one examiner (NJP) with regard to pulpal, periodontal and masticatory health as outlined in the original study.

Data collection. Examiners (ARC, PFAB, RWJP, MGDK and SE) assessed the subjects independently using a modified version of the United States Public Health Service (USPHS) data collection form (Fig. 1) used by Poyser *et al.* (1).

In the original data collection form, there were several observational increments in the categories of 'Anatomic Form', 'Restoration Staining' and 'Marginal Adaptation'. The observational increments in these categories were dichotomised, as illustrated in Table 1.

For example, in the 'Anatomic Form' category of the original study, there were three observational increments: 'Intact or <10% loss', 'Bulk fracture with 50–90% still present' and 'Bulk fracture with <50% still present'. In the present study, this was merged in to two observational increments; 'more than 50% composite still remaining' and '<50% composite still remaining but without total loss'.

Results

Patient demographics and clinical status

Fifteen (83%) of the 18 patients who were included in the original study were reassessed at 7 years. Three (17%) patients were lost to follow up resulting in the loss of 18 restorations from the study. Of the 15 patients reviewed, 13 were reviewed at both 2·5 years and at 7 years post-treatment, and two patients were only reviewed at 7 years (Fig. 2).

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[‡]Kerr UK Ltd, Peterborough, UK.

[§]Hu-Friedy Mfg. B.V., Rotterdam, the Netherlands.

[¶]Hanel-GHM-DentalGmbH, Baden-Württemberg, Germany.

Clinical observations recorded by examiners
ARC, PFAB, RWJP, MGDK & SE

	43	42	41	31	32	33

(Please ☑ where appropriate)

Visual Assessments of Dried Teeth (without magnification)

Total Absence of Restoration

Missing restoration						

Anatomic Form – % of remaining restoration

≥50% composite remaining						
<50% composite remaining						

Restoration Staining – Labial & Incisal surfaces only

None/Mild						
Moderate/Severe						

Marginal Discoloration – Labial margin only

No Staining						
Staining						

Shade Match – Labial & Incisal surfaces only

Acceptable						
Unacceptable						

Tactile Assessment of Dried Teeth with a WHO Probe

Surface Roughness – Labial & Incisal surfaces only

Smooth						
Rough						

Marginal Adaptation – Labial margin only

Catch Clinically Acceptable						
Catch Not Clinically Acceptable						

Occlusal Assessment in ICP (RWJP only)

Re-establishment of posterior occlusal contacts in ICP

	18	17	16	15	14	24	25	26	27	28
Shimstock Holding Contact										

Fig. 1. Clinical observations of each patient recorded by examiners ARC, PFAB, RWJP, MGDK and SE.

In the cohort of 15 patients that were assessed at 7 years, the ages ranged between 38 and 78 years (mean age 58 years). A total of 145 direct composite restorations were placed on the worn anterior dentition of which 89 restorations were placed on the lower anterior teeth. Each patient had all of their mandibular anterior teeth restored except patient 8 who only required restoration of five of his mandibular anterior teeth. Four of the 89 mandibular restorations were excluded from the analysis of the results of this study as the teeth had restorations *in situ* prior to entering the study (Patient ID 1, 10 and 13). Thus, 85 direct composite restorations placed on the worn anterior dentition were included for further analysis (Table 2).

Restoration survival

For the purpose of this study, 'Survival' of a restoration was defined as any restoration that had not been lost, replaced or repaired in the preceding 7 years.

Table 1. Modifications made to the original data collection form for dichotomising categories of clinical observation

Category	Baseline marking categories	Amended marking sheet at 7-year review
Anatomic form	Intact or <10% loss Bulk fracture 50–90% present	≥ 50% composite remaining
	Bulk fracture <50% present	<50% composite remaining
Restoration staining	None Mild	None/Mild
	Moderate Severe	Moderate/Severe
Marginal adaptation	No catch Catch Clinically Acceptable	Catch Clinically Acceptable
	Catch Not Clinically Acceptable	Catch Not Clinically Acceptable

Seventy-two of the 85 restorations (85%) had survived at the 7-year follow-up thus eight of 15 patients (53%) experienced survival of all of their restorations.

One patient who attended for reassessment (Patient ID 15) experienced complete loss of five of the six mandibular restorations that were initially placed. If this patient is excluded from the analysis then the overall survival would be 90% of restorations at 7 years (71 restorations of 79 restorations in a total of 14 patients).

