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Original Article

Success and survival rates of immediate anatomic zirconia implants: a prospective clinical and radiographic evaluation

Mohammed Yamen Al-Shorbaji Al-Moziek[1], Issam AlKhouri[1], Rami Shurbaji Mozayek[2*]

[1] Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Damascus University, Damascus, Syria.

[2] Department of Prosthodontics, Faculty of Dentistry, Syrian Private University, Damascus, Syria.

Corresponding author:
Rami Shurbaji Mozayek
Department of Prosthodontics, Faculty of Dentistry, Syrian Private University.
Damascus, Syria.
Email: ramishm88@gmail.com

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Modern immediate titanium implants have two major drawbacks which are the black metal appearance that might be seen through the mucosa and the gap between implant and extraction socket. Immediate anatomical zirconia implants were introduced to match the shape of the extracted root and fill the socket without gaps while still providing better metal-free appearance. **Aim:** This study aims to investigate success and survival rates of immediate anatomical zirconia implants. **Methods:** This prospective interventional study was held between 2017 and 2020 in the faculty of dental medicine, Damascus University, Syria. The sample consisted of 27 immediate anatomical zirconia implants in 21 patients from both genders. Implants were designed and manufactured starting from CBCT image and prior to extraction. Specialized software applications were used to modify implant design. Implants went through different processing procedures to make them ready for insertion immediately after tooth extraction. Restorations were made after a minimum period of 3 months, clinical and radiographic follow ups were performed after 10 - 13.5 months from restoring the implants in order to evaluate their success/survival. Repeated measures ANOVA was used to assess marginal bone loss, t test for probing depth assessment. **Results:** Immediate anatomical zirconia implants showed success in (n=17) 63% of total cases, satisfactory survival (n=3) 11.1%, compromised survival (n=2) 7.4% and they failed in (n=5) 18.5%. **Conclusions:** Immediate anatomical zirconia implants had low success/survival rates when compared to conventional immediate implants. Therefore, they cannot be considered as a predictable alternative in their current form.

Keywords: Dental implants. Tooth extraction. Tooth root.

Introduction

Dental implants are the most favorable choice for replacing missing teeth since they achieve high success rate (90-100%)[1]. However, it was preferred to wait 6-9 months after tooth extraction to have a complete healing before the insertion of dental implants which was known as late implant placement, this period is becoming shorter with more advancement in dental materials and surface treatment methods and nowadays implant insertion can be done after 2-3 months of the extraction, that was called early implant placement[2,3]. Recent studies showed that dental implants can be inserted in the same day of extraction in carefully selected cases (immediate implant placement)[4]. After clinical and radiographic follow-up, immediate implantation showed similar results and success rate compared to late and early implantation[2,3]. On the other hand, screw shaped immediate implants have the disadvantage of mismatching the alveolar socket which leads to gap formation that needs to be filled with bone graft to prevent epithelial and connective tissues growth toward this gap space especially when the distance between alveolar crest and implant neck is more than 2mm[5].

In 1969, Hodosh was the first to try solving this mismatching problem in immediate implants by using custom made implants that matches the extracted root, this technique reduced bone and soft tissue trauma. But since PMMA (Poly methyl methacrylate) was used to make the implants osseointegration could not be achieved but rather a soft-tissue capsule was formed resulting in implant failure[6]. In 1992, titanium was used instead of PMMA for making implants in the same previous technique and osseointegration was achieved in 88%[7]. In 2001 zirconia root-shaped implants were introduced and 100% primary stability in the first month was obtained but due to high failure rate in 12months follow-up these implants were not recommended for clinical use until more modifications were made and clinical evidence for stability and osseointegration was confirmed[8,9]. Pirker and Kocher added proximal macro-retentions for the root-shaped zirconia immediate implants. This addition increased the survival rate to 92% in 12 months follow-up period and achieved excellent aesthetic and functional aspects with minimal bone resorption and gingival recession[4].

