Systematic Review of Literature of Cemented Femoral Components: What Is the Durability at Minimum 20 Years Followup?

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Abstract

Background Cemented femoral total hip arthroplasty may be one of the most successful surgical interventions of all time. However, although results are very encouraging over the early to mid-term followup, relatively few studies have analyzed the durability of these implants beyond 20 years followup. To evaluate the performance of contemporary implants, it is important to understand how previous implants perform at 20 or more years of followup; one way to do this is to aggregate the available data in the form of a systematic review.

Questions/purposes (1) How durable is cemented femoral fixation in the long term (minimum 20-year followup) with

respect to aseptic loosening? (2) Is the durability of cemented femoral fixation dependent on age of the patient? (3) Are the long-term results of the cemented femoral fixation dependent on any identifiable characteristics of the prosthesis such as surface finish?

Methods A systematic review was performed to identify long-term studies of cemented femoral components. After application of inclusion and exclusion criteria to 1228 articles found with a search in PubMed and EMBASE, 17 studies with a minimum of 20-year followup on cemented femoral components were thoroughly analyzed in an attempt to answer the questions of this review. The quality of the studies reviewed was assessed with the Methodological Index for Nonrandomized Studies (MINORS) instrument. All studies were case series and cohort sizes ranged from 110 to 2000 hips for patients older than 50 years of age and 41 to 93 hips for patients younger than 50 years at the time of surgery.

Results Among the six case series performed in patients older than 50 years of age, survivorship for aseptic loosening of the femoral component ranged from 86% to 98% at 20 years followup. There were no obvious differences for younger patients when analyzing the five studies in patients younger than age 50 years in which survivorship free from aseptic loosening for these studies ranged from 77% at 20 years in one study and 68% to 94% at 25 years in the other studies. Although data pooling could not be performed because of heterogeneity of the studies included here, it appeared that stems with a rougher surface finish did not perform as well as polished stems; survivorship of stems with rougher surface finishes varied between 86% and 87%, whereas those with smoother finishes ranged between 93.5% and 98% at 20 years.

Conclusions Excellent long-term fixation in both older and younger patients can be obtained with cemented,

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polished femoral stems. These results provide material for comparison with procedures performed with newer cementing techniques and newer designs, both cemented and cementless, at this extended duration of followup.

Introduction

Cemented femoral THA may be one of the most successful surgical interventions of all time. Although results are very encouraging over the early to mid-term followup period, patients are living longer and undergoing THA at younger ages, so it is important to analyze the durability of these implants beyond 20 years followup.

There have been many reports in the literature regarding the second-decade followup of THA, specifically cemented THA, but few studies have investigated results beyond the 20-year followup period—a service life that may be relevant in particular for younger patients undergoing the procedure—and thus it seems necessary to aggregate data on earlier cemented implants to provide a basis for comparison against any changes in operative technique or implant design that since have occurred.

We therefore attempted to answer the following questions regarding cemented femoral component fixation: (1) How durable is cemented femoral fixation in the long term (minimum 20-year followup) with respect to aseptic loosening? (2) Is the durability of cemented femoral fixation dependent on the age of the patient? (3) Are the long-term results of the cemented femoral fixation dependent on any identifiable characteristics of the prosthesis such as surface finish?

Materials and Methods

A systematic review was performed to identify long-term studies of cemented THA, specifically cemented femoral components. A search was performed using EMBASE and PubMed databases with the following query phrase: ((Cemented) AND (total hip arthroplasty)) AND (((Charnley) OR (Exeter)) OR (((long term) OR (long-term)) AND ((follow up) OR (follow-up) OR (survivorship) OR (results) OR (outcomes))) OR (((minimum) OR ((follow-up) OR (follow up))) AND (((twenty year) OR (twenty-year) OR (20 year) OR (20-year)) OR ((twenty-five year) OR (twenty five year) OR (25 year) OR (25-year)) OR ((thirty year) OR (thirty-year) OR (30 year) OR (30-year)) OR ((thirty five year) OR (thirty-five year) OR (35 year) OR (35-year)))). The search terms “Charnley” and “Exeter” were specifically included given that a large majority of long-term THA studies report on these prostheses. Studies with a minimum

of 20 years followup of primary, cemented femoral components were included in this review. Studies consisting of disease-specific cohorts (ie, developmental dysplasia, avascular necrosis, rheumatoid arthritis, etc) were excluded as were biomechanical articles and articles without human cohorts. Any studies without a minimum of 20 years of followup, regardless of average followup duration, were excluded. Given that authors only speak English, articles in any other language were also excluded. With our initial search query, a total of 1228 articles were identified on the subject matter. After application of our inclusion and exclusion criteria, a review of the references of the full text that were evaluated for inclusion was also performed to search for any citations that may not have been included in the initial search; a total of 17 articles were included for review (Fig. 1). We did not hand-search conference proceedings as a means of gathering data for this review.