Table 3 illustrates the correlation between survival and three clinical variables. For analysis, the average amount of time taken for each restoration was dichotomised to less than or more than 11 min per restoration [11 min was chosen as the cut-off time as it was found to be the average time taken to build up each restoration in the original study (1)]. The mean height of the composite restoration was also dichotomised to less than or more than 2 mm.

The average time taken to build up each restoration was the only clinical variable found to effect the survival of a restoration. It was found that restorations which took longer to fabricate were statistically less likely to have survived to the 7-year assessment.

Survived restoration performance

The performance of the 72 restorations that had survived to the 7-year follow-up were analysed below.

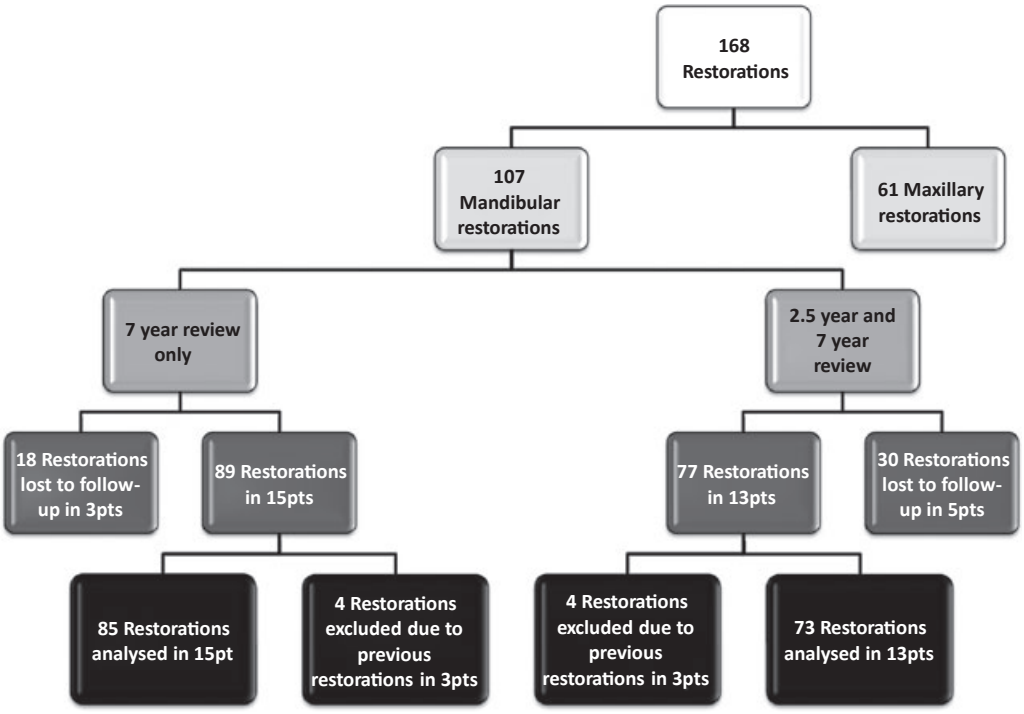

Fig. 2. Flow diagram showing fate of restorations at 2·5- and 7-year review.

Table 2. Examiner agreement and arbitration of those visual categories, which had a split disagreement

	Results for observations		Results for observations after arbitration using clinical photographs	
Clinical variable	Observations in which there was agreement	Observations in which there was no agreement	Observations in which a result was obtained	Observations in which there was no agreement
Anatomic form	86%	14%	92%	8%
Restoration staining	97%	3%	100%	0%
Marginal discolouration	76%	24%	90%	10%
Shade match	100%	0%	100%	0%
Surface roughness	97%	3%	97%	3%
Marginal adaptation	96%	4%	96%	4%

Table 3. Effect of circumferential preparation, mean height of composite and mean build-up time on restoration survival in the 15 patient cohort

	Restoration survival in the 15 patient group			
	Survived	Failed	*P*-value (two-tailed)	Statistical significance?
Circumferential preparation				
Preparation	31	6	1·0000	No
No preparation	41	7		
Mean height of composite build-up				
≤2 mm	41	10	0·2273	No
>2 mm	31	3		
Mean time taken to build up each restoration				
<11 min	35	1	0·0059	Yes
>11 min	37	12		

In Poyser *et al.*'s study (1), the authors calculated the score for an observation using the most frequently recorded result by the examiners, that is, the mathematical mode. When there was a disagreement in the observation, the examiners never differed by more than one observational increment. Thus, in the original study, the authors were able to allocate a score for every observational increment.