Literature has so few studies regarding zirconia root-shaped immediate implants and most of them are just case reports[6-8]. More studies are needed to confirm this technique as an alternative treatment plan. Thus, this study aims to: Investigating success and survival rates of immediate anatomical zirconia implants

Materials and Methods

A prospective interventional study was conducted between September 2017 and July 2020 at the Department of Oral and Maxillofacial Surgery, Faculty of Dental Medicine, Damascus University, Syria. This study was approved by the ethics committee of Damascus University (scientific research council decision no.940 date 30/1/2017) and an informed consent was signed by every participant.

27 immediate anatomical zirconia implants were inserted for 21 patients with indication for one or more dental extraction (3 patients received 2 implants each, one patient received 4 implants and 17 patients received on implant each). 5 implants were placed in the anterior region of the maxilla, 3 implants were placed in the anterior region of the while 12 implants were placed in the premolars region of the maxilla, 7 implants were placed in the premolars region of the mandible; Sample size was calculated using G-power software with significance level 0.05 and effect size 0.763[10]. 17 implants were inserted in the maxillary arch and 10 implants in the mandible. These patients fulfilled the following eligibility criteria:

Eligibility criteria

Patients with age over 18 years with clear indication for extraction such as (unrestorable tooth, deep root caries, and longitudinal fracture), having normal position of the tooth that needs to be extracted with natural opposing dentition and no traumatic occlusion were included. The integrity of the surrounding alveolar bone was checked with no acute infection in the surgical site and good oral hygiene was included. No systemic diseases or conditions preventing surgical procedures such as diabetes, pregnancy and chemotherapy were present.

Alcoholic, heavy smokers (more than 20 cigarettes per day) and teeth with irregular root shape were excluded.

After thorough clinical examination, CBCT was obtained to evaluate tooth dimensions then designing a 3D model of the anatomical implant by using several software programs: MIMICS® (Materialise's Interactive Medical Image Control System) (Materialise N.V., Leuven, Belgium), 3-Matic® V13.0 (Materialise N.V., Leuven, Belgium), Autodesk Meshmixer V3.5. 0.5mm macro retentions were added on proximal surfaces, bucco-lingual dimension was reduced by 0.1-0.2 mm whereas the coronal part was modified as a prepared abutment with shoulder finishing line (fig. 1).