Each study was reviewed in detail by two authors (JJC, NAB) for demographic information; component information and cementing technique; length of followup; and rates of revision for any reason, revision of femoral component for aseptic loosening, radiographic evidence of loosening (not including revised for loosening), and femoral osteolysis. Attempts were made to extract data for these variables in terms of rates of a given outcome per entire cohort as well as the number of hips at risk at time of followup to present a data set that would be more uniformly comparable across various studies. All studies were case series and cohort sizes ranged from 110 to 2000 hips for patients older than 50 years of age at time of primary THA to 41 to 93 hips for patients younger than 50 years of age at the time of primary THA. The quality of the 17 studies included in this review was evaluated using the validated Methodological Index for Nonrandomized Studies (MINORS). The average MINORS score for these 17 studies was 10 with a range of 7 to 11 [24]. Data pooling (meta-analysis) was not performed because the studies were retrospective, heterogeneous, and diverse in their inclusion

Fig. 1 Flowchart depicts application of inclusion and exclusion criteria to search query results.

and exclusion criteria. We therefore present our results as ranges of survivorship (or reoperation frequencies), as reported by the primary source studies that we included.

To answer our first question on overall survivorship free of aseptic loosening, 13 long-term followup studies on nine different cohorts of (two cohorts reported more than once at various followup intervals) cemented THA, all performed at least at a minimum of 20 years of followup, were identified (Table 1). The majority of these studies (10 of 13) were performed on the Charnley THA (Formerly Thackery, now DePuy, Leeds, UK, or Zimmer, Warsaw, IN, USA) with three additional long-term studies performed on the Harris Design-2 (Howmedica, East Rutherford, NJ, USA) [19], Exeter (Stryker, Newbury, UK) [16], and Müller straight stem (Zimmer, Winterthur, Switzerland) [8].

To evaluate stem survival in older versus younger patients (using the age of 50 years as our cutoff), we found four studies of three cohorts (one cohort reported at minimum 20 and 25 years) identified in our literature search (Table 2).

Only two studies speaking to our third research question (on surface finish) met our inclusion criteria [8, 23]. These pertained to the Harris Design-2 (Howmedica) and the Müller straight stem (Zimmer, Winterthur, Switzerland), which have an average roughness (Ra) of 0.8 μm and 0.5 to 1.5 μm (mean, 1.0 μm), respectively, as opposed to the polished Charnley or Exeter stems in the remaining cohorts.

Results

Aseptic Loosening

Kaplan-Meier survivorship at 20 years for the endpoint of revision of the femoral component for aseptic loosening ranged from 86% to 98% survival for studies reporting this data [8, 14, 16, 22, 23]. Even in the worst-case scenario analysis performed by Ling et al. [16], in which all hips with unknown revision status at minimum 20 years were considered to be revised for aseptic loosening, Kaplan-Meier survivorship at 20 years was still 85.6% at the endpoint revision of femoral component for aseptic loosening. No other studies that we found provided worst-case analyses, but had some done so, some survival estimates in the worst case would have been much lower, because loss to followup was as high as 16% (11 of 68 hips) [19]. Revisions for aseptic loosening of the stem ranged from 2% (six of 336 hips [14]) to 5% (18 of 333 hips [12]) of all hips studied in the minimum 20-year followup cohorts [12, 14, 16, 22, 23]. Revision rates for aseptic loosening for these same cohorts ranged from 3% (three of 94 hips [22]) to 5% (five of 91

hips [14]) when analyzing only hips with complete minimum 20-year followup. There was an additional 4% (four of 94 hips [22] and four of 91 hips [14]) to 57% (39 of 333 hips [12]) of hips with radiographic evidence of loosening in cemented stems with minimum 20-year radiographs in studies reporting these data [12, 14, 22].