In the present study, several of the observations were dichotomised, as illustrated above. Despite this, there were also occasions in which the examiners did not agree on the observational increment. Because of the dichotomisation of the observations, the authors agreed that it would be inappropriate to use a mathematical mode. Thus, a definitive score for an observation was only accepted if at least four of the five examiners agreed on the increment.

Unlike the previous study, if there was a two to three split between the examiners, the observation for that tooth was not recorded. On such occasions, the observation was reassessed using clinical photographs by an additional examiner (ASAK). Arbitration was only possible for the visual observations relating to 'Anatomic form', 'Restoration staining' and 'Marginal discolouration' and provided the definitive result for this observation. If a patient's clinical photographs were unavailable then the observation was recorded as inconclusive and excluded from the analysis of the results (Table 2). Arbitration from clinical photographs was not possible for the tactile observation ('Surface roughness' and 'Marginal adaptation').

Anatomic form. The 'Anatomic form' observation was dichotomised to include 'survived' restorations with more or <50% of the original restorative material remaining. Of the 72 restorations that survived at 7 years, 63 restorations (88%) had more than 50% of their restorative material remaining, three restorations (4%) had less than this amount, and no agreement was achieved on six restorations (8%).

It should be noted that 50% loss of 'Anatomic Form' related to a vertical reduction in the amount of direct composite material and not to a reduction in mesio-distal width. There were no surviving restorations which were noted to have a reduction in their mesio-distal width.

Restoration staining. At 7 years, all of the survived restorations had 'none/mild staining' (72). No patients exhibited 'moderate/severe staining' of their restorations.

Marginal discoloration. At 7 years, 48 of the survived restorations (67%) had no evidence of marginal discolouration on their labial or incisal aspects, 17 (23%) had marginal discolouration, and no agreement was achieved on seven restorations (10%).

Shade match. At 7 years, 71 of the survived restorations (99%) were deemed to have an acceptable shade match between it and the tooth tissue. One restoration (1%) did not have an acceptable shade match.

Surface roughness. At 7 years, 69 of the survived restorations (96%) were observed to have no surface roughness on their labial and incisal surfaces. No restorations were judges to have surface roughness, and three restorations (4%) could not be agreed upon by the examiners.

Marginal adaptation. At 7 years, 69 of the survived restorations (96%) had a clinically acceptable catch between the surface and the adjacent tooth tissue, no restorations had an unacceptable catch, and three restorations (4%) could not be agreed upon.

Periodontal health. The periodontal health of the 72 teeth with survived restoration was assessed. Two of the 15 patients experienced bleeding on probing around at least one tooth surface. In addition, two patients experienced Grade I mobility of their restored teeth. No teeth were tender to percussion.

Tooth vitality. All the restored teeth were deemed responsive to electric pulp testing and thermal stimuli.

Successful restorations. A restoration was deemed to be successful at 7 years if it fulfilled the following criteria:

1 Survived (not been lost, replaced or repaired) at 7 years.
2 50% or more of the restorative material was remaining regardless of wear or fracture.
3 No or mild restoration staining.
4 No surface roughness.
5 No marginal discolouration.
6 A clinically acceptable shade match.
7 A clinically acceptable marginal adaptation.

Of the 85 restorations included for analysis, 43 restorations (51%) were successful.

Correlations between the observations and clinical variables in survived restorations. A Fisher's exact test was used to investigate the correlation between the observations and the clinical variables of interest (preparation, height and time). A *P*-value of $<0{\cdot}05$ was considered to be statistically significant. The results are displayed in Table 4.

No correlation was found between any of the clinical variables and the performance of the restorations.

Patients' opinions at the 7-year reassessment. The opinions of the 15 patients regarding their dental treatment were measured using a 100-millimetre visual analogue scale with a higher score representing a more negative response in questions 1, 2 and 3 and a more positive response in question 4. The questions related to the restorations on the respondents' lower teeth only.

