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Original Research

Rehabilitation of marginal mandibulectomy patients using immediately loaded basal implant-supported prostheses★

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ABSTRACT

Objectives: To evaluate the treatment outcomes and patient satisfaction following the use of fixed, immediately loaded, basal implant- reconstructive prostheses in a cohort of patients who underwent marginal mandibulectomy.

Methods: Ninety-seven Basal Cortical Screw implants (BCS®[1]; Dr. Ihde Dental AG, Gommiswald, Switzerland) were inserted in 15 marginal mandibulectomy patients. Clinical, radiographic, and prosthetic parameters, as well as patient satisfaction, were evaluated at 1 week and 3, 6, 9, 12, 18, 24, 36, 48, and 60- months after implant insertion. Clinical evaluations included measurement of the plaque (PI) and modified gingival indices (MGI), and the probable pocket depth (PPD). Implant survival and implant success were assessed using the James–Misch implant health quality scale and the Albrektsson criteria for implant success.

Results: The implants showed optimum health with 100 % survival and success rates. None of the implants were mobile, lost, or fractured. There was a non-significant increase in the PI at 3, 6, 9, 12, 18 months, a significant difference at 24, 36, 48, 60-months follow-up visits, and a significant decrease in the MGI and PPD. Radiographic findings showed an increase in bone–implant contact and peri-implant bone level. Evaluation of the prostheses revealed some manageable complications. All patients were satisfied and reported that they would choose the same treatment modality again.

Conclusions: Basal implant- reconstructive prostheses provide optimum clinical and radiographic success, with 100 % implant survival and success rates, and patient satisfaction in marginal mandibulectomy cases.

1. Introduction

Maxillofacial defects, including defects attributable to marginal mandibulectomy, are usually associated with esthetic and functional disfigurement, which adversely affects the patient's psychological state, mastication, comfort, esthetics, speech, and quality of life [1–5]. Marginal mandibulectomy involves resection of part of the mandibular bone and its overlying soft tissues, leaving the inferior border intact to maintain continuity [1,3]. In the past few decades, several surgical techniques [4–7] have been considered for the reconstruction of mandibular defects, ranging from no reconstruction, with only primary closure of the overlying soft tissues [6,7]; the use of reconstructive plates and meshes [4,6–8]; to the use of non-vascularized or vascularized bone grafts [3,2–5,7,9]. The choice among these techniques is dictated by many factors, which have been described in previous studies [2–4,7,8]. These factors include mainly the location and extent of the resection [2,4,7], the nature and stage of the disease [2], the amount of residual soft and hard tissues [2,4], the use and impact of radiation and chemotherapy on the remaining oral cavity structures [2,3,8], the degree of salivary gland impairment [2], the patient's age and medical condition [2], surgical expertise and the availability of a

Abbreviations: BCS®, Basal Cortical Screw implants; MGI, Modified Gingival Index; PI, Plaque Index; PPD, Probable Pocket Depth.

★ AsianAOMS: Asian Association of Oral and Maxillofacial Surgeons; ASOMP: Asian Society of Oral and Maxillofacial Pathology; JSOP: Japanese Society of Oral Pathology; JSOMS: Japanese Society of Oral and Maxillofacial Surgeons; JSOM: Japanese Society of Oral Medicine; JAMI: Japanese Academy of Maxillofacial Implants.

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multidisciplinary team approach [2], and finally, patient preference [7].

The ultimate goal of mandibular reconstruction is to retain the previous external appearance of the patient [2], restore the resected oral structures [2,3], improve mastication and phonation [2], control the dripping of saliva, enhance and/or maintain tongue mobility, thereby improving patients' quality of life [1,2,9]. For partially edentulous patients, removable reconstructive appliances can be fabricated, and their success is primarily dependent on the number and condition of the remaining teeth, the quality and quantity of the residual bone and soft tissue after mandibulectomy, the location of the defect, the inter-occlusal space, the degree of tongue mobility impairment, and finally, patient acceptance [1]. When adequate residual bony support and multiple healthy remaining teeth are present, removable reconstructive appliances can be used with a predictably successful result [1,2,10]. In contrast, cases with compromised ridges and tooth support are poor candidates for the use of removable reconstructive appliances [1,2].

Considering the intra-oral anatomy, prosthodontic treatment is more challenging for anterior than for posterior defects, because compromised tongue mobility is associated with loss of the genioglossus and geniohyoid muscles [9]. In addition, many completely edentulous patients with anterior defects present with obliterated mandibular sulci that clearly compromise the prosthesis stability, retention, and support, thus increasing patient discomfort [1]. In patients undergoing mandibular resection, when a prosthesis cannot be inserted with satisfactory stability, it may be advantageous to use endosseous implants to improve prosthesis stability, retention, support, and patient quality of life [1,9–16].

The limited amount of residual bone after resection, the proximity of vital adjacent structures, such as the inferior dental nerve, the interocclusal space, as well as the addition of radio- and/or chemotherapy as a treatment modality for oral cancer, may compromise the use of conventional endosseous implants [1,5,11,12]. Consequently, implant therapy may involve bone augmentation from the fibula, tibia, or ribs to improve the bony foundation area, which adds complications related to the augmentation procedure to those associated with a susceptible implant [1,8,12]. Moreover, bone grafting itself is an invasive two-step surgery that is associated with a significant increase in the possibility of complications related to donor site morbidity, graft infection, grafted bone resorption, increased cost, the need for maxillofacial team expertise, and appropriate facilities [1,4,5,12,17].

In elderly and completely edentulous patients, these problems are exacerbated, since the patients usually have a severely atrophied mandible, inadequate vestibule [1], and a complicated medical situation, making them poor candidates for major reconstructive treatment [14]. Hence, there is an increased need for a less invasive procedure with fewer complications that can still provide a stable and retentive prosthesis.

With advances in the development of dental implants and the introduction of different implant designs and systems, including basal implants, bone grafting procedures may no longer be obligatory [18–30]. The initial stability of these implants is achieved through anchoring into the cortical/basal bone, which makes this implant design advantageous for treating patients with maxillofacial defects [18–30]. Basal Cortical Screw (BCS®) implants are a special type of crestal basal implants characterized by use of a crestal insertion approach, similar to other endosseous implants. These implants contain horizontal plates that anchor deeply into the basal bone. They are one-piece implants with unique characteristics, such as a small penetrating guiding tip that is used to centralize the implant and that reduces blood supply interruption at the osteotomy site, and a smooth polished vertical shaft that allows transmission of the masticatory occlusal load deeply into the strongest basal bone and that prevents plaque accumulation and consequent peri- implantitis. Moreover, it has an iso-elastic property that permits implant bending without affecting implant survival rate [18–20,31]. Thus, these screws facilitate the use of immediately functional fixed implant-supported prostheses [18–30].