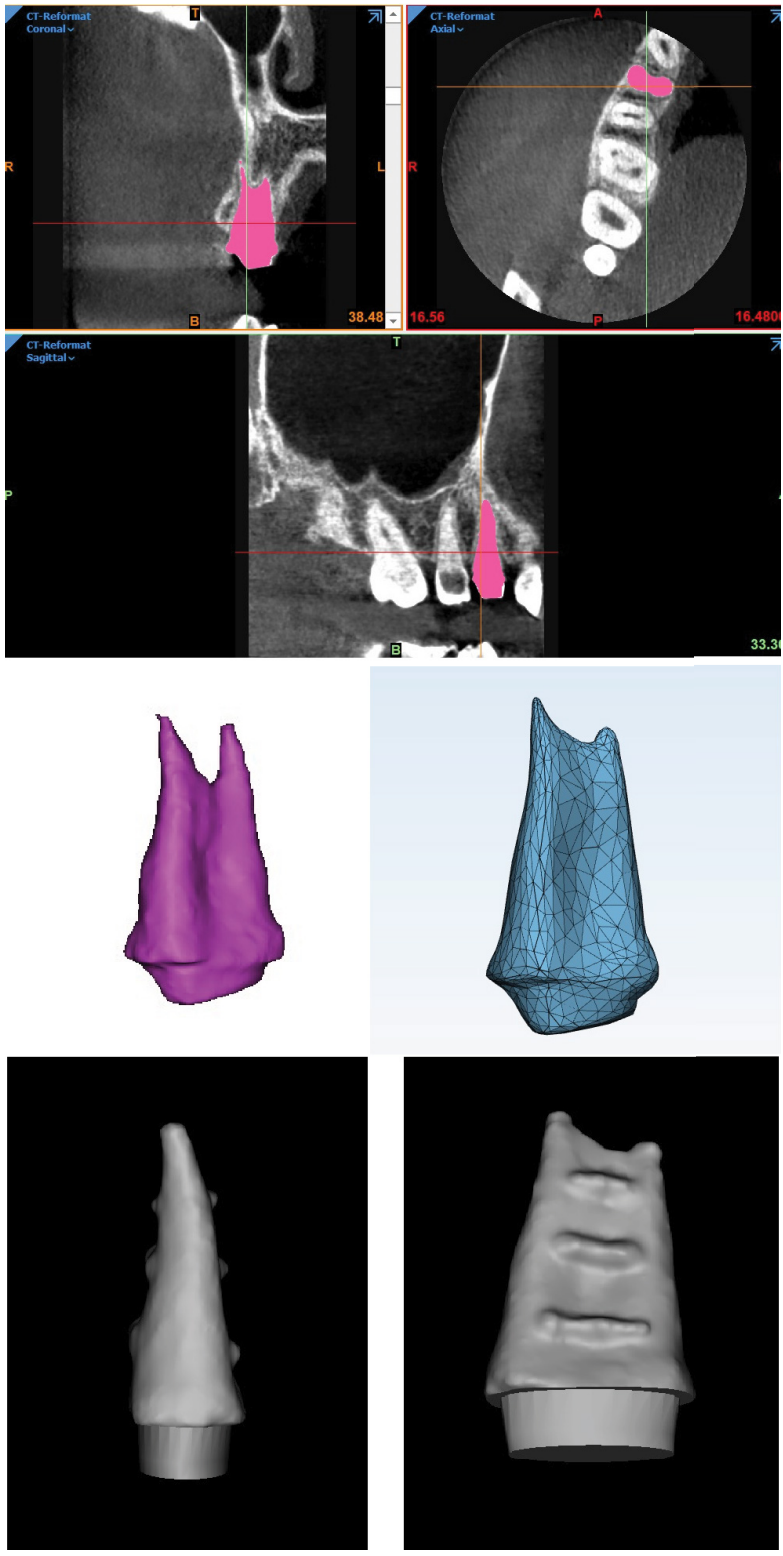

Figure 1. Designing the 3D model of the anatomical implant.

With the help of a CAD-CAM system, zirconia (Y-TZB) implants were manufactured according to the designed models. Implant root surface was sandblasted with 50μ aluminum oxide powder for 0.5 second under pressure of 5 bar[11].

Then implant was put in a furnace in 1500ºC for 8 hours to complete zirconia sintering followed with 99% ethanol bath in ultrasonic cleaning device for 10 minutes and another 10 minutes with distilled water. After that implant root was submerged in 70% hydrofluoric acid solution for 24 hours in room temperature to have surface micro-roughness[12], then it was returned to the ultrasonic ethanol and distilled water baths for 10 minutes each to completely clean the implant surface from any residual contaminants. The implant was packaged and sterilized with gamma radiation (2.5 RAD)[13].

Surgical stage

Oral cavity was disinfected with chlorhexidine (CHX) mouthwash, then atraumatic extraction with suitable elevators and forceps was performed. Immediate anatomical zirconia implant was inserted with finger pressure or by gentle taps on a surgical mallet when needed. Primary stability was evaluated with palpation and percussion, and radiographic evaluation with CBCT was done immediately after surgery. Prosthetic stage was initiated after at least 3 months and zirconia restoration was cemented (fig. 2).

Follow up

Clinical and radiographic follow-ups were made according to the following time table: Pre-surgery stage, immediately after surgery (T0), prosthetic stage (T1): 3 - 4.5 months after T0, Follow up stage (T2): 10 - 13.5 months after T1.