The majority of patients expressed a low level of concern regarding sensitivity to hot or cold drinks, cold air or sweet foods. The mean response was measured at 12·8 mm with a range from 0 to 100.

There was a moderate concern with regard to the overall appearance of the restored lower teeth with a mean of 38·9 mm and a range from 0 to 100 mm.

There was also moderate concern relating to the patients' views about the longevity of the restored lower dentition. The mean value was 44·8 mm and the range was from 0 to 100 mm.

The patients also expressed general satisfaction with regard to improvement in their perceived chewing function. The mean score was 60·3 mm with a range from 0 to 100 mm.

Despite the large range in VAS scores, all the patients reported that their treatment matched their expectations and would recommend it to others.

Table 4. Effect of circumferential preparation, mean height of composite and mean build-up time on various clinical variables in the 15 patient cohort

Patients seen at	Restoration staining		Marginal discolouration		Shade match		Surface roughness		Marginal adaptation	
7 years	None	Staining	None	Staining	Acceptable	Unacceptable	Satisfactory	Rough	Acceptable	Unacceptable
Preparation	31	0	18	10	30	1	30	1	31	0
No preparation	41	0	30	7	41	0	39	1	38	2
P value (two-tailed)	1		0·1595		0·4306		1		0·501	
Statistical significance	No		No		No		No		No	
≤ 2 mm	41	0	31	8	40	1	39	2	38	2
>2 mm	31	0	17	9	31	0	30	0	31	0
P value (two-tailed)	1·0000		0·2546		1		0·5050		0·5010	
Statistical significance	No		No		No		No		No	
<11 min	35	0	21	9	35	0	33	1	33	2
>11 min	37	0	27	8	36	1	36	1	36	0
P value (two-tailed)	1·0000		0·5787		1·0000		1·0000		0·2394	
Statistical significance	No		No		No		No		No	

In the free text, the study participants reported advantages of this treatment relating to cosmetic improvements, improved chewing function and a preferable alternative to removable partial dentures. A reported disadvantage was the difficulty to access this type of treatment and maintenance of the restorations in primary dental care.

Immediate post-operative VAS responses to sensitivity, appearance and longevity were extremely high when compared with responses at the 7-year review. This may be due to the initial superseding of patient expectations. As can be seen from Fig. 3, the initial responses at 1-month post-operatively then dropped off significantly, but a gradual improvement up to 7 years was finally achieved. A statically significant difference was found between the pre-operative and 7-year review VAS responses for aesthetics ($P = 0{\cdot}0099$) and longevity ($P = 0{\cdot}0018$). No statically significant difference was seen for sensitivity.

Patients assessed at both 2·5 years and 7 years. Of the 15 patients seen at the 7-year reassessment, 13 patients were seen at both the 2·5-year and 7-year appointment. Two patients were not able to attend for the 2·5-year assessment but were able to attend at 7 years. The results from the 13 patient are briefly described below.

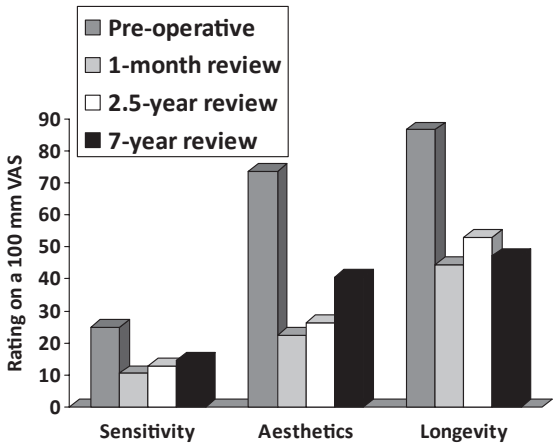

Fig. 3. The mean VAS scores of the 13 review patients that attended all three reviews (1 month, 2·5 years, and 7 years), recorded pre-operatively, at the 1-month review, at the 2·5-year review, and at the 7-year review for sensitivity, aesthetics and longevity.

Of the 107 mandibular restoration placed in 18 patients, 77 of these were placed in the 13 patient cohort who were reassessed twice. Four restorations were excluded from further analysis as they were placed on previously restored teeth. Of the 73 mandibular restorations available for analysis, 61 (84%) survived for 7 years. If a restoration was deemed not

to have survived for 7 years, it was removed from the analysis below.