Several studies [17–30] have reported the use of basal implants as an alternative to bone grafting in severely resorbed ridges. Lazarov [20] assessed a series of 87 consecutive patients who received 1169 immediately loaded, one-piece Strategic Implants® for supporting fixed complete-arch or segmental maxillary and/or mandibular metal-ceramic bridges. He found that the cumulative survival rate of BCS® implants was 97.5 % after 48–57 months of follow-up, with no signs of peri-implantitis. Furthermore, Ahmad et al. [22] described a successful full-mouth rehabilitation of a 24-year-old patient with cleidocranial dysplasia by using immediately loaded basal implant-supported fixed prostheses. After 3 years of function, the patient showed excellent oral health and reported her satisfaction with the esthetic and functional aspects of the prostheses. Osman et al. [23] reported the successful rehabilitation of a 22-year-old female patient who underwent with subtotal maxillectomy and in whom immediately loaded basal implant-supported fixed prostheses were used. Ghalaut et al. [24] highlighted the successful use of 18 single-piece BCS® implants to accomplish an immediate-function full-mouth rehabilitation of a severely periodontally compromised patient. Singh et al. [25] also reported the successful use of BCS® implants in a freshly extracted socket of a grossly carious, hemisected first molar.

Nevertheless, there is a gap in knowledge regarding the use and outcomes of immediately loaded, fixed, basal implant-supported prostheses as a treatment alternative for the rehabilitation of patients undergoing marginal mandibulectomy. To our knowledge, this is the first study investigating the use of the basal implant –reconstructive prostheses in patients with marginal mandibulectomy, which still present challenges for both maxillofacial surgeons and prosthodontists with relatively limited prosthetic treatment options. The aim of this study was to evaluate the treatment outcomes (survival rate, success rate, hard and soft peri-implant tissue health, patient satisfaction, and prosthetic and surgical failure) of immediately loaded, fixed, basal implant-reconstructive prostheses in the treatment of patients who had undergone marginal mandibulectomy over 60-months follow-up period.

2. Methods

2.1. Sampling technique

This longitudinal prospective study was conducted at the department of implants in authors Dental Hospital. Ethical approval was obtained from the Ethics Committee of the hospital as well as the Ethics Committee of the Ministry of Health of the authors (number: WK/OS/AETEA/44).

The investigation was conducted according to the principles embodied in the Helsinki Declaration of 1975 for biomedical research involving human subjects, as revised in 2004. Each patient was informed about the treatment plan and asked to participate in the study voluntarily. Written informed consent was acquired from all participants.

We included patients who underwent marginal mandibulectomy without bone grafting (only primary closure of the wound), who were indicated for implant treatment at the Oral Maxillofacial Department, and who met the following criteria: A history of marginal mandibulectomy at least 1 year prior to the study;

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age ≥ 18 years; severely compromised teeth and/or residual ridge support and precluded bone grafting procedure, a history of an unsatisfactory removable reconstructive prosthesis, a request for a fixed prosthesis and/or a conservative treatment approach, medical ability to undergo implant surgery; and willingness to participate in the study. Patients who had received radiotherapy after mandibulectomy within the past year were excluded.

The included patients were treated by a single expert maxillofacial surgeon [more than 10 years] and a single prosthodontist [more than 10 years] using the same technique for all patients.

2.2. Pre-surgical preparation

Complete medical and dental history of the patients was recorded, after which the patients underwent comprehensive clinical assessment. Photographs (Figs. 1, 2), digital dental panoramic X-rays were acquired for each patient. (Planmeca Pro Max, Helsinki, Finland) (Fig. 3) A diagnostic cone-beam radiograph was used to verify the position of the inferior alveolar nerve. Before the implant procedure, a diagnostic wax-up was fabricated for the patients using the steps described below to evaluate the patient's esthetics and to determine the accurate teeth positions.

A primary impression was taken using alginate irreversible hydrocolloid impression material (Hydrogum-www.zhermack.com) and a stock tray. The impressions were poured at room temperature. A special tray was constructed of self-cured acrylic resin material (Lucitone Fas-Pro+; Dentsply Sirona, York, PN, USA). From the same study cast, a record block was constructed using self-cured acrylic resin and a wax occlusion rim. The level of the occlusal plane and the amount of lip support were adjusted according to the esthetics to 2 mm below the lower lip and parallel to the ala-tragus line laterally. An ear bow record (ADDler FB-1500; Cori Dent, Tokyo, Japan) was used to articulate the maxillary cast in a semi-adjustable articulator. The vertical dimensions at rest and occlusion were recorded, and the maxillary and mandibular casts were articulated using the centric relationship. The diagnostic wax-up was fabricated, try-in was performed, and the patient's approval was obtained. The diagnostic wax-up was processed using heat-cured acrylic resin to act as a temporary removable mandibular reconstructed prosthesis.

2.3. Surgical procedure

A total of 97 BCS® implants (Dr. Ihde Dental, Gommiswald, Switzerland) were inserted in 15 patients using a one-stage implant protocol. Implant osteotomies were performed using infiltration local anesthesia (lidocaine 2% with 1:100000 concentration of epinephrine; Spain) and flapless techniques. The number and location of implants used depended on the anatomic and morphologic conditions of the residual bone after resection. The inserted implants had a diameter of 3.5 or 4.5 mm and a length of 10–23 mm. (Fig. 4 a, b) The primary stability was assessed using the reverse torque technique at 35 N/cm. Since implants have iso-elastic properties and can be bent [18,20,31], the irregular implants were bent using bending tools of the corresponding implant system to ensure favorable prosthetic alignment [18,20,31]. Per oral amoxicillin and clavulanate potassium 1 mg (Megamox; HIKMA, Amman, Jordan), and diclofenac potassium 50 mg (Rapidus; Tabuk, Kingdom of Saudi Arabia) were prescribed.