Radiographical settings were

Field of view (FOV) 5x5 cm, voxel size 0.3mm, 85kV, 15mA and exposure time 9 seconds; radiographical follow-ups included the assessment of vertical marginal bone loss around implant in T1 and T2 (fig. 3).

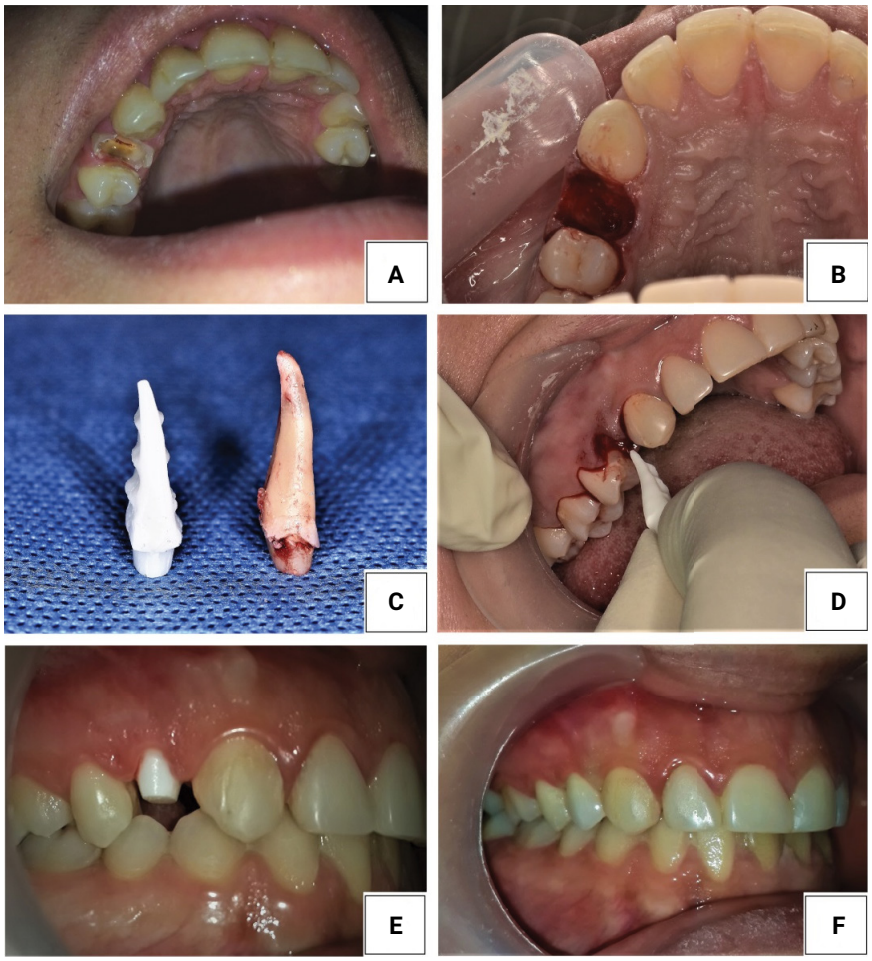

Figure 2. Clinical stages for placing immediate anatomical zirconia implant. (A) Before tooth extraction (B) Immediately after extraction (C) Natural extracted tooth and correspondent immediate anatomical zirconia implant (D) Inserting the immediate anatomical zirconia implant into the socket. (E) Implant inside alveolar socket (F) After definitive restoration cementation.

Clinical follow-ups included the evaluation of the following

Implant success/survival was evaluated according to the international conference of oral implantologists held in Italy in 2007 (table 1)[14], Probing depth (fig. 4) was measured in 4 sides and the average was calculated for every stage then the differences between averages were assessed, Percussion test in T1 and T2 (as positive percussion is the unique crystal sound indicating rigid fixation or osseointegration)[15,16], Clinical mobility was assessed by palpation with blunt end instrument in T1 and T2, Pain on pressure in T1 and T2, Implant success and survival in T1 and T2.