Seemingly similar durability rates continued to be demonstrated at even further followup intervals with four cohorts being followed to a minimum of 25 years of followup and still demonstrating a 89.8% to 93% survivorship free from revision of the femoral component for aseptic loosening and a 3% (nine of 330 hips [3] and 10 of 357 hips [2]) to 4% (eight of 228 hips [20]) revision rate for revision of the stem for aseptic loosening (Table 1) [1–3, 20]. The longest identified followup of a cemented femoral component was performed by Callaghan et al. [4] who followed a cohort of 330 primary, Charnley THAs for a minimum of 35 years. Only 10% of stems followed for 35 years were revised for aseptic loosening and 35-year survivorship free of revision of stem for aseptic loosening in that series was 93%. There was also a 12% radiographic evidence of loosening in hips followed for a minimum 35 years.

Stem Survival in Patients Younger Than 50 Years of Age

Callaghan et al. [5] and Keener et al. [13] reported 94% and 93% survivorship of the femoral component at 20 and 25 years, respectively, for the endpoint of aseptic loosening in a cohort of 93 patients younger than 50 years old at the time of index THA. Aseptic loosening (including hips revised for loosening and radiographic evidence of loosening) was present in 18% and 22% in this cohort at 20 and 25 years postoperatively, respectively (13 of 72 hips and 13 of 60 hips, respectively) [5, 13]. These findings were corroborated by Halley and Glassman [10] who reported an 85.2% survivorship of the femoral component from aseptic loosening at 22 years. Additionally, Halley and Glassman [10] reported a 9% rate of revision for loosening (five of 55 hips) and an additional 4% rate of radiographic evidence of loosening for hips that were not revised (two of 55 hips) at minimum 20-year followup. Despite these results, a study by Lampropoulou-Adamidou et al. [15] demonstrated 77% survival at 20 years in terms of aseptic loosening of the femoral component in a much younger patient cohort (age 35 years old or younger at the time of index THA).

Association Between Surface Finish and Stem Survival

There were two different cohorts in this review that received a matte finished stem [8, 23] as opposed to the

Table 1. Minimum 20-year followup studies of cemented femoral stems

Study	Femoral component [#]	Number of hips/patients	Mean age at index THA (years)	Average length of followup (years)	Revision for any reason	Femoral component revised—aseptic loosening	Femoral component radiographic loosening (does not include revised for loosening)	Femoral osteolysis
Berry et al. [1]	Charnley—hand-packing cementing technique	2000/1689	63.5	Minimum 25	KMS: 77.5%	KMS: 89.8%	NR	NR
Schulte et al. [22]*	Charnley—hand-packing cementing technique	330/262	65	Minimum 20	31 hips (10%); KMS 80%	All hips: 8 (3%); hips with minimum 20-year followup: 3 (3%); KMS: 95%	All hips: 12 (4%); hips with minimum 20-year followup: 4 (4%)	54 hips (57% of those with minimum 20-year followup)
Callaghan et al. [3]*	Charnley—hand-packing cementing technique	330/262	65	Minimum 25	32 hips (10%); KMS 76%	All hips: 9 (3%); hips with minimum 25-year followup: 4 (7%); KMS: 91%	All hips: 12 (4%); hips with minimum 25-year followup: 1 (2%)	33 hips (56% of those with minimum 25-year followup)
Callaghan et al. [6]*	Charnley—hand-packing cementing technique	330/262	65	Minimum 30	39 hips (12%)	All hips: 10 (3%); hips with minimum 30-year followup: 3 (10%)	All hips: 14 (4%); hips with minimum 30-year followup: 3 (10%)	NR
Callaghan et al. [4]*	Charnley—hand-packing cementing technique	330/262	65	Minimum 35	39 hips (12%); KMS: 78%	All hips: 10 (3%); hips with minimum 30-year followup: 3 (10%); KMS: 93%	All hips: 15 (5%); hips with minimum 35-year followup: 4 (12%)	NR
Klapach et al. [14] [†]	Charnley—second-generation cementing technique	357/321	69	Minimum 20	41 hips (12%); KMS: 82%	All hips: 6 (2%); hips with minimum 20-year followup: 5 (5%); KMS: 98%	All hips: 10 (3%); hips with minimum 20-year followup: 4 (4%)	34 hips (40% of those with minimum 20-year followup)
Buckwalter et al. [2] [†]	Charnley—second-generation cementing technique	357/321	69	Minimum 25	42 hips (12%); KMS: 80%	All hips: 10 (3%); hips with minimum 25-year followup: 5 (11%); KMS: 93%	All hips: 13 (4%); hips with minimum 25-year followup: 3 (6%)	NR
Clauss et al. [8]	Müller straight stem—second-generation cementing technique	165/161	69	Minimum 20	17 hips (10% of all hips)	KMS: 87%	NR	40 hips (36% of those with minimum 20-year followup)
Kavanagh et al. [12]	Charnley—hand-packing cementing technique	333/300	64	Minimum 20	36 hips (11%); KMS: 84%	18 hips (5% of all hips)	Hips with minimum 20-year followup: 39 hips (57% with probable or possible loosening)	NR
Ling et al. [16]	Exeter—hand-packing cementing technique	433/374	67	Minimum 20	8 of 33 hips with minimum 20-year followup (24%)	14 hips (3% of all hips); KMS: 93.5% (85.8% in worst case scenario analysis)	NR	4 hips (16 of unrevised stems with minimum 20-year followup)