2.4. Prosthetic procedure

Immediately after implant placement, impression copings were inserted and secured to the implant's head (abutment). Final impressions were taken using a monophase vinyl polysiloxane impression material (VPS; Ivoclar Vivadent AG, Schaan, Liechtenstein) and poured using type IV dental stone (Elite Rock, Zhermack, Badia Polesine, Italy) at room temperature. On the next day, a metal framework splinting the implants was constructed and tried in the patient's mouth, and the passive fit was ensured. This framework helped to splint the implants and ensure better biomechanical force distribution and passive fit [32–34]. The jaw relationship was assessed, a prosthesis try-in was performed, an acrylic veneer

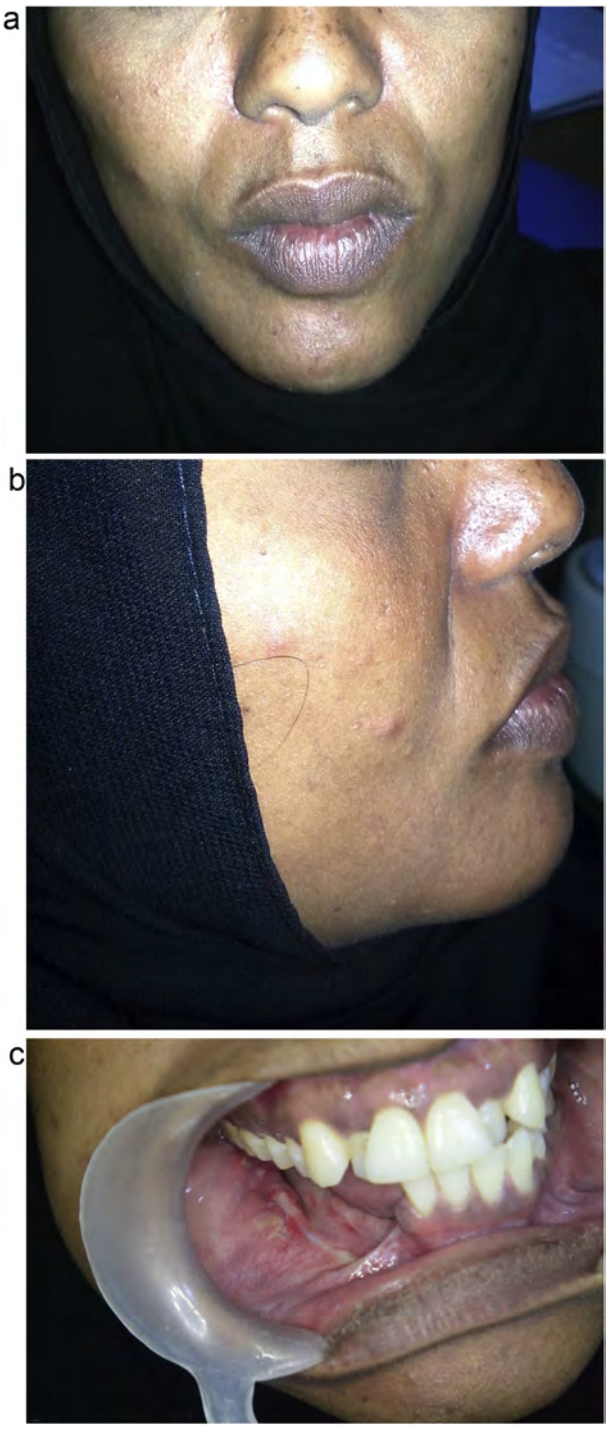

Fig. 1. Clinical presentation of patient code no 03.
A. Extra-oral frontal view of the patient showing a depressed right cheek after mandibulectomy.
B. Extra-oral lateral view of the patient.
C. Intra-oral view of the patient showing reduced ridge height after right marginal mandibulectomy.

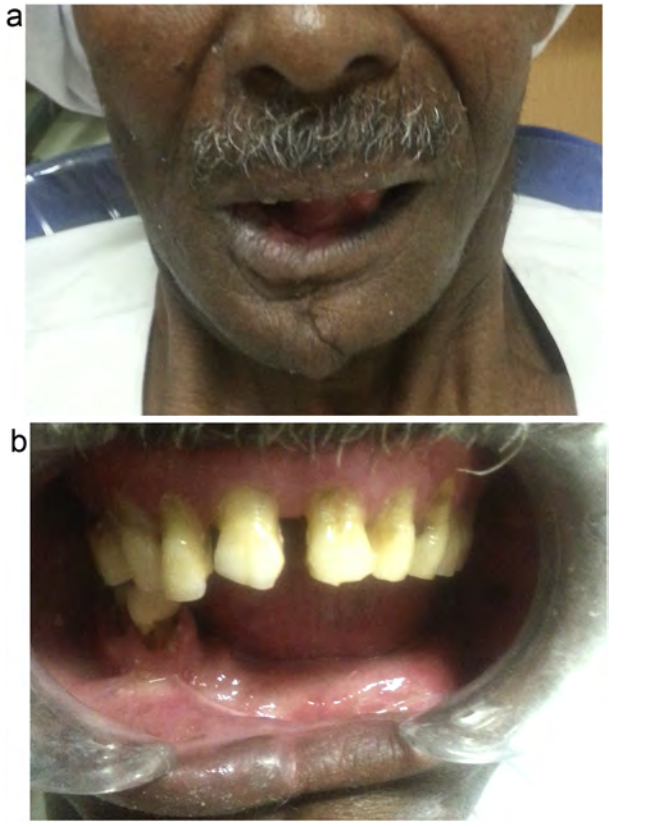

Fig. 2. Clinical presentation of patient code no 02.
A. Extra-oral frontal view of patient code no 02.
B. Intra-oral view of the patient showing reduced ridge height after marginal mandibulectomy and obliterated mandibular sulci anteriorly.

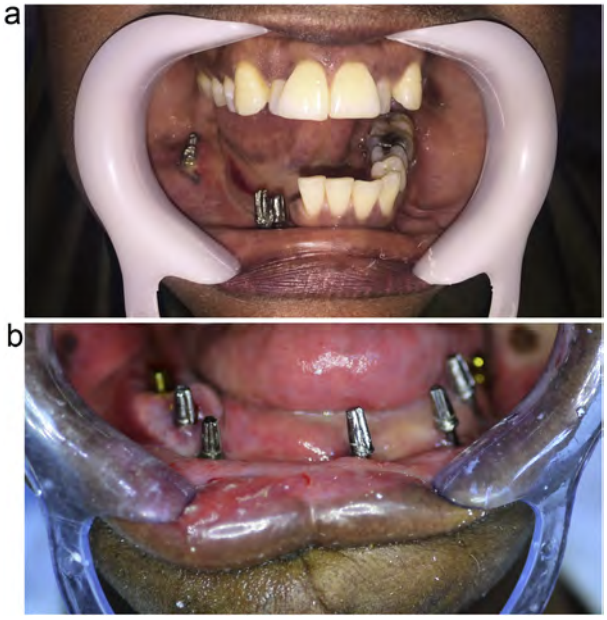

Fig. 4. The distribution of the basal cortical screw (BCS®) implants.
A. Clinical intra-oral view of patient code no 03 showing the implant distribution.
B. Clinical intra-oral view of patient code no 02 showing the implant distribution.

material was used to compensate for the hard and soft tissue loss, and the finished prosthesis was delivered on the third day. The extension, stability, esthetics, jaw relationship, and patient acceptance of the prosthesis were evaluated, and once considered satisfactory, the final prosthesis was cemented using Fuji I glass ionomer luting cement (GC Corporation, Tokyo, Japan) (Fig. 5). The labial and lingual denture bases were convex and concave, respectively, highly polished, and did not extend to the full depth of the sulcus in order to prevent food entrapment, allow good oral hygiene, give access to saliva for removing any food remnants, and permit the identification of any abnormal changes in the soft and hard tissues at the resection site. Digital dental panoramic radiographs were acquired postoperatively. Moreover, a cone beam CT was obtained when there is a risk of Inferior Dental Nerve involvement (Figs. 6, 7).