Statistical Analysis

Repeated measures ANOVA was used to assess marginal bone loss, t test for probing depth assessment. P-value <0.05 was considered statistically significant. Statistical analysis was carried out by SPSS v.25 software.

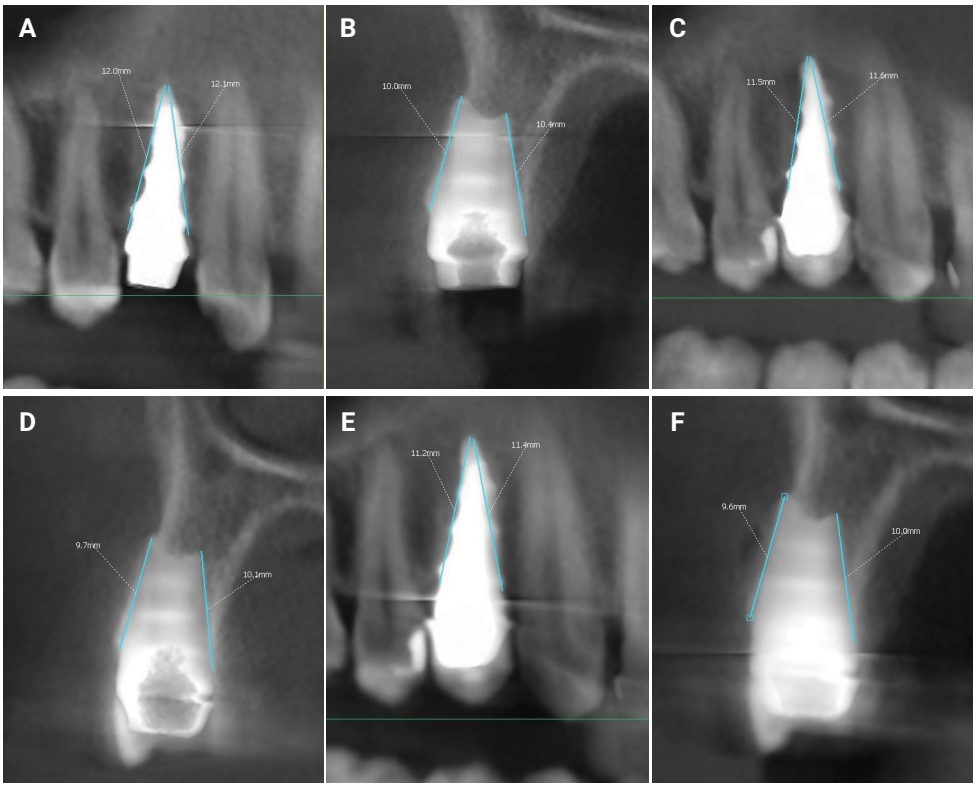

Figure 3. Vertical marginal bone loss around immediate anatomical zirconia implant (A,B) bone measurement in T0 (C,D) bone measurement in T1 (E,F) bone measurement in T2.

Table 1. Implant Quality Scale

I. Success (optimum health)	a) No pain or tenderness upon function
	b) 0 mobility
	c) less than 2 mm radiographic bone loss from initial surgery
	d) No exudates history
II. Satisfactory survival	a) No pain on function
	b) 0 mobility
	c) 2–4 mm radiographic bone loss
	d) No exudates history
III. Compromised survival	a) May have sensitivity on function
	b) No mobility
	c) Radiographic bone loss more than 4 mm (less than 1/2 of implant body)
	d) Probing depth more than 7 mm
	e) May have exudates history
IV. Failure (clinical or absolute failure)	Any of following:
	a) Pain on function
	b) Mobility
	c) Radiographic bone loss more than 1/2 length of implant
	d) Uncontrolled exudate
	e) No longer in mouth