Table 1. continued

Study	Femoral component [#]	Number of hips/ patients	Mean age at index THA (years)	Average length of followup (years)	Revision for any reason	Femoral component revised—aseptic loosening	Femoral component radiographic loosening (does not include revised for loosening)	Femoral osteolysis
Mullins et al. [20]	Charnley—first- generation cementing technique	228/193	60	Minimum 25	28 hips (12% of all hips); KMS: 84.1% at 20 years, 77.4 % at 25 years	8 hips (4% of all hips)	Hips with minimum 25- year followup: 4 (15%)	NR
Skutek et al. [23]	Harris Design-2— second-generation cementing technique	195/166	68	Minimum 20	10 hips (5% of all hips); KMS: 83%	8 hips (4% of all hips); KMS: 86%	0 hips	NR
Wroblewski et al. [25]	Charnley—hand- packing cementing technique	110/94	75 at time of follow- up	Minimum 30	13 hips (12% of all hips)	5 hips (5% of all hips)	14 hips (13% of all hips)	11 hips (10% of all hips)

*,†These are studies of the same patient cohorts, for the respective symbols, performed at different intervals of followup; [#]Femoral component manufacturer data: Charnley THA (formerly Thackery, now DePuy, Leeds, UK, or Zimmer, Warsaw, IN, USA), Harris Design-2 (Howmedica, East Rutherford, NJ, USA), Exeter (Stryker, Newbury, UK), and Müller straight stem (Zimmer, Winterthur, Switzerland); NR = not reported; KMS = Kaplan-Meier survivorship.

polished Charnley or Exeter stems in the remaining cohorts. These stems were the Harris Design-2 (Howmedica) and the Müller straight stem (Zimmer, Winterthur, Switzerland), which have an average Ra of 0.8 μm and 0.5 to 1.5 μm (mean, 1.0 μm), respectively. Although data pooling could not be performed because of heterogeneity of the studies included here, it appeared that stems with a rougher surface finished did not perform as well as polished stems; survivorship of stems with rougher surface finishes varied between 86% and 87%, whereas those with smoother finishes ranged between 93.5% and 98% at 20 years [14, 16, 22].

Discussion

Cemented THA has been extensively studied and demonstrated to be successful over the 10- to 15-year followup interval; however, relative few studies have evaluated the long-term durability of cemented THA at 20 years or more. Evaluation of the long-term outcome of an operation is important to determine the durability of the results of the procedure and in addition to provide a means for comparison with any changes in the procedure or advancement in technology over time. This systematic review evaluated the minimum 20-year followup of primary, cemented femoral components in the general population and in patients younger than age 50 years in an attempt to answer the following questions: (1) How durable is cemented femoral fixation in the long term (minimum 20-year followup) with respect to aseptic loosening? (2) Is the durability of cemented femoral fixation dependent on the age of the patient? (3) Are the long-term results of the cemented femoral fixation dependent on any identifiable characteristics of the prosthesis such as surface finish?