Oral hygiene instructions were given to the patients, including the use of a very soft small interdental toothbrush to clean the bottom of the prosthesis and of mouth wash to ensure washing away of food remnants through the hygienic space provided by the prosthesis. Patients were recalled after a week and examined both clinically and radiographically. The measurements obtained at this time point were considered as baseline values. Patient complaints were also dealt with at this stage. Moreover, the patients were scheduled for a follow-up program at 3, 6, 9, 12, 18, 24, 36, 48, and 60 months. At each follow-up visit, patients were examined both clinically and radiographically.

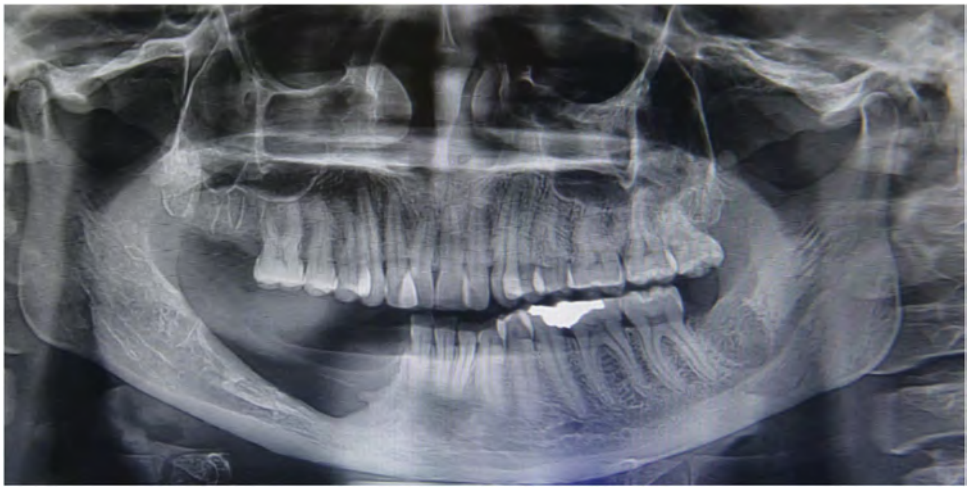

Fig. 3. Dental panoramic view before implant insertion (pre-treatment), showing the right marginal mandibulectomy of patient code no 03.

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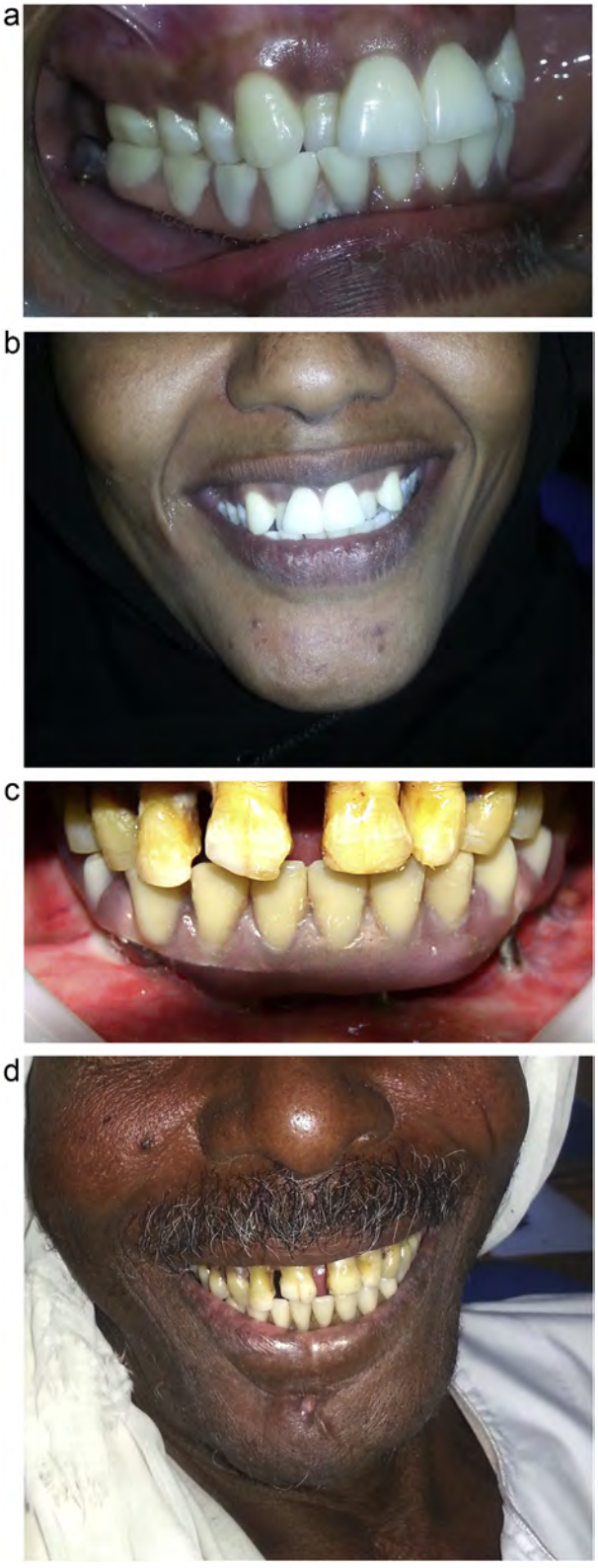

Fig. 5. The final fixed, immediately loaded maxillary and mandibular basal implant-supported prostheses.
A. Clinical intra-oral view of patient code 03. Note the extension of the prosthesis and the hygienic space.
B. The extra-oral view of patient code no. 03.
C. Intra-oral view of patient code 02.
D. Extra-oral view of the patient code 02.

2.5. Outcome variables and measurements

Implant survival rate was determined according to a previous report [35]. Implant survival was defined as the presence of the implant inside the mouth at the time of examination [35].

Implant success rates were assessed using the modified James–Misch health implant quality scale [35] (success/optimum health, satisfactory survival, compromised survival, or failure) and the Albrektsson criteria [36] for implant success (peri-implant bone resorption < 1.5 mm in the first year of function and < 0.2 mm in subsequent years, as well as absence of suppuration, peri-implant infection, continuous pain, implant mobility, and evidence of peri-implant radiolucency) [36].