Table 5 illustrates the correlation between survival of restorations in the 13 patient cohort and three clinical variables. Similar to the 15 patient group, the average amount of time taken to build up each restoration was the only clinical variable found to effect the survival of a restoration. Restorations that took more than an average of 11 min to fabricate were statistically less likely to have survived to the 7-year reassessment. The reasons for this are discussed in the following sections.

Thirty-eight (52%) of the total number of 73 restorations were deemed to be successful using the aforementioned criteria. There was no association between the three clinical variables investigated and the performance of the restoration (Table 6). The exception to this was an apparent borderline positive statistical correlation between a restoration height of >2 mm and marginal discolouration in this group.

Case examples.

1 An example of a typical case is shown in Fig. 4.
2 Three examples showing moderate-to-severe failures reviewed at 7 years (Fig. 5).

Table 5. Effect of circumferential preparation, mean height of composite and mean build-up time on restoration survival in the 13 patient cohort

	Restoration survival in the 13 patient group		*P*-value (two-tailed)	Statistical significance?
	Survived	Failed		
Circumferential preparation				
Preparation	26	5	1·0000	No
No preparation	35	7		
Mean height of composite build-up				
≤2 mm	30	9	0·1237	No
>2 mm	31	3		
Mean time taken to build up each restoration				
<11 min	24	0	0·0065	Yes
>11 min	37	12		

Discussion

Restoration performance

Fifteen of the original 18 patients were reviewed at 7 years (83%) and of the three who were not reviewed, two had died and one could not be contacted. For the patients analysed at 7 years, 85% of

Table 6. Effect of circumferential preparation, mean height of composite and mean build-up time on various clinical variables in the 13 patient cohort

Patients seen at 7 years	Restoration staining		Marginal discolouration		Shade match		Surface roughness		Marginal adaptation	
	None	Staining	None	Staining	Acceptable	Unacceptable	Satisfactory	Rough	Acceptable	Unacceptable
Preparation	31	0	18	10	30	1	30	1	31	0
No preparation	41	0	30	7	41	0	39	1	38	2
P value (two-tailed)	1		0·1595		0·4306		1		0·501	
Statistical significance	No		No		No		No		No	
≤2 mm	41	0	31	8	40	1	39	2	38	2
>2 mm	31	0	17	9	31	0	30	0	31	0
P value (two-tailed)	1·0000		0·2546		1		0·5050		0·5010	
Statistical significance	No		No		No		No		No	
<11 min	35	0	21	9	35	0	33	1	33	2
>11 min	37	0	27	8	36	1	36	1	36	0
P value (two-tailed)	1·0000		0·5787		1·0000		1·0000		0·2394	
Statistical significance	No		No		No		No		No	