Limitations of this study include the exclusion of all papers not published in English and the fact that only two databases were screened (PubMed and EMBASE); thus, it is possible that articles indexed elsewhere or published in other languages might not have been included. There also were only four different stems included in this review, which is a limitation on the available literature. Additionally, we have attempted to extract small sets of data from a large collection of studies; however, whenever one begins using isolated statistics from various sources, there is the potential for making conclusions from the data out of the original context. This is a limitation with all systematic reviews. Limitations more specific to this review include the numbers of patients lost to followup for reasons other than death in many of these studies, which often results in overestimates of survivorship when authors report only best-case analyses, as well as the high percentage of patients who died during these long followups, which

Table 2. Minimum 20-year followup studies of cemented femoral stems in patients younger than 50 years old

Study	Femoral component [†]	Number of hips/patients	Mean age at index THA (years)	Average length of followup (years)	Revision for any reason	Femoral component revised—aseptic loosening	Femoral component radiographic loosening (does not include revised for loosening)	Femoral osteolysis
Lampropoulou-Adamidou et al. [15]	Charnley—first-generation (n = 20) and second-generation (n = 21) cementing technique	41/28	32	Minimum 23	23 hips (56% of all hips; 62% of hips with minimum 23-year followup)	14 hips (34% of all hips; 38% of hips with minimum 23-year followup); KMS: 77% at 20 years and 68.2% at 25 years	Unrevised hips with minimum 23-year followup: 8 (53%)	5 hips (33% of unrevised hips with minimum 23-year followup)
Halley and Glassman [10]	Charnley—hand-packing cementing technique	68/54	37	Minimum 20	15 cups and 12 stems (22% and 18% of all hips, respectively)	5 hips (7% of all hips); KMS: 85.2% at 22 years	2 hips (4% of 50 hips with available radiographs)	6 hips (12% of 50 hips with available radiographs)
Callaghan et al. [5]*	Charnley—hand-packing cementing technique	93/69	42	Minimum 20	27 hips (27% of all hips); KMS: 69% at 25 years	4 hips (6% of hips with minimum 20-year followup); KMS: 94% at 25 years	9 hips (13% of hips with minimum 20-year followup)	17 (20% of those with minimum 20-year followup)
Keener et al. [13]*	Charnley—hand-packing cementing technique	93/69	42	Minimum 25	29 hips (69% of all hips); KMS: 60% at 30 years	4 hips (7% of hips with minimum 20-year followup); KMS: 93% at 30 years	9 hips (15% of hips with minimum 25-year followup)	NR

* These are studies of the same patient cohorts performed at different intervals of followup; [†]femoral component manufacture data: formerly Thackery, now DePuy, Leeds, UK, or Zimmer, Warsaw, IN, USA; NR = not reported; KMS = Kaplan-Meier survivorship.

creates a competing event (violating an assumption of Kaplan-Meier survivorship) perhaps further overestimating survivorship. Additionally, many of these studies were selected patient populations with the younger and more active patients receiving other stem designs during the periods of study. This as well can cause an overestimate of the apparent efficacy of these femoral components.

In this review, we identified 17 studies that followed cemented femoral components for a minimum of 20 years. In aggregate, these studies looked at 4353 cemented femoral components in 12 different cohorts with the majority consisting of polished stems (3993 hips either Charnley or Exeter) and 360 stems having a matte finished with either the HD-2 or MMS femoral component [8, 23]. For eight of the cohorts, stems were placed with a traditional hand-packing technique [1, 3–6, 10, 12, 13, 16, 20, 22, 25]; for three cohorts, stems were placed with second-generation cementing techniques [2, 8, 14, 23] and one cohort consisted of patients with both techniques used [15]. The data presented in this systemic review are supported with data from national registries around the world. Although there are relatively few data from registries on cemented stems into the 20-year followup period, there are additional 15- to 20-year registry data that can be compared with the studies in this review to further support their findings. A study of 62,305 primary cemented THAs from the Norwegian Arthroplasty Register demonstrated a revision rate of cemented stems resulting from aseptic loosening of 5.9% (95% confidence interval, 5.3%–6.4%) [9]. Additionally, an analysis of the Finnish Arthroplasty Registry that analyzed 34,296 cemented stems demonstrated a 20-year survivorship at the endpoint of aseptic loosening of 82%

for composite-beam cemented stems and 77% for loaded-taper cemented stems [17]. Despite these available data, there remains room for more definitive results. The authors believe more definitive conclusions regarding durability of cemented femoral components in the long term could be obtained with larger pooling of data in terms of meta-analyses, although this will require properly designed prospective source studies to achieve, and by analyzing these data with “worst-case scenario” analysis to help eliminate limitations encountered with common statistical analysis of long-term THA.