Clinical examination of peri-implant soft tissues was performed and recorded at each follow-up appointment, and included measurement of the plaque index (PI) as described by Mombelli et al. [37] (score 0: no detection of plaque; 1: plaque can be detected by running a probe across the implant; 2: plaque can be seen by the naked eye; and 3: an abundance of plaque). The modified gingival index (MGI) was measured in accordance with the modified Löe and Silness criteria [38] (score 0: normal peri-implant mucosa; 1: mild inflammation, a slight change in color, and slight edema; 2: moderate inflammation, redness, edema, and glazing; and 3: severe inflammation, marked redness and edema, and ulceration). The presence (score 1) or absence (score 0) of calculus around the implant was recorded both labially and lingually, using the calculus index (CI). Probable pocket depth (PPD) was measured from the mucosal margin to the bottom of the probable pocket in millimeters using a short shank probe with gentle pressure [38]. Since the prosthesis had a hygienic design, there was a space between the prosthesis flange and the mucosa that allowed the introduction of a short shank probe. Probing was performed using gentle pressure, and in cases wherein complete peri-implant soft tissue healing around the implants had occurred, the pocket depth was considered to be 0 mm, and introduction of the probe was strictly avoided in accordance with the "Consensus on probing around basal implants" recommendations [39].

The prosthesis was examined for the following characteristics: prosthesis mobility and de-cementation, lip support, extent of tooth exposure, fracture of the veneer material, and unnatural wear of the opposing dentition.

Radiographic evaluation was performed using the same standard digital panoramic views and by the same technician to detect implant loss and/or fracture and evaluate the bone–implant contact (BIC) and peri-implant bone level. To ensure standardization, the same machine was used for all assessments.

Patient satisfaction was evaluated by asking patients about their overall satisfaction and their satisfaction in relation to esthetics, mastication, phonation, comfort. These parameters were considered the most commonly used variables to assess satisfaction [20,40]. The patients were also asked if they would choose the same treatment again using Yes/No answer-type questions.

2.6. Intrarater reliability test

The intrarater reliability of a single investigator was evaluated using repeated measurements obtained at different intervals. The reliability scores were 0.7, 1.0, 0.7, and 0.9 for the PI, CI, MGI, and PPD, respectively.

2.7. Statistical analysis

All data were recorded on patient evaluation sheets and statistically analyzed using Statistical Package for Social Sciences SPSS

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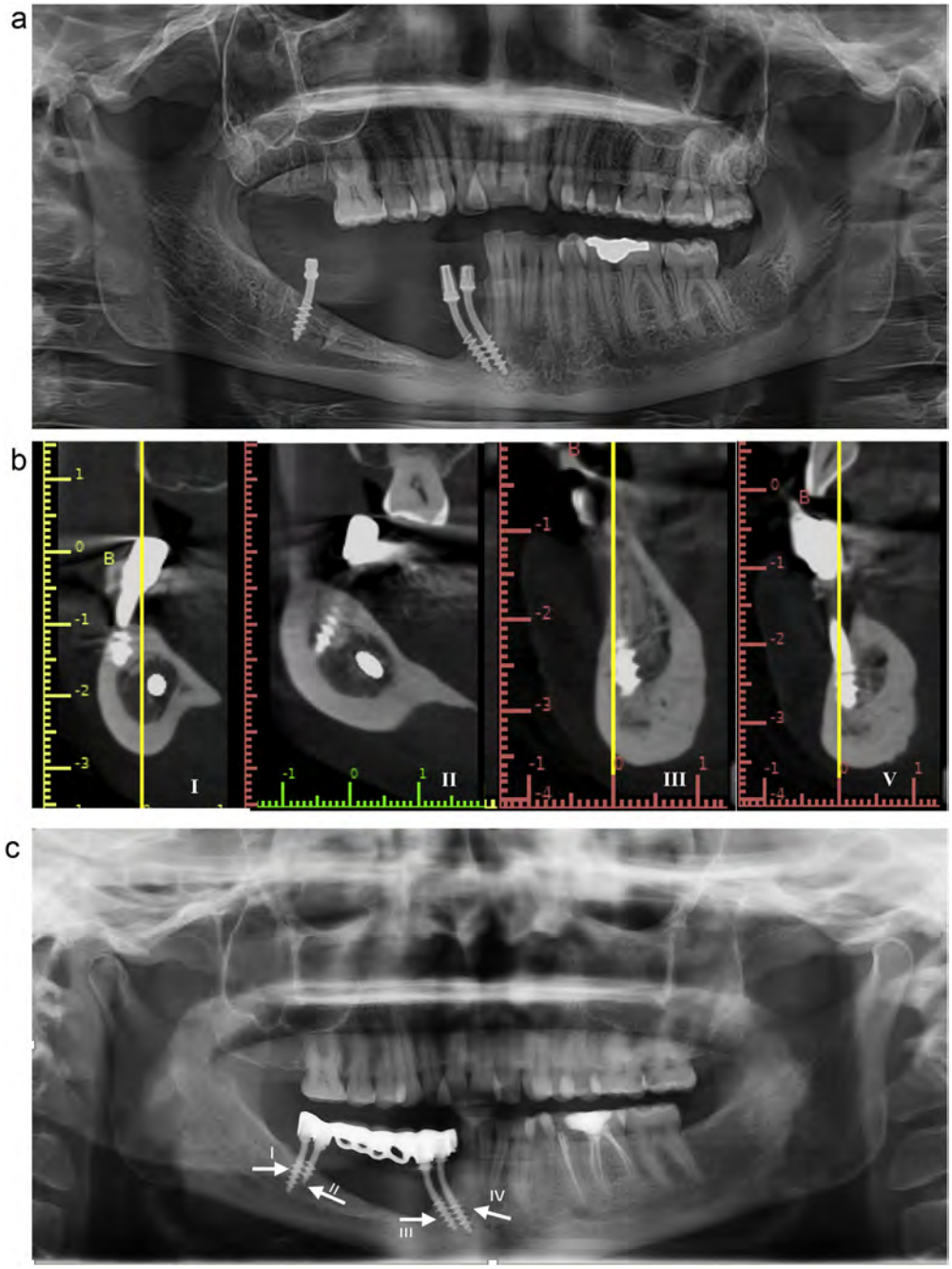

Fig. 6. The post-operative and follow up radiographs of the patient code no 03.
A. The panoramic radiograph of the patient at the 1-week follow-up visit (baseline).
B. Cone beam CT of patient code no 03, verifying the implant position in relation to the Inferior Alveolar Nerve at the area of: I. 46. II. 46. III.43. IV. 42. (Note that the implant(I) at the area 46 has been inserted at the 24-month's follow –up visit).
C. The panoramic radiograph of the patient at the 60 months' follow-up visit (Note the 4th implant that has been inserted at the 24-month's follow –up visit).