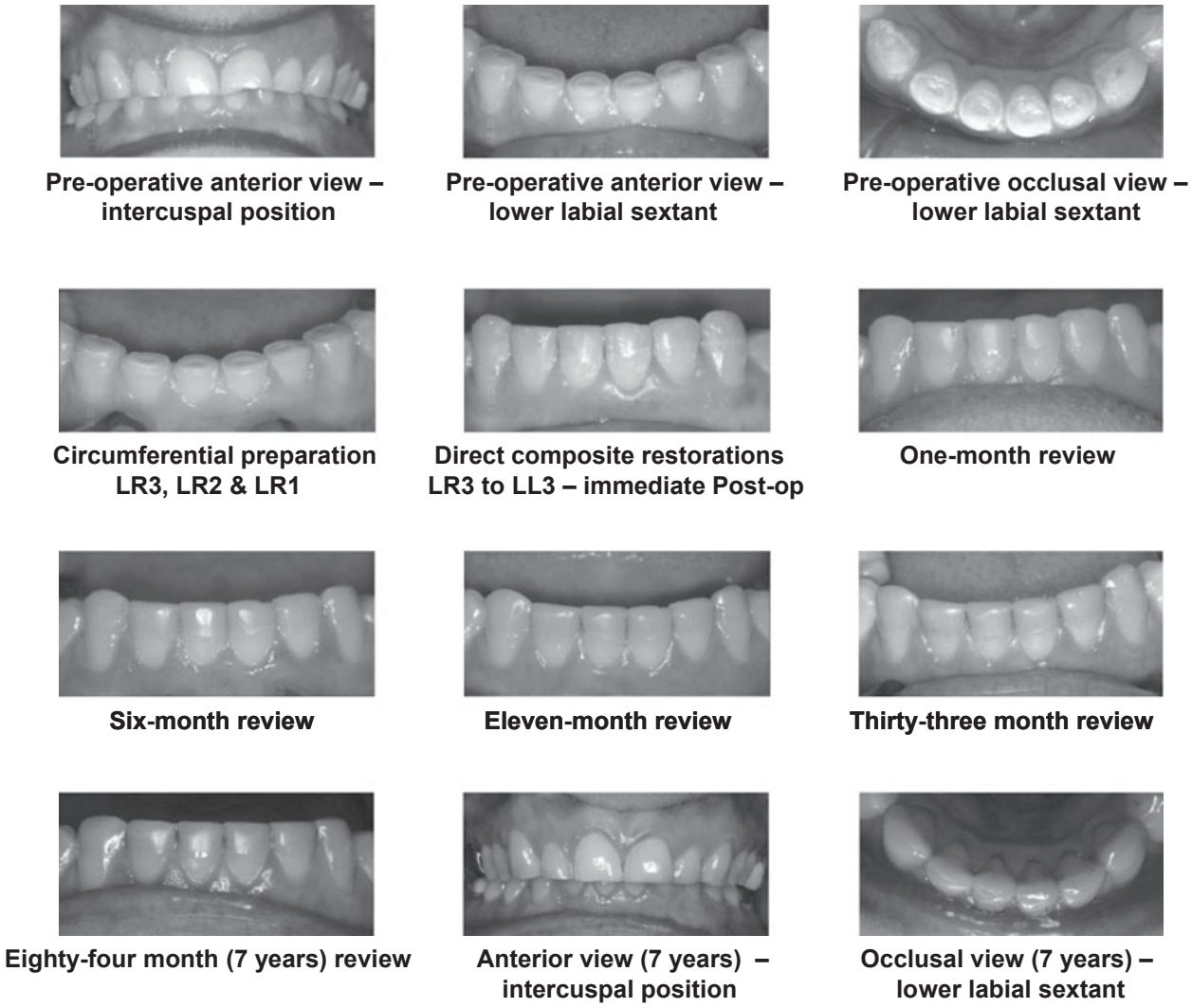

Fig. 4. Pre-operative and review images illustrating the performance of direct composite restorations to the worn mandibular incisor and canine teeth over a period of 84 months (7 years).

their restorations were present (survived), and eight patients had all of their restorations intact (success). Using our criteria for success, 51% of all restorations were *successful,* with no clinically significant problems in relation to the clinical variables recorded. In a similar study, Gulamali *et al.* (2) revealed that 7% of all of their surviving restorations were successful and exhibited no modes of failure. Although this study looked at a similar broad criteria, of localised anterior tooth wear of multifactorial aetiology, it is tenuous to make direct comparisons as they also included a majority of restorations in the anterior maxilla with just 22% of the data from mandibular restorations and a follow-up period of 10 years. In addition, their study

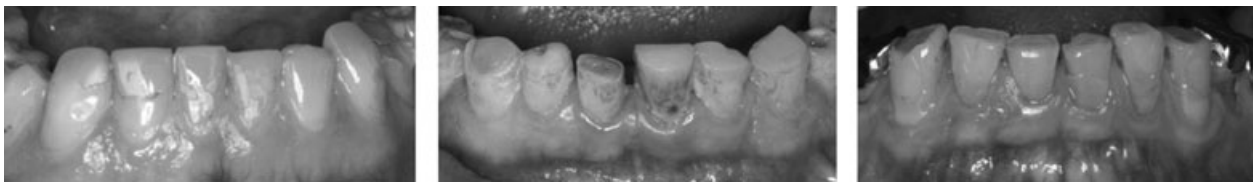

Fig. 5. Post-operative review images of three patients illustrating the typical failure modes experienced at 7 years of service.

involved multiple operators with varying levels of experience and seniority. Our comparatively high success and survival rates may reflect other variables such as a single experienced operator using the same material with the same nurse and a standardised clinical technique. The patient cohort may also bias the results with increased motivation to protect and preserve their restorations.

Direct composite build-ups are comparatively cheap and simple to place and are also amenable to repair. This study suggests that their predictability and hence cost-effectiveness is also favourable in the medium to long term.