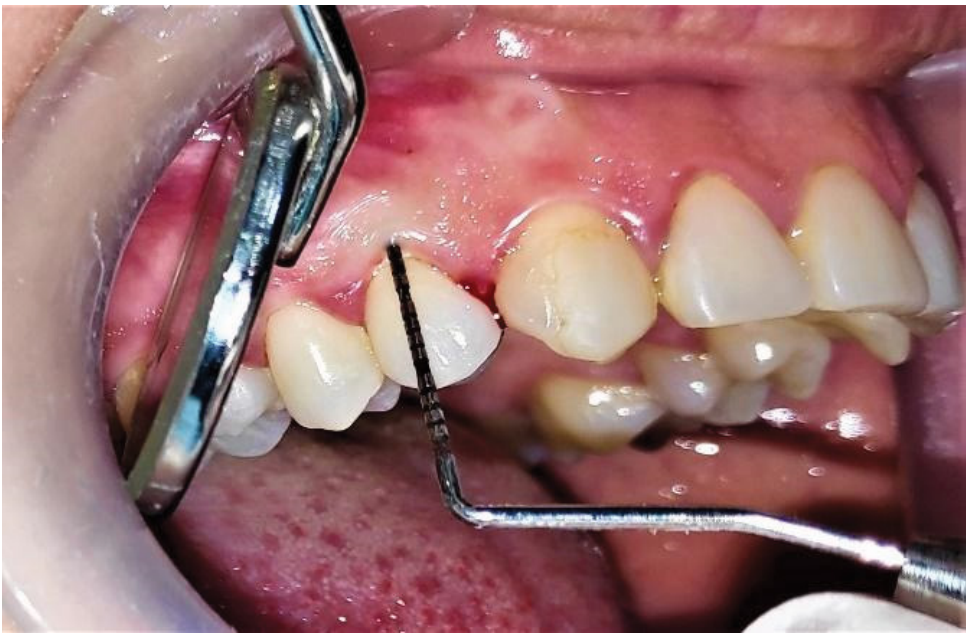

Figure 4. Probing depth.

Results

Sample consisted of 27 immediate anatomical zirconia implants inserted for 21 patients [(n=7) 33.3% males and (n=14) 66.7% females] aged between (21-55 years), 17 implants were inserted in the maxilla and 10 in the mandible, and their total length ranged between 13.1 - 20mm.

At T1, (n=23) 85.2% implants survived and (n=4) 14.8% of the implants failed which were excluded from further statistical study. The implants were considered successful in (n=21) 77.8% of cases, satisfactory survival in (n=2) 7.4% and compromised survival in (n=0) 0%.

At T2, (n=22) 95.65% implants survived and (n=1) 4.35% of the implants failed. The implants were considered successful in (n=17) 73.91% of cases, satisfactory survival in (n=3) 13.04% (3 implants showed vertical bone resorption more than 2 mm) and compromised survival in (n=2) 8.7% (2 implants showed vertical bone resorption more than 4mm with bleeding index of 2,3). In 3 of the failed cases the patients stated that they were having hard food when they first felt mobility in their implants whereas for the remaining 2 implants the patients stated that they started to feel an increasing mobility till the failure occurred. Follow-up results of implants success/failure results are shown in (table/fig. 2).

Table 2. Count and percentage for implants success/ failure

	Count	percentage
Osseointegration	**22**	**81.5%**
Success	17	63.0%
Satisfactory survival	3	11.1%
Compromised survival	2	7.4%
Failure	**5**	**18.5%**
Before restoration	4	14.8%
After restoration	1	3.7%
Total	**27**	**100%**

The average vertical bone loss was 0.70±0.61 mm between T0 - T1, 0.68±0.58 mm between T1 - T2 and in total 1.38±1.19 mm between T0 - T2, the results were statistically significant for the difference in vertical bone averages in studied time groups (p<0.05) (table 3).