Statistics software (version 22; IBM Corp., Armonk, NY, USA). P values < 0.05 were considered statistically significant (95 % confidence interval). Categorical study data are summarized as number (frequencies) and percentages, and continuous variables are summarized using descriptive statistics (N, mean, median, standard deviation). The Wilcoxon signed-rank test was used for comparing measurements (plaque index, modified gingival index, and probable pocket depth) between the baseline and the follow-up visits.

3. Results

Fifteen patients, who received a total of 97 implants, were included in this study. These patients were predominantly men (n = 10) and had a median age of 52 years (range, 38–81 years) (Table 1).

Of the 97 BCS® implants that were placed, 48 (49.5 %) were placed in the anterior region, 26 (26.8 %) in the premolar region, and 23 (23.7 %) in the molar region. While 74 of the implants (76.3 %) were opposed by natural dentition, 16 (16.5 %) were opposed by

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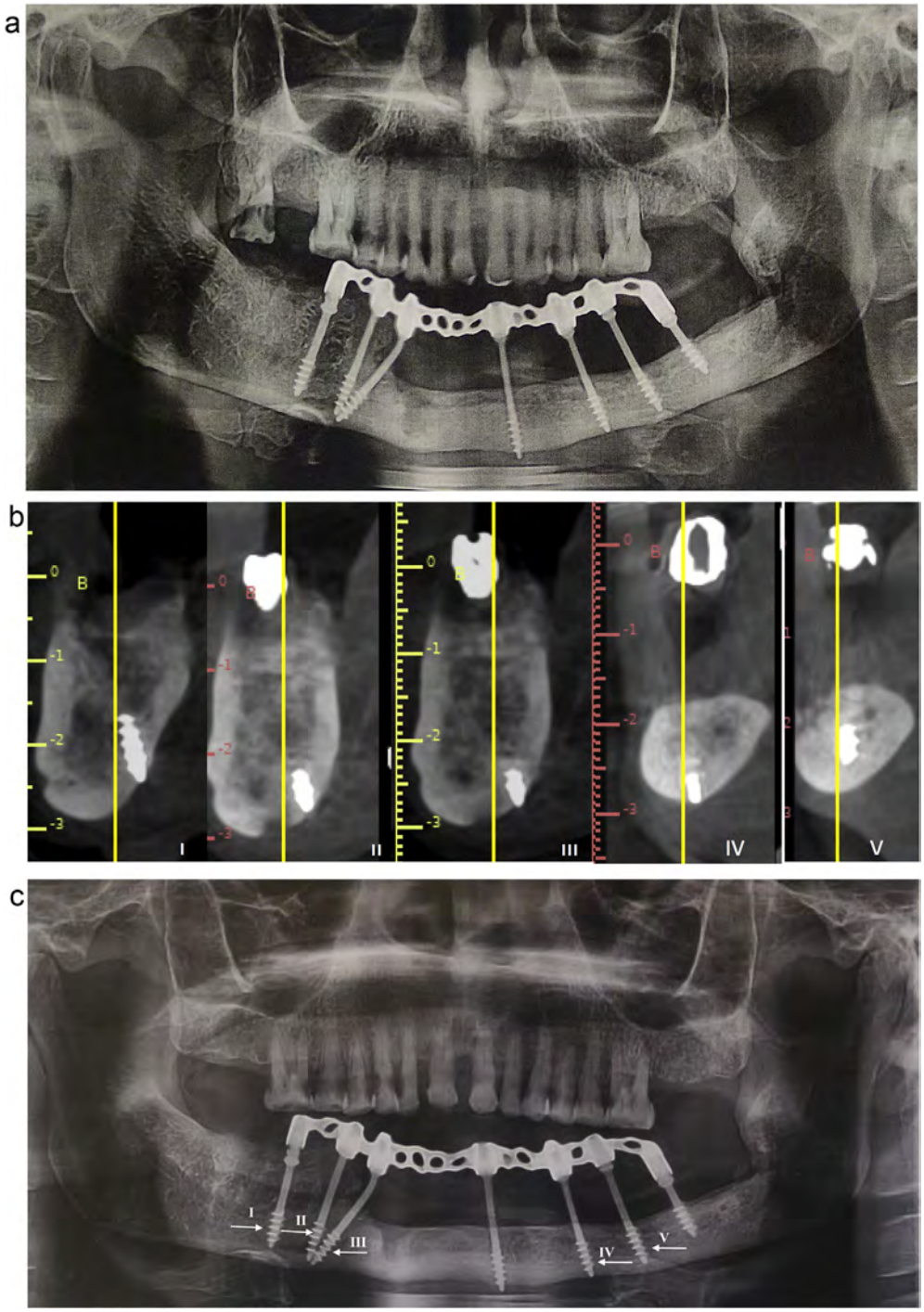

Fig. 7. The post-operative and follow up radiographs of the patient code no 02.
A. The panoramic radiograph of the patient at the 1-week follow-up visit (baseline).
B. Cone beam CT of patient code no 02, verifying the implant position in relation to the Inferior Alveolar Nerve at the area of: I. 46. II. 44. III.43. IV. 33. V. 35.
C. The panoramic radiograph of the patient at the 60-months follow-up visit.

other implant prostheses and six (6.2 %) by fixed prostheses; one (1%) of the implants was opposed by missing teeth (Table 1).

3.1. Implant survival and success rate

In accordance with the modified James–Misch health scale [35], all implants exhibited optimum health, with a 100 % success rate considering Albrektsson's [36] criteria for implant success and a 100 % survival rate, as none of the implants were lost.

3.2. Peri-implant tissue results

The Wilcoxon signed-rank test showed non-significant differences in the PI between the baseline and follow-up visits at the 3, 6, 9, 12, and 18-month follow-up visits and significant differences at 24, 36, 48, and 60- months as compared to baseline ($P = 0.414$, $P = 1.0$, $P = 0.366$, $P = 0.09$, and $P = 0.491$, $P = 0.004$, $P = 0.011$, $P = 0.047$, and $P = 0.002$ respectively; Table 2).

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Table 1
Patients and implant distribution within the sample.

Patients and implants' variables		Patients/Implants number (n)	Percentage%
Sex	Male	10	
	Female	5	
	Total	15	100 %
Implant distribution per region	Anterior	48 implants	49.5 %
	Premolar	26 implants	26.8 %
	Molar	23 implants	23.7 %
	Total	97 implants	100 %
Opposing dentition	Opposed natural dentition	74 implants	76.3 %
	Opposed implant supported prostheses	16 implants	16.5 %
	Fixed prostheses	6 implants	6.2 %
	Missing teeth	1 implant	1%
	Total	97 implants	100 %

Table 2
The mean plaque index (PI), calculus index (CI), modified gingival index (MGI), and probable pocket depth (PPD) throughout the follow-up intervals.