Composite is readily available to practitioners and offers almost unrivalled clinical flexibility and preservation of natural tooth tissue. In most cases, it provides an acceptable aesthetic result. Patients who present with pathological tooth surface loss already have significant damage to their teeth. A technique, which can protect the teeth, restore aesthetics and function with no incumbent harm to the worn teeth, seems hard to argue against ethically, practically and biologically. The technique of directly bonding composite to worn teeth at an increased vertical dimension has been in carried out and the outcomes reported on widely in the UK (2–4).

Interexaminer variability

The data collection sheet was modified with the intention of eliminating subjective bias and to establish a clear distinct result for each variable observed. Interestingly, there was unanimous agreement on five of the six clinical observations; restoration staining, marginal discolouration, shade match, surface roughness and marginal adaptation. There was less robust agreement on the assessment of the amount of remaining restoration. Initially, we speculated that this might be due to a lack of study casts for assessment in three of the 15 reviewed patients (two of whom were in the group of 13 patients reviewed at both 2·5 and 7 years). Data analysis, however, showed this not to be the case as disagreements occurred in reporting on patients with post-operative casts available. It is the authors' opinion that disagreement is caused by the inherent clinical difficulty in accurately assessing the amount of remaining composite after 7 years, with no objective baseline from which to accurately measure.

Circumferential preparation

Opinion varies regarding the clinical advantages of making a preparation to the natural tooth tissue prior to placing an adhesive direct composite build-up. Tables 3–6, illustrate that our clinical outcomes and measures of success and restoration survival were similar regardless of whether tooth preparation was carried out or not. There were no statistically significant differences caused by tooth preparation on any of the outcome variables.

The results also show a similar proportion of failures between prepared and non-prepared teeth; although the majority of failures 38% (five of 13) occurred in one patient whom reported unusual eating habits. On questioning, the patient reported an enjoyment in eating a diet consisting mainly of hard and crunchy foods. One should therefore use caution in extrapolating these results for the population.

There is little evidence here to support the preparation of the natural tooth tissue for any of the clinical parameters we assessed. Whilst patients and their worn teeth need individual assessment and planning, and some may warrant a small amount of preparation prior to build up, the authors conclude that the vast majority of cases can be effectively treated in an entirely additive way.

Walls (5) assessed porcelain onlays with buccal cervical extensions to restore occlusaly worn anterior teeth. He showed little benefit in including cervical extensions to the restoration design as despite fracture of cervical porcelain, the onlays remained attached to the occlusal dentine (when followed up for a minimum of 50 months). Chana *et al.* (6) concluded that the degree of axial wall extension had no influence on survival of posterior resin-bonded gold alloy onlay restorations. They also showed that restorations restored using techniques in line with the 'Dahl' concept (7–10), with localised interocclusal space creation, were as successful as those that were conformatively restored with no changes to the occlusal vertical dimension.

Procedural time

In the original clinical study, 107 direct composite restorations were placed, and the mean time taken to complete each restoration on each tooth was calculated to be approximately 11 min. In this study, we

used this length of time as a guide in our statistical analysis to help determine whether there was a relationship between the time taken to place the composite restorations, and it effect on survival and on other clinical variables.

Within the limitations of this study, restorations that took more procedural time (11 min+) to place were statistically less likely to have survived at 7 years. This could be explained as those restorations, which took longer to place may have been in difficult patients, where moisture control was difficult, and therefore, placement was compromised and possibly more likely to fail. Procedural time had no effect on any other clinical variable.

Patient opinion

Asking patients to complete the VAS questionnaires offered an opportunity for them to impart their feedback on this treatment modality and the effects it has had on their quality of life. Most patients reported a pleasing level of happiness with their restorations over 7 years with regard to aesthetic and functional gains. Particular note was made of restoration longevity, which was shown to be the most important clinical factor for meeting patient expectations. No statically significant difference was found between the 2·5-year review and 7-year review VAS responses for sensitivity ($P = 0{\cdot}1347$), aesthetics ($P = 0{\cdot}1974$) and longevity ($P = 0{\cdot}6664$). This suggests that the benefits in patient perceived improvement in tooth aesthetics and concerns about tooth longevity at 2·5 years continued to the 7-year interval. Despite the large range in VAS scores, all the patients reported that their treatment matched their expectations and would recommend it to others.