Table 3. Repeated-Measures ANOVA for average vertical bone loss

	Side	Mean	Std. deviation	Minimum	Maximum	95% confidence interval for Mean		P value
						Lower Bound	Upper Bound	
T0 – T1	Mesial	0.68	0.61	0.20	2.40	0.41	0.95	
	Distal	0.72	0.66	0.10	2.50	0.43	1.01	
	Buccal	0.75	0.64	0.00	2.50	0.47	1.03	
	Lingual	0.65	0.60	0.00	2.50	0.38	0.92	
	Mean	0.70	0.61	0.08	2.45	0.43	0.97	0.000284
T1 – T2	Mesial	0.72	0.62	0.10	2.30	0.45	1.00	
	Distal	0.70	0.63	0.20	2.40	0.43	0.98	
	Buccal	0.67	0.59	0.10	2.20	0.41	0.93	
	Lingual	0.62	0.54	0.10	2.00	0.38	0.86	
	Mean	0.68	0.58	0.18	2.20	0.42	0.94	0.000056
T0 – T2	Mesial	1.40	1.20	0.50	4.60	0.87	1.94	
	Distal	1.42	1.24	0.40	4.90	0.87	1.97	
	Buccal	1.42	1.15	0.10	4.60	0.91	1.93	
	Lingual	1.27	1.09	0.10	4.50	0.79	1.75	
	Mean	1.38	1.15	0.30	4.65	0.87	1.89	0.000035

Repeated-Measures ANOVA test: p < 0.0005

Average probing depth was 2.19±1.10 mm in T1 and 2.55±1.22 mm in T2 with statistical significance (P<0.05) (table 4).

Table 4. T test for probing depth difference between T1 and T2

T value	P value	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
				Lower	Upper
-4.247	0.0001	-0.46	0.31	-0.87	-0.30

Percussion test results were positive in (n=23) 85.2% of cases and negative in (n=4) 14.8% in T1. In T2 the four failed implants were not included in statistical calculations so the total number of studied implants in T2 was 23 implants, (n=22) 95.65% of the remaining surviving implants were positive and (n=1) 4.3% were negative.

Mobility was recorded in (n=4) 14.8% of implants in T1 and in (n=1) 4.3% of the surviving implants in T2.

Pain on pressure was observed in (n=4) 14.8% of implants in T1 and (n=1) 4.3% of the surviving implants in T2. Follow up results are shown in (table 5).

Table 5. Follow-ups results

	T1	T2
average vertical bone loss	0.70±0.61 mm	0.68±0.58 mm
Average probing depth	2.19±1.10 mm	2.55±1.22 mm
Positive percussion test	(n= 23) 85.2%	(n=22) 95.7%
Mobility	(n= 4) 14.8%	(n= 1) 4.3%
Pain on pressure	(n= 4) 14.8%	(n= 1) 4.3%

Discussion

Using immediate anatomical implants eliminate the gap formation between implant and alveolar socket so there will be no need for using bone grafts[4]. Besides, using zirconia implants enhances aesthetic aspects especially in the anterior region and reduces plaque accumulation with less inflammation in the surrounding soft tissue. In addition, zirconia possesses high biocompatibility and mechanical properties which suits dental implants[4,17-18].

The method described in this study for immediate anatomical zirconia implants introduced the advantage of having anatomical implants prior to extraction so they can be applied to the fresh socket in the same appointment unlike what was used in previous studies for immediate zirconia anatomical implants where laser scanning was done to the extracted tooth and then the implant was manufactured, this procedure usually takes 4-7 days and will increase the chance of failure due to fibrous tissue formation around implant instead of osseointegration[4,8,19,20].

Proximal protrusions were added to the implant design to play the role of macro-retentions which provided more primary stability by engaging to the bone of the proximal spaces, also bucco-lingual dimension was reduced by 0.1-0.2 mm to protect the thin

buccal plate from fracturing while inserting the implant and to prevent bone resorption due to implant pressure on buccal bone[4].