Peri-Implant soft tissue Index	Follow up- Visit	Mean	SD	P value
Plaque Index PI	Baseline	0.08	0.28	–
	3 months	0.06	0.24	0.414
	6 months	0.08	0.28	1.0
	9 months	0.05	0.22	0.366
	12 months	0.15	0.36	0.09
	18 months	0.11	0.32	0.491
	24 months	0.26	0.51	0.004
	36 months	0.23	0.45	0.011
	48 months	0.20	0.47	0.047
	60 months	0.26	0.51	0.002
Calculus Index CI	Baseline	0	0	–
	3 months	0	0	1.0
	6 months	0	0	1.0
	9 months	0	0	1.0
	12 months	0	0	1.0
	18 months	0	0	1.0
	24 months	0	0	1.0
	36 months	0	0	1.0
	48 months	0	0	1.0
	60 months	0	0	1.0
Modified Gingival Index	Baseline	0.67	0.66	–
	3 months	0.39	0.55	0.001
	6 months	0.12	0.33	0.001
	9 months	0.01	0.10	0.001
	12 months	0	0	0.001
	18 months	0	0	0.001
	24 months	0.08	0.28	0.001
	36 months	0.06	0.24	0.001
	48 months	0.03	0.17	0.001
	60 months	0.06	0.24	0.001
Probable Pocket Depth	Baseline	2.28	1.90	–
	3 months	1.55	1.47	0.001
	6 months	0.84	1.02	0.001
	9 months	0.32	0.65	0.001
	12 months	0.16	0.40	0.001
	18 months	0.05	0.22	0.001
	24 months	0.11	0.32	0.001
	36 months	0.21	0.41	0.001
	48 months	0.14	0.38	0.001
	60 months	0.22	0.44	0.001

Wilcoxon signed-rank test.

There was no change in the CI throughout the follow-up period (P = 1.0; Table 2).

There were statistically significant differences in the MGI between the baseline and all follow-up visits (all P = 0.001) according to the Wilcoxon signed-rank test (Table 2).

Statistically significant differences were also observed in the PPD between the baseline and all follow-up visits (all P = 0.001; Table 2).

3.3. Peri-implant bone level

Throughout the follow-up period, none of the implants were lost, mobile, or fractured. At the end of the 60 months' follow-up period, both the BIC and peri-implant bone levels had increased from the baseline levels. No features suggestive of peri-implantitis were detected around any of the implants (Figs. 6, 7).

3.4. Prosthesis results

Only one implant superstructure showed a fracture of the veneer material. For the same patient, the supra-structure prosthesis has been replaced, and an additional implant has been inserted at the 24 months follow-up visit for optimum esthetic and prosthesis's biomechanical results (Fig. 6 b,c). There were no instances of de-cementation, discoloration, metal-framework fracture, or wear of the opposing dentition. The amount of lip support and the extent of tooth exposure were acceptable in 93.3 % of the patients; lip support and the extent of tooth exposure were compromised in only one patient. No phonetic problems were detected in any of the patients (Table 3).

3.5. Patient satisfaction

All patients expressed their overall satisfaction with the outcome of the implant treatment and reported an improvement in esthetics, mastication, phonation, comfort, and self-esteem. They also said that they would choose the same treatment again (Table 4).

4. Discussion

This longitudinal study analyzed the treatment outcome of immediately loaded, fixed, basal implant-supported prostheses for oral rehabilitation of marginal mandibulectomy patients. Implants showed 100 % success and survival rates with an optimum peri-implant soft and hard tissue health.

Tumor resection is a lifesaving procedure that can adversely affect the functioning, esthetics, self-esteem, and quality of life of patients [1]. The main goal of mandibular reconstruction is to improve the health of patients, restore masticatory function, and maximize the patients' quality of life [1–5]. In comparison to traditional removable prostheses, implants provide a superior foundation for prosthesis retention and support [1]. In patients who have undergone marginal mandibulectomy, conventional implants increase the need for bone grafting, which might add to the resultant complications [1]. In contrast, basal implants do not require bone grafting, since they anchor into the basal bone, which is a considerable advantage in patients with maxillofacial defects [9,15–26]. They also permit the use of fixed implant-

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Table 3
Prosthesis evaluations parameters.

Complication type	Complication		Number of patients (N)		Percentage%
Prosthesis Complications	Pain		During function	1	6.7%
			Continuous pain	0	0%
			No pain	14	93.3 %
			Total	15	100 %
	Implant loss		0		0%
	Mobile implant		0		0%
	Fractured implant		0		0%
	Prosthesis de-cementation		0		0%
	Prosthesis discoloration		0		0%
	Veneer fracture		1		6.7%
	Framework fracture		0		0%
	Wear of the opposing dentition		0		0%
Esthetic Complications	Lip Support	Acceptable	14		93.3 %
		Not acceptable	1		6.7%
	Amount of teeth shown	Acceptable	14		93.3 %
		Not acceptable	1		6.7%
Phonetic	Acceptable		15		100 %
	Not acceptable		0		0%

Table 4
Demonstrates the patient satisfaction evaluations parameters.

	Parameter	Patient satisfaction	Number of patients (N)	Percentage %
Patient satisfaction	Esthetics	Satisfied	15	100 %
		Not satisfied	0	0%
	Mastication	Satisfied	15	100 %
		Not satisfied	0	0%
	Phonation	Satisfied	15	100 %
		Not satisfied	0	0%
	Comfort	Satisfied	15	100 %
		Not satisfied	0	0%
	Overall satisfaction	Satisfied	15	100 %
		Not satisfied	0	0%

supported prostheses, which do not require any contact with the oral mucosa, eliminate the risk of mucosal irritation, prevent frictional ulcers, and reduce mucosal pain and discomfort, as previously reported [10,41]. Takaoka et al. [10] reported the use of removable implant-supported prosthesis in a patient with marginal resection. During the follow-up, the patient complained of mucosal pain and discomfort that necessitated the construction of an alternative fixed prosthesis treatment, which significantly improved the patient's health and satisfaction. Hence, investigators documented some biological and mechanical complications with fixed-implant mandibular reconstructive prostheses, including plaque accumulation, peri-implantitis, and screw fracture/loosening [41,42]. The hygienic design and the smooth surface design of the implants used in this study reduced the possibility of plaque adherence, improved the patients' oral hygiene, and eliminated the biological complications reported with fixed implant-supported prostheses [18–20,22]. Moreover, the mono-block implant design diminished mechanical complications [18,16–26]. Furthermore, the use of fixed prostheses significantly improved patient psychology [10,21].