The patient cohort, anecdotally, seemed to understand and appreciate the need for continued maintenance and replacement of their restorations. They also were frank in sharing with the authors the difficulties that they had faced accessing primary dental care to maintain and repair their restorations when necessary. There was a perception of a disparity in the skill mix between primary and secondary care that this cohort remarked on.

If there were a disparity in either skill mix or experience with this technique, this may have an important bearing on the patients' dental future at the time of discharge. The authors highlight that there is a need for patients to be able to gain access to this type of routine treatment in primary dental care. This also poses a good opportunity for general dental practitioners to develop their skills and confidence in using this technique, as many will already be skilled in the use of direct composite resins on a daily basis.

This study does not analyse or offer comment on the financial cost of completing the initial build-up and whether fees associated in the primary care setting would influence the popularity or specifics involved. We also dismissed any opportunity to analyse the outcome of repair techniques. Of importance may be whether a worn composite can be predictably added to or whether it is clinically advantageous to remove any worn composite remnants and replace the build-up in full. This may be a focus for review in future publications.

The authors believe that patients go on to 'internalise' their restorations and accept them as 'their own'. The patients generally enjoyed the benefits of their treatment but did express their concern about the ability to access quality maintenance of their restoration in primary dental care after discharge.

Comparison with other reports

This study has specifically assessed the performance of direct composite restorations placed on worn mandibular anterior teeth. Although some studies have reported on the use of direct composite resin for the management of the worn anterior dentition, they do not differentiate between maxillary and mandibular restorations. One could argue that data from these other studies are more heterogeneous and cannot be directly compared with our findings. A study by Gow and Hemmings (11) reported no bulk failures of 75 indirect Artglass restorations placed on the palatal aspect of worn maxillary anterior teeth at 2 years. Hemmings *et al.* (3) reported the bulk failure of seven of 104 (7%) direct composite restorations placed on the anterior dentition at 30 months. This is similar to our original figure of 6% at 2·5 years reported in the original study.

Patient satisfaction was also reported to be high in the studies by Hemming *et al.* (3), Redman *et al.* (4) and Gow and Hemmings (11) where the restoration of worn anterior teeth using a similar type of technique was used.

Conclusion

This study reports on the outcomes of a further clinical assessment of direct composites placed in the worn mandibular dentition in the same cohort of patients assessed by Poyser *et al.* at 2·5 years. It can be concluded from this 7-year prospective randomised controlled split-mouth clinical trial that the direct placement of composite restorations at an increased occlusal vertical dimension is a predictable process with long-standing satisfactory aesthetic benefits, and good long-term survival. Although composite restorations will continue to wear in time, they will often be an aesthetically pleasing and functioning restoration with the benefits of tooth protection/preservation. Pre-operative circumferential preparation did not influence restoration survival, patient satisfaction or other clinical variables (restoration staining, marginal discolouration, shade match, surface roughness and marginal adaptation). The time taken to initially build up the restorations was shown to be statistically significant with a longer procedural time meaning less chance of the restoration being present at 7 years.

This treatment modality exhibited no biological complications for the teeth, supporting periodontium or TMJ apparatus. The placement of these restorations provided an improvement in the aesthetics of the teeth, a reduction in the concern over the longevity of the worn lower anterior teeth, and improvements with regard to sensitivity experienced with hot or cold foods or drinks. Marginal breakdown was the most frequently recorded clinical complication.

Direct composite restorations have distinct biological advantages compared with full-coverage crown restorations and for the majority of patients they perform well, offer a high degree of patient satisfaction and require an acceptable level of maintenance. When failure inevitably does occur, repair and/or replacement is predictable and straightforward. The treatment is entirely additive, so the patient has seemingly endless fall-back positions as time goes by. This contrasts remarkably with conventional full-coverage crowns whereby failure may lead to pulpal death, core fracture or even tooth loss.

Disclosure/Acknowledgments

The authors certify that the procedures undertaken on human subjects in this study is with the understanding and written consent of each subject in accordance with the World Medical Association Declaration of Helsinki (version 2002; www.wma.net/e/policy/b3.htm) and that it has been independently reviewed and approved by the relevant institutional Ethical Committee.

The authors also certify that there is no conflict of interest with any financial organisation regarding the materials discussed in this manuscript.

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