The excellent durability of cemented femoral stems in the general population is also seen in younger patients when one evaluates the literature on cemented stem fixation in patients 50 years or younger at minimum 20-year followup with multiple reports demonstrating similar survivorship data and revision rates [5, 10, 12]. Lampropoulou-Adami et al. [15] did report slightly less durability with 38% of hips revised for aseptic loosening of the femur at minimum 23 years (14 of 37 hips); however, this was in an even younger population with the entire cohort being younger than 35 years old at the time of their primary cemented THA. National registry data of cemented stems in younger patients demonstrated similar findings as documented in this systematic review with analysis of the Nordic Arthroplasty Register Association demonstrating survival rate of 80.5% for revision for aseptic loosening of a cemented stem in 6824 hips in patients aged 55 years or younger at the time of surgery [21] and a followup study of the Finnish Arthroplasty Register of patients 55 years of age and younger who received a cemented THA ($n = 140$ hips) demonstrated a 81% survivorship at 15 years for revisions

Fig. 2A–C Preoperative (A), postoperative (B), and 35-year followup (C) radiographs show a cemented Charnley THA in a patient aged 42 years at the time of index THA with a great clinical and radiographic outcome.

for aseptic loosening [18]. To better address this question more definitively (best femoral component for older versus younger patients in the long term), a direct comparison of cemented femoral components in patients younger than 50 years and patients older than 50 years would need to be performed to help eliminate errors associated with attempts at comparing cohorts with varying methods, surgeons, implants, etc.

This review demonstrates that cemented fixation of the femoral stem in the general population has excellent durability at minimum 20 years of followup, especially when looking specifically at polished stems, which had 20-year revision rates of 3% to 5% and survivorship free from revision for aseptic loosening as high as 95% in hips that obtained minimum 20-year followup [14, 22]. Although this review was not able to directly compare varying finishes (as a result of the lack of minimum 20-year followup comparing such characteristics), there did appear to be an inferior survivorship for stems with matte finishes versus polished stems, suggesting long-term durability is improved with polished stems.

Although this review only identified two cohorts followed for a minimum of 20 years with matte-finished stems [8, 23], the relatively lower survivorship in comparison to the polished Charnley and Exeter stems (86% and 87% survivorship free from revision for aseptic loosening versus 93.5% to 98%) in this review is further suggestive of the belief that rougher surface stems, especially those with $Ra > 0.4 \mu\text{m}$, are more deleterious to the cement mantle and contribute to progressive loosening of the stem [7, 11, 19]. This claim is somewhat supported with Clauss et al.'s registry-based analysis of 828 cemented Muller-type straight stems (Zimmer, Winterthur, Switzerland) where it analyzed differences in survivorship free from aseptic loosening based on various differences in design of this stem over the years (specifically surface roughness and stem material) [7]. In this series, worsening 15-year survivorship for the endpoint of aseptic loosening was demonstrated with successive increases in surface roughness, irrespective of stem material, with survivorship for the smoothest stem (0.5–1.5 μm roughness) of 82% and 59% survival for the roughest stems (4–6 μm proximal and 0.5–1.5 μm distal ($p < 0.001$) [7].

Although difficult to perform, to more definitively support this claim, a randomized controlled trial of varying stem finishes would need to be performed and carried into the long-term followup interval to directly answer the question of impact of stem finish on long-term durability.

In conclusion, if polished femoral stems (such as Exeter and Charnley-type stems) are used and careful attention to achieving a quality cement mantle is paid, excellent long-term fixation in both older and younger patients can be obtained with cementing the femoral component in the

THA construct (Fig. 2A–C). This systematic review of long-term followup (greater than 20 years) of cemented femoral components demonstrated durability of 86% to 98% survival free from aseptic loosening in patients older than age 50 years and provides some baseline data that may serve as a benchmark for comparison with newer designs and techniques.

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