The implant survival rate in our study was 100 %, which matched the survival rate reported by Lazarov [20], who found a 97.5 % cumulative survival rate for BCS® after 4 years of function. In other studies on conventional endosseous implants [43–46], implant and prosthesis survival rates were 91 %–100 % and 96.4 %–100 %, respectively, over 1–6 years of follow-up. However, when considering the outcome of conventional implants in patients with maxillofacial defects, the implant survival rates reported in previous studies were lower (82.4 %–100 %) [47–50], probably because of the different types of bone grafts needed for placing such implants. The survival rate was approximately 97.2 % at the 12-month follow-up, 86.5 % at 60 months, and 79.3 % at 120 months when osseointegrated implants were used with a reconstructive free fibula flap. On the other hand, Yusa et al. [13] investigated the survival rates of 45 implants placed in the reconstructed and residual bone of patients with mandibular reconstruction; these were 92.6 % and 100 %, respectively.

Although the PI showed an increase at the follow-up visits in this study, the scores were still within the range of values reported in a previous study by Mombelli et al. [51], where they ranged from 0 to 3. Since the plaque adhered to the prostheses and not to the smooth surface of the implants, this insignificant increase in the PI may be attributed to the micropores of the acrylic resin veneer material, which is used to compensate for both the hard and soft-tissue loss associated with mandibulectomy. This result proved the observations of many other studies that reported plaque adherence over the acrylic prosthesis, even though it appears to be highly polished [52–56].

Despite the advancement in implant surfaces and textures, it has been scientifically proven that a smooth surface is better than a rough surface for implants, from a biological point of view. The surface texture is considered to be a crucial determinant for biofilm formation. As the rough surface of the implant is exposed to the oral cavity, it may permit the adherence of plaque biofilm. Moreover, the detachment or peeling of the surface coating under occlusal forces may aggravate the situation. Thus, the result of this study was in line with previous observations [12,18–23].

The excellent results obtained for the MGI in the present study might be related to the smooth polished surface and the thin mucosal penetration diameter of the implants, which permit quick peri-implant soft-tissue healing and result in a decrease or even elimination of both soft-tissue inflammation and infection. This trend was in agreement with the observations reported by Ihde et al. [18,19,29], Lazarov [20], Ahmad et al. [22], and Osman et al. [23].

However, the PPD increased from baseline, particularly when implants were immediately placed in extraction sockets. On com-

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pletion of socket healing, the pocket depth was significantly reduced or even eliminated. This observation was in accordance with the findings of previous studies [54,55] that reported sulci with depths greater than 5–6 mm around endosseous implants. Misch et al. [35], Cutrim et al. [57], Abreu et al. [58], Brägger et al. [59], and Sailer et al. [60], reported greater probing depths around dental implants than around natural dentition.

After 60 months of follow-up, all implants showed increased BIC values; this can be explained by the type of implant design used in this study, which permits very fast soft-tissue healing protecting the crestal bone, since implant splinting permits immediate loading of implants as well as better distribution of the occlusal force. These findings were in line with those obtained by Ihde et al. [18,19,29], Misch et al. [32,33,61], and others [62–64], who stated that splinted implants exhibit a better load-sharing area and decrease the risk of implant overload, thereby helping to decrease the extent of crestal bone loss. Avila et al. [65] also reported a higher success rate with splinted prostheses (94.7 %) than with single-crown implants. Additionally, the balanced occlusion used in this study prevented the offset forces and increased implant longevity, as also reported previously [64,66–68]. Moreover, the use of immediate loading stimulates the peri-implant bone and enhances the bone turnover around the implant, resulting in a more organized lamellar bone.

Clinical examination of the patient who experienced pain indicated that the pain arose from the immediately inserted implant after tooth extraction and was, therefore, more related to the healing process of the extraction socket than to the implant itself. The same observation was reported by Ihde et al. [18].

In the present study, only one patient showed fracture of the veneer of the crown. Clinical examination of this patient revealed a malaligned canine tooth opposing the fractured crown. The sharp canine tip could have caused the fracture when making contact during both protrusive and lateral movements. This result was in accordance with a study conducted by Goodacre et al. [67] who documented that 7% of the patients (range, 3–24 %) experienced a fracture of the acrylic resin of fixed and removable implant-supported prostheses. Moreover, several authors [67–70] have considered that acrylic and composite fractures comprise the majority of facial/occlusal veneer-material failures. In a study by Linkevicius et al. [68], more than half of the fractured prostheses showed contact in protrusive and/or lateral mandibular movements. On the other hand, Purcell et al. [69] reported that insufficient support for artificial teeth, either from the mandibular framework or denture base, or from premature anterior contacts, might cause acrylic tooth fracture. Priest et al. [70] found that the most common prosthetic complication associated with the use of mandibular metal–acrylic resin implant complete fixed dental prostheses was the need for replacement of denture teeth as a result of wear or fracture.

Our examination of the patient who reported esthetic complications revealed that an extra-oral incision (midline lip splinting incision) had led to a depressed lower lip due to post-operative scaring; thus, and increased amount of teeth were shown when the patient smiled (Figs. 2a and 5 d). This observation was in line with the literature concerning the disadvantages of the midline lip splinting technique and stressed the need for using a modified technique with a more esthetic result [71,72]. The patient in the present study was reassured.

Patient satisfaction in the present study was in line with that in other studies where dental implant prosthetic rehabilitation had significantly improved the maxillofacial patients' oral function and postoperative quality of life [13,15,16]. In accordance with this observation, a significant improvement in patient satisfaction (a score of 7.7 out of 8) was reported by Awadalkreem et al. [21] following basal implant treatment. Overall, 96.7 % of the participants rated their comfort following the use of basal implant-supported prostheses as excellent, 93.3 % of participants assessed their satisfaction with mastication as excellent, and 88.3 % rated their esthetic satisfaction as excellent. Finally, 93.3 % of the patients evaluated their speech as excellent after basal implant treatment [21].

The limitations of this study include the relatively small sample size and the short follow-up period. Future studies with larger sample sizes and more extended follow-up periods will enhance clinical decision-making and improve the treatment outcomes.

5. Conclusion

The results of our study suggest that the use of immediately loaded, fixed implant prostheses supported by BCS® implants is a practicable treatment modality with a high success rate and survival rate (100 %). The patients in this study also exhibited optimum implant health and reported an improvement in their satisfaction and quality of life.

Ethical approval

Ethical approval for the study was obtained from the Ethics Committee of the relevant hospital as well as the Ethics Committee of the Ministry of Health, number: [WK/OS/ AETEA/44].

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Author contribution statement

All authors contributed to the conception, design, data analysis and interpretation, as well as the drafting, critical evaluation, approval of the article, and agreed to its publication.

Declaration of Competing Interest

The authors report no declarations of interest.

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