In this study, the immediate anatomical zirconia implant success, survival and failure rates after one year follow-up were evaluated in accordance with the classification that describes implant condition from the consensus conference of the international congress of oral implantologists held in Pisa, Italy, 2007[14].

Percussion test is one of the simplest tests that can be done to evaluate osseointegration of dental implants. However, this test is considered subjective and depends mainly on the practitioner's expertise and cannot be solely relied on, thus this study also used pain on pressure and clinical implant mobility as indices to determine osseointegration in addition to percussion test[15,16].

4 out of 27 of the immediate anatomical zirconia implants (14.8%) showed no resonant (Crystal) sound on percussion and some pain when applying finger pressure on their abutments in addition to having clinical mobility in the pre-prosthetic stage between T0 -T1, these implants were considered failure. One more of the remaining implants showed no resonant (Crystal) sound, pain on mastication and clinical mobility at follow-up in T2 and was also considered failure; this increased the total failed implants to 18.5%. The negative percussion test result, presence of pain and clinical mobility were present altogether in all failing cases and absent when osseointegration is observed, this is consistent with what Pirker and Kocher stated[4].

Pain on percussion was found only in the cases of failed implants and it was associated with clinical mobility and dull percussion sound, this was also consistent with what Pirker and Kocher stated[4].

Probing depth mean increased from T1 to T2 by 0.36mm with statistical significance, that was consistent with what Pirker and Kocher stated about soft tissue response in their study of immediate anatomical zirconia implants (Soft tissue retraction ranged from 0–1.5 mm (0.5±0.7mm)[4].

In the current study, survival rate in T2 was 81.5%. In other studies regarding immediate screw-shaped titanium implants survival rate ranged between 94.6 – 96.9% which was higher than the result for immediate anatomical zirconia implants discussed in this article[21-23]. The survival rate was 100 % for anatomical implants made with direct laser metal sintering technique (DLMS)[10], 94.4% for anatomical hybrid implants (Replicate system/ NDI) with titanium root and zirconia abutment[24]. Thus zirconia anatomical implants as they were described in this study are still less predictable than other techniques and materials in immediate implantation.

The total failure rate was 18.5%, 14.8% were before prosthetic stage and 3.7% after. Failing in early stage was also stated in other immediate implantation studies[4,24,25] [table/figure 10] and it can be explained with: Not achieving enough primary stability to withstand the immediate load on implants, trauma caused by having hard food before osseointegration, failure to achieve osseointegration because of zirconia implants surface treatment. All failed implants were removed and sockets were curetted and washed with normal saline, no inflammatory signs or other changes were seen in the sockets. This could be due to zirconia high biocompatibility.

The limitations of this study were: Bone density around implants could not be assessed in CBCT images due to metal artifact around zirconia. Primary stability could not be measured using resonance frequency analysis because this technique uses a transducer that connects firmly to implants or abutments and that transducer is not available for custom made implants.

In conclusion, immediate anatomical zirconia implants as they were described in this study showed low survival and cannot be considered a predictable treatment plan. Also the increase of early stage failure in immediate anatomical zirconia implants can be explained with not achieving adequate primary stability for the implant. This type of implants has strict indications and application criteria and still needs more research.

Data Availability

Datasets related to this article will be available upon request to the corresponding author.

Conflict of Interests

None.

Author Contribution

Study conception and design: Mohammed Yamen Al-Shorbaji Al-Moziek, Issam AlKhouri, Rami Shurbaji Mozayek.

Data collection: Mohammed Yamen Al-Shorbaji Al-Moziek.

Analysis and interpretation of results: Mohammed Yamen Al-Shorbaji Al-Moziek, Issam AlKhouri, Rami Shurbaji Mozayek.

Draft manuscript preparation: Mohammed Yamen Al-Shorbaji Al-Moziek, Rami Shurbaji Mozayek.

All authors actively participated in the discussion of the manuscript's findings, and have revised and approved the final version of the manuscript